Next from Japan!

Future Coal-Fired Thermal Power Generation

Advancing Highly Efficient Technology and Environmental Performance

Can we really call “smokeless” chimneys smokeless? Isogo Thermal Power Plant, located in Yokohama, a large city with a population of 3.7 million people, brings just such a question to mind. Let us give you an overview of this plant, which is said to be the cleanest coal-fired thermal power plant in the world.

Coal, which was often historically thought of as “black diamond,” supported Japan’s postwar reconstruction. Many people might regard coal as a “resource of the past,” as it ceased to be Japan’s mainstay energy source following the end of the period of high economic growth. However, the real situation is quite different outside Japan. Surprisingly, coal-fired thermal power plants supply around 41% of the global volume of electricity generation. The supply ratio is 78% in China, 68% in India and 46% in the United States. Even Germany, which is eager to use renewable energy, relies on coal-fired thermal power plants for slightly more than 40% of its total electricity generation.

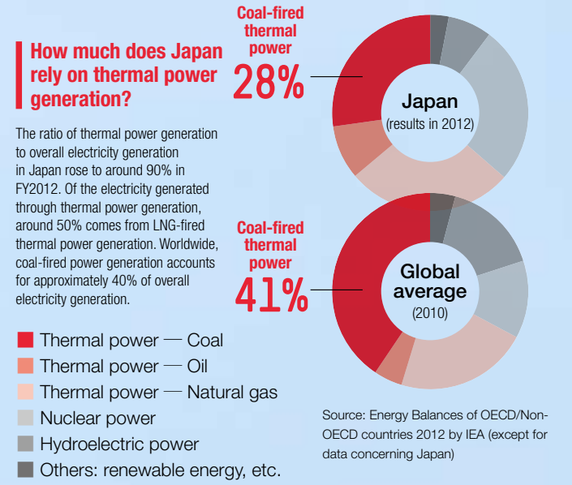
Meanwhile, although the ratio is lower in Japan compared with other countries, coal-fired thermal power plants still account for around 28% of the volume of Japan's electricity generation. Coal-fired power generation, along with LNG (liquefied natural gas) -fired power generation, is an important power source. Moreover, now that Japan’s nuclear power plants have suspended operation, resulting in a growing dependence on LNG-fired power generation, coal-fired power generation is gathering attention as a base power source. This is because coal as an energy source is not only cheap but is in ample supply. In addition, as a result of environmental protection measures such as soot filtering and the steady development of highly efficient power generation technology since the 1980s, the traditional image of coal-fired power plants as a source of massive emissions of black smoke as well as a major emission source of CO2 are also changing drastically.

Isogo Thermal Power Plant in Yokohama is a symbol of the above changes. We visited the plant to uncover the secrets to the plant’s high efficiency and “greenness.”

*The figures above are results in 2010 (for Japan, those in FY2012).

How much does Japan rely on thermal power generation?

The ratio of thermal power generation to overall electricity generation in Japan rose to around 90% in FY2012. Of the electricity generated through thermal power generation, around 50% comes from LNG-fired thermal power generation. Worldwide, coal-fired power generation accounts for approximately 40% of overall electricity generation.



Source: Energy Balances of OECD/Non-OECD countries 2012 by IEA (except for data concerning Japan)

Isogo Thermal Power Plant CLICK!

A 200-meter chimney is the symbol of Isogo Thermal Power Plant. Technology eliminating smoke has made it possible to locate this plant near residential areas. The plant was designed to be in harmony with the landscape of the port city of Yokohama.

Coexistence with the local community: The starting point of a power generation technology for taking the technology to a global level

As one of the planet's few urban-located thermal power plants, Isogo Thermal Power Plant accepts a constant stream of visitors from both within and outside of Japan including VIPs and researchers. The visitors come to see "USC," a technology that boasts the world highest standard for energy effeciency. We asked Hiroshi Sasatsu, the plant manager, about the technology.

Hiroshi Sasatsu, manager of Isogo Thermal Power Plant, operated by Electric Power Development Co., Ltd. (J-Power)

"Which should we choose, 'super' or 'ultra'?" "As this is Japanese technology, we should pay respect to Ultraman (a Japanese hero), rather than Superman." Perhaps, a conversation like that occurred in relation to the naming of this new technology. The "USC"(Ultra-Supercritical) technology that Isogo Thermal Power Plant is so proud of was commercialized by Electric Power Development Co., Ltd. (J-Power) for the first time in the world. "Ultra-Supercritical," or USC, is a term coined in Japan, said Hiroshi Sasatsu, the manager of Isogo Thermal Power Plant, with a smile.

"'Supercritical (SC)' is a technical term that means 'surpassing criticality.' The phrase 'ultra-supercritical' implies performance surpassing supercriticality. This has now become a standard name of the technology and is being used around the world," Sasatsu says. This USC-type plant achieves the highest efficiency among commercially available coal-fired power generation technologies . Isogo Thermal Power Plant's thermal efficiency reaches 45% - the highest in the world.

"High thermal efficiency means that the use of coal can be reduced. That lowers the power generation cost, and the most important thing is that CO2 emissions can be reduced. The new Units 1 and 2 emit around 20% less CO2 compared with the former Units 1 and 2. Improving efficiency is the key to improving the environment."

History of the Quest for Higher Temperature and Pressure

Coal-fired power generation generates steam by burning coal, and the steam provides the power to drive the turbine, thereby generating electricity. The higher the temperature and pressure of the steam is, the stronger the power to drive the turbine and the more electricity generated from the energy provided by the coal. The history of Isogo Thermal Power Plant has been a quest to achieve ever-higher temperature and pressure.

The former Units 1 and 2 (with a combined power generation capacity of 530,000 kW), which started operating in the 1960s, were replaced with a new Unit 1 (600,000 kW) in 2002 and with Unit 2 (600,000 kW) in 2009, in order to expand the power generation capacity, improve environmental performance, and increase efficiency. In the meantime, the main steam temperature has been raised from 560 degrees Celsius to 600 degrees Celsius and the steam pressure has been boosted from 16.6 megapascals to 25 megapascals.

"We began demonstration tests of USC technology in the 1980s at J-Power's Wakamatsu Research Institute with the support of the former Ministry of International Trade and Industry. We have been working to develop technology using equipment made of materials that can withstand high temperature and high pressure. We moved toward commercialization through a step-by-step review process. Regarding the development of power plants, we need to make long-term, comprehensive efforts, including with regard to operation and maintenance."

"Yokohama Approach": Model Case of a Pollution Prevention Agreement

Isogo Thermal Power Plant generates around 8.1 billion kWh of electricity annually. This is equivalent to around a third of the electricity used in the whole of Yokohama City. The area of the plant is only 12 hectares, around 2.5 times as large as Tokyo Dome. We can see how well the plant was downsized. We must also mention the plant's excellent environmental performance.

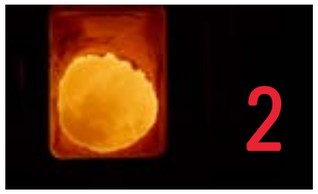
"There are two perspectives – global and local - on environmental protection. As for the global perspective, we address CO2 reduction through the highly efficient technology that I mentioned earlier. Meanwhile, as for the local perspective, the removal of air-polluting substances is imperative since the plant is located in Yokohama, a large city. In this respect, in 1964, J-Power and Yokohama City concluded a "pollution prevention agreement," the first such agreement in Japan. When replacing the old units with the new Units 1 and 2, we concluded an "environmental protection agreement," again under which we are placing top priority on removing NOx, which causes photochemical smog, and SOx, which causes acid rain, as well as dust and soot.

Our agreement with Yokohama City, known as the Yokohama Approach, has become a model case of pollution prevention agreements concluded between local governments and companies. Dry-type desulfurization equipment installed at Isogo Thermal Power Plant, which is the first such equipment to be installed in Japan, removes more than 95% of SOx, while denitrification equipment removes around 90% of NOx. Electric dust collection equipment removes more than 99% of dust. "The most important thing is to continue safely operating Isogo Thermal Power Plant as a reliable power plant," Sasatsu says as his closing thoughts.

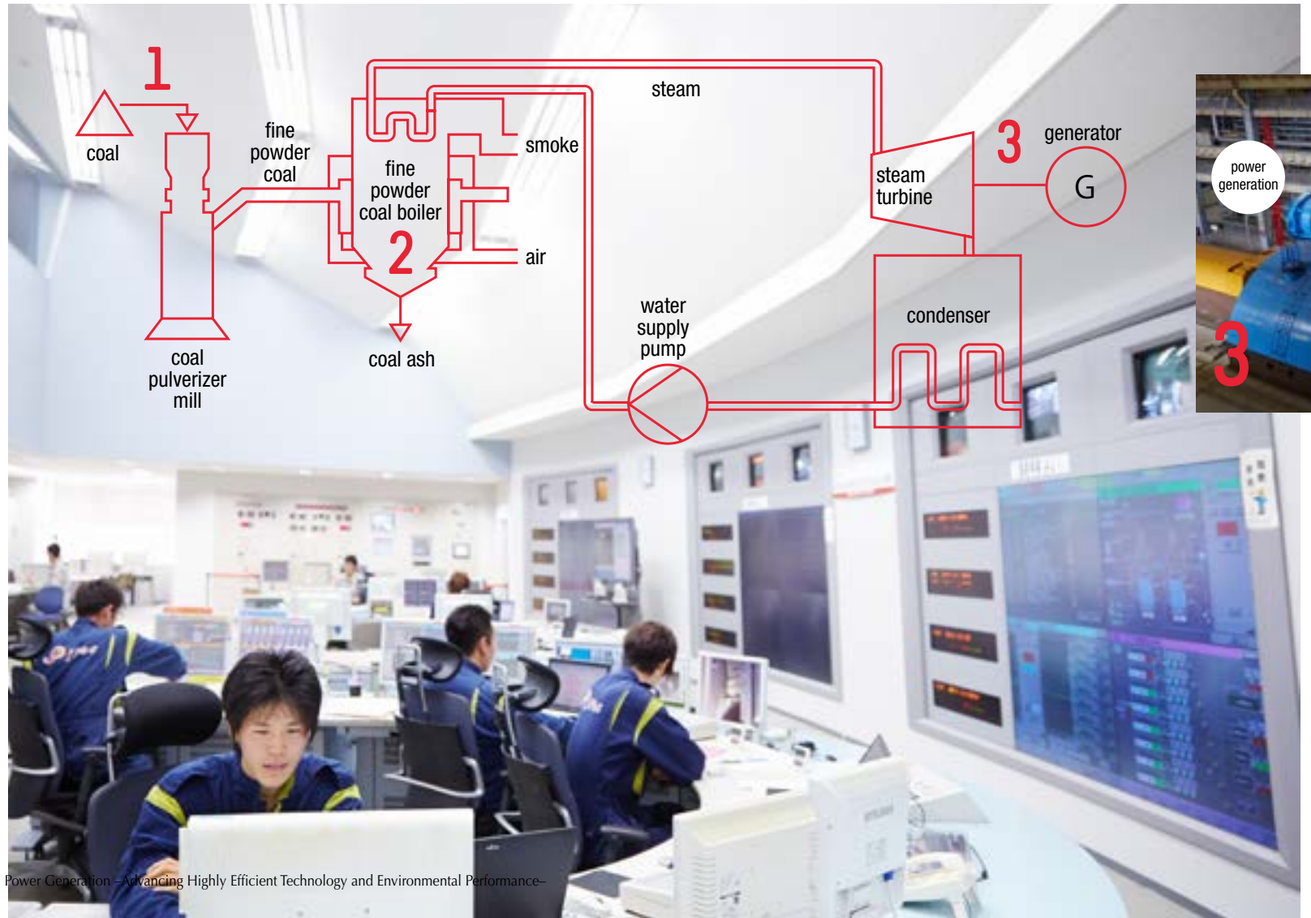
Dry-type desulfurization equipment uses activated coke created from coal to absorb SOx contained in exhaust gas. The activated coke is recycled.

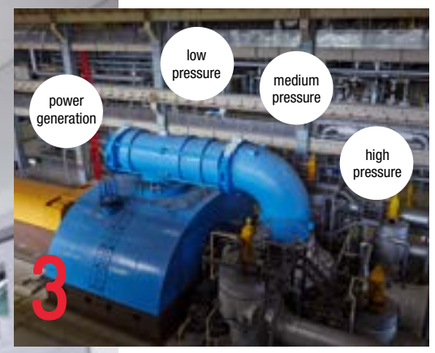
USC: World-leading power generation technology

USC uses the fine coal combustion method. Coal transported to the plant is burned after being pulverized into fine powder with a grain diameter of around 70 microns.



Isogo Thermal Power Plant is the first power plant in Japan to use a tower-type boiler. Inside the boiler, the temperature reaches 1,300 degrees Celsius. Water flowing through thousands of narrow pipes is heated to generate high-temperature, high-pressure steam.





The jet and expansion forces of the steam transmitted to the turbine turn the blades at high speed. As the generator rotor turns, electricity is generated.

The operation center operates Units 1 and 2 and also operates and monitors environment protection facilities. Numerical data concerning SOx and NOx are transmitted in real time to the division in charge at the Yokohama City Government.

Open Lecture! Learn and Understand

Lecture on Coal-Fired Thermal Power Generation

Coal-fired thermal power generation is ever advancing. What are the mechanisms behind this way to generate electricity? What kind of and how high are expectations for this method of generation? We will provide you with lectures to answer such questions.

1 Lecture 1 Economics

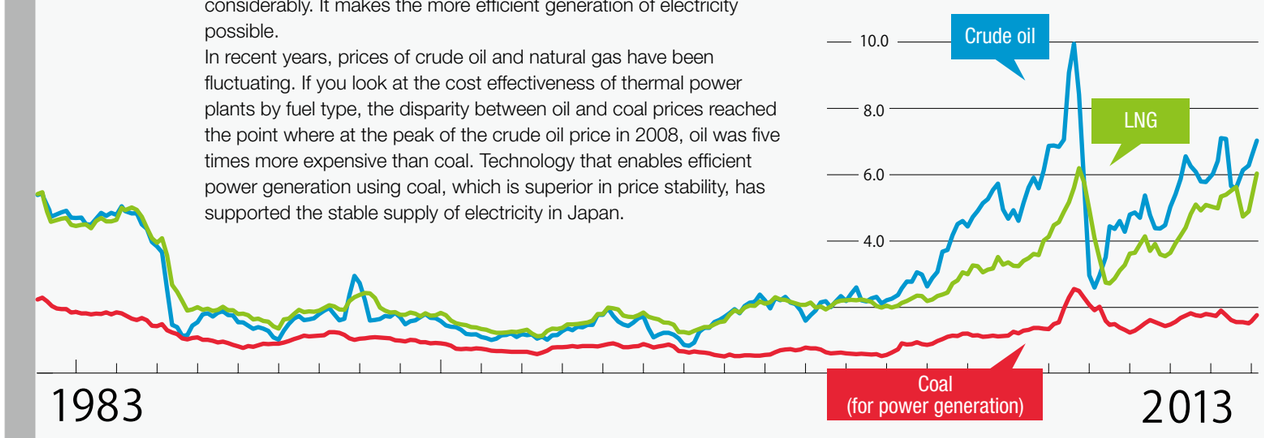
Amazing Cost Performance

Coal-fired thermal power generation is attractive because of its cheap fuel price and stability of the market compared with other fuels used for thermal power generation. If these characteristics are combined with the advantage of USC technology, cost performance improves considerably. It makes the more efficient generation of electricity possible.

In recent years, prices of crude oil and natural gas have been fluctuating. If you look at the cost effectiveness of thermal power plants by fuel type, the disparity between oil and coal prices reached the point where at the peak of the crude oil price in 2008, oil was five times more expensive than coal. Technology that enables efficient power generation using coal, which is superior in price stability, has supported the stable supply of electricity in Japan.

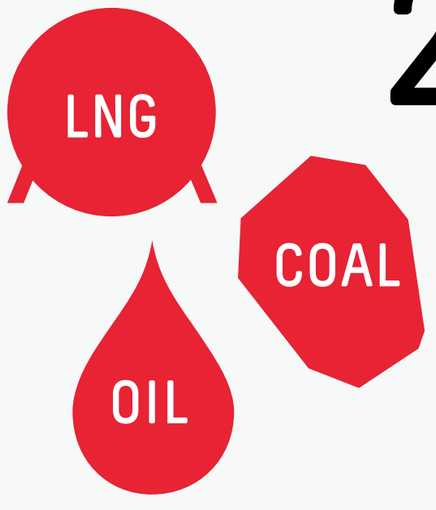
Changes in the average import CIF price

(JPY/1,000 kcal)



2 Lecture 2 Science

What is Thermal Power Generation?



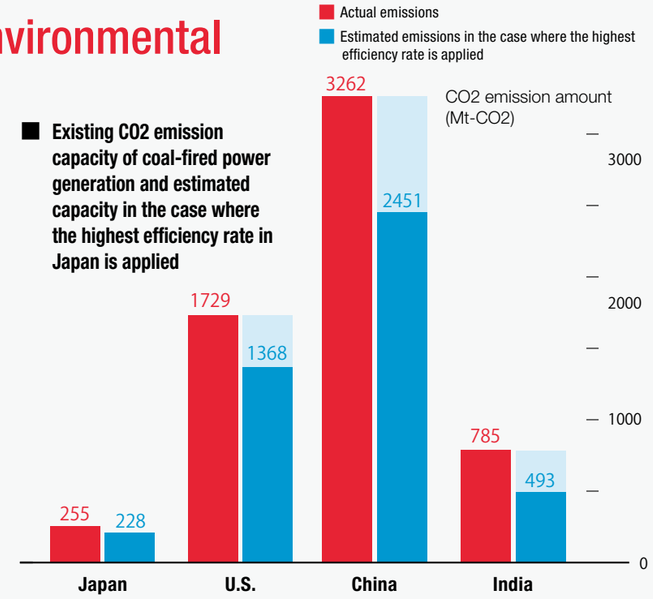
Thermal power generation is a system that generates electricity by using the power of high-temperature, high-pressure steam generated by the burning of fossil fuels to drive the turbine. The problem with coal-fired thermal power generation has been the large amount of CO2 emitted during the power generation process. However, the development of technologies to reduce CO2 emissions is underway. Meanwhile, LNG (liquefied natural gas) is attracting attention as a clean resource that emits only a small amount of CO2. If the difficulty of storing and transporting gas is reduced, LNG is expected to become a more useful source of energy. Oil is the most widely used fossil fuel, as it can be easily stored and is superior in terms of supply flexibility. The problem with oil is its volatile price. It is important to consider a power source mix in light of the advantages and disadvantages of each of the resources.

3 Lesson 3 Social Study

Ever Improving Environmental Performance

Coal used to be regarded as a fuel that severely harms the environment with its sooty smoke. However, that image is becoming a thing of the past. In order to realize environmentally-friendly coal-fired thermal power generation, Japan has successively developed technologies to reduce CO2 emissions and remove air polluting substances from the smoke. Coal-fired thermal power plants in Japan have already realized clean exhaust gas by introducing desulfurization and denitrification technologies. As for the thermal efficiency, Japanese power plants using SC (supercritical) and USC (ultra-supercritical) technologies have achieved the highest efficiency rate in the world. If coal-fired thermal power plants in the United States, China and India were replaced with the kind of cutting-edge plants operating in Japan, CO2 emissions could be reduced by as much as around 1.5 billion tons, according to one estimate.

Existing CO2 emission capacity of coal-fired power generation and estimated capacity in the case where the highest efficiency rate in Japan is applied



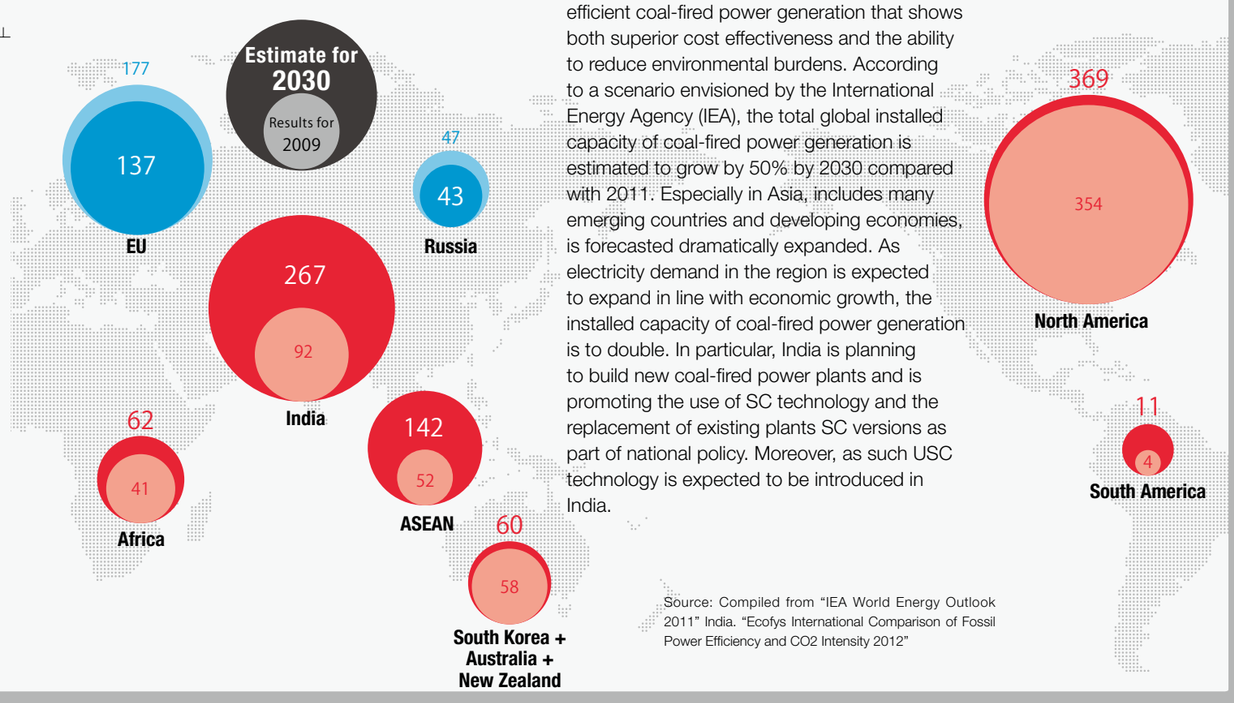
Source: Compiled from "IEA World Energy Outlook 2011" and "Ecofys International Comparison of Fossil Power Efficiency and CO2 Intensity 2012"

4 Lesson 4 International Relations

Electricity Demand in Asian Region to Double

There is growing need globally, for highly efficient coal-fired power generation that shows both superior cost effectiveness and the ability to reduce environmental burdens. According to a scenario envisioned by the International Energy Agency (IEA), the total global installed capacity of coal-fired power generation is estimated to grow by 50% by 2030 compared with 2011. Especially in Asia, includes many emerging countries and developing economies, is forecasted dramatically expanded. As electricity demand in the region is expected to expand in line with economic growth, the installed capacity of coal-fired power generation is to double. In particular, India is planning to build new coal-fired power plants and is promoting the use of SC technology and the replacement of existing plants SC versions as part of national policy. Moreover, as such USC technology is expected to be introduced in India.

Estimate worldwide installed capacities of coal-fired thermal power generation (Unit: GW)



Source: Compiled from "IEA World Energy Outlook 2011" India. "Ecofys International Comparison of Fossil Power Efficiency and CO2 Intensity 2012"

Contributing to the Global Power Plants

Contribution to Emerging Economies where Demand is Growing

In emerging economies, where remarkable economic development and industrial diversification are proceeding, electricity demand is growing for various usages ranging from factories that are the recipients of foreign investment, to households. However, when emerging economies procure power generation facilities, huge investments are needed, which impose fiscal budget constraints. In that respect, the utilization of Independent Power Producer (IPP) and public funds is the best means to resolve financial problems. For example, if public financial support is promoted in countries where new coal-fired thermal power plants are expected to be constructed, including the three Asian countries shown in the above figure, and in Poland and other East European countries where active replacement of old plants is expected, Japanese high efficient coal-fired thermal power generation technology will be disseminated.

Poland

Coal-fired thermal power generation accounts for around **90%** of the electricity generation.

Source: "Electric Power Business in Foreign Countries 2nd Ed. 2 2010" by the Japan Electric Power Information Center.

India

298,253 MW

Estimated demand in 2011-2021

Viet Nam

146,800 MW

Estimated demand in 2011-2030

Indonesia

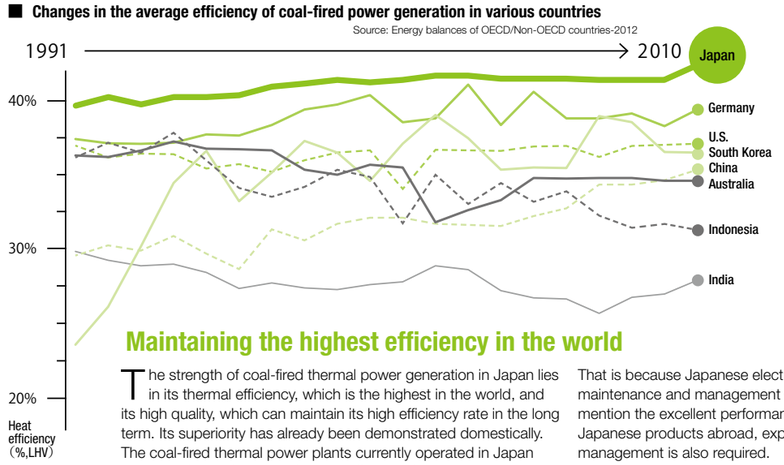
55,484 MW

Estimated demand in 2011-2019

Source: "Electric Power Business in Foreign Countries 1st Ed. 1 Supplemented Ver., 2. "Energy and Electricity Situations in Major Asian Countries 2011" by the Japan Electric Power Information Center and an extract from a report on the project to promote dissemination of anti-global warming technologies called "Possibility and Effect of Introduction of Highly Efficient Coal-Fired Thermal Power Facilities in Indonesia" (March 2011) by the Institute of Energy Economics, Japan.

■ **Changes in the average efficiency of coal-fired power generation in various countries**

Source: Energy balances of OECD/Non-OECD countries-2012



Maintaining the highest efficiency in the world

The strength of coal-fired thermal power generation in Japan lies in its thermal efficiency, which is the highest in the world, and its high quality, which can maintain its high efficiency rate in the long term. Its superiority has already been demonstrated domestically. The coal-fired thermal power plants currently operated in Japan have maintained their high thermal efficiency for several decades. That is because Japanese electric utilities take meticulous care in maintenance and management work, including plant control, not to mention the excellent performance of equipment. When promoting Japanese products abroad, export of excellent know-how of plant management is also required.

How Much can Efficiency Improve?

Ever Advancing Power Generation

We have introduced the frontline of coal-fired thermal power generation but there still have further possibilities. To achieve everhigher efficiency, technologies including development such as the A-USC (Advanced Ultra-Supercritical) technology and IGFC (Integrated Coal Gasification Fuel Cell Combined Cycle) technology are continuing to advance.

"If the most of the existing coal power plants are replaced with A-USC power plants, both coal consumption and CO_2 emissions can be reduced by more than 10%," says Masafumi Fukuda of the Research Institute for Advanced Thermal Power Systems. A-USC is a next-generation system that will be superior to USC technology, which currently boasts the highest thermal efficiency in the world. The steam temperature within the A-USC system will be around 700 degrees Celsius, 100 degrees higher than the temperature within existing power generation systems. "The key to commercializing the A-USC technology is the development of new heat-resistant materials and equipment. As Japan's development project is proceeding mostly according to schedule, various technology evaluations will be completed by fiscal 2016. We will catch up with Europe and the United States, which are now ahead of us. Commercialization will be within sight, so we would like to show the feasibility to users." Also the IGFC, which is a triple-combined highly-efficient power generation technology integrating fuel cells, and both gas and steam turbines, drawing close attention.
The IGCC (Integrated Coal Gasification Combined Cycle) technology, which constitutes the foundation of the IGFC, has already achieved some results with regard to the oxygen-blown type of the technology on a pilot scale in the EAGLE project (Kitakyushu City, Fukuoka Prefecture). We aim to realize "innovative low-carbon coal-fired thermal power generation technology" by developing CO2 separation and recovery technology as well as the IGFC technology, with the IGCC as the foundation technology.

Fukuda standing before the rendering of boiler test equipment

Ultra-Supercritical

Generates steam within the boiler and uses the steam turbine to drive the generator. Increases the thermal efficiency by raising the steam temperature to around 600 degrees Celsius.

● Already commercialized

Advanced Ultra-Supercritical

Raises the steam temperature to around 700 degrees Celsius. The key is the development of materials that can withstand a harsh operating environment of ultra-high temperature and pressure for several decades.

● Commercialization timeframe: During the 2020s

Integrated Coal Gasification Combined Cycle

Gasifies coal and generates electricity through a combined cycle system. Enables the use of types of coal that are difficult to use in existing facilities.

● Commercialization timeframe: During the 2020s

Integrated Coal Gasification Fuel Cell Combined Cycle

Uses a fuel cell in addition to IGCC technology. Plans to achieve a thermal efficiency of 55% by 2025.

● Commercialization timeframe: During the 2030s