# Aiming to raise the generating efficiency of coal-fired thermal power and achieve low-carbon emissions, J-POWER is developing clean coal technologies that are the keys to creating next-generation, coal-fired thermal power generation facilities.

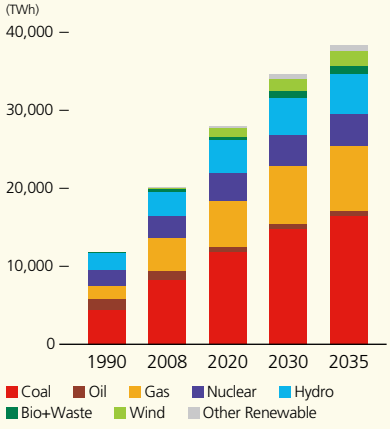
## Coal Is a Major Energy Source for Electric Power Generation

Compared to oil and natural gas reserves, coal deposits are abundant and dispersed broadly in many countries throughout the world. In terms of supply, it is the stablest and most-economical of all fossil fuels. Many countries around the world rely on coal as a primary power generation fuel source, including countries with high energy consumption. For example, China uses coal for approximately 80% of the power it generates, while in the United States the ratio is 50%. On a worldwide basis, coal is the most-prevalent source of energy, accounting for roughly 40% of all electric power generated.

Going forward, the number of coal-fired thermal power plants is projected to grow further. It is believed that coal-fired thermal power generation will continue to be a crucially important energy source for meeting ever-increasing worldwide demand.

At the same time, the combustion of coal and other fossil fuels generates $CO_2$, a greenhouse gas, and $CO_2$ from coal-fired thermal power plants accounts for roughly 30% of the world's energy-derived $CO_2$ emissions. Because rising demand for energy in such emerging countries as China and India is projected to increase those countries' coal use by a substantial margin, reducing $CO_2$ emissions from coal-fired thermal power generation has become an international issue.

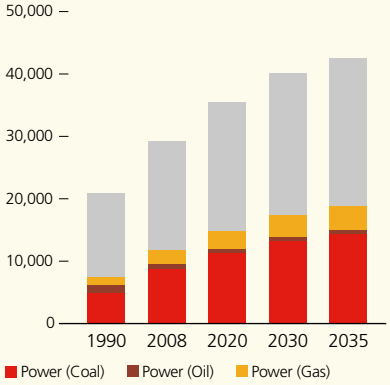
**Estimated Global Power Generation Output by Power Source**




Source: Compiled from current policies scenario* in *IEA World Energy Outlook 2010*

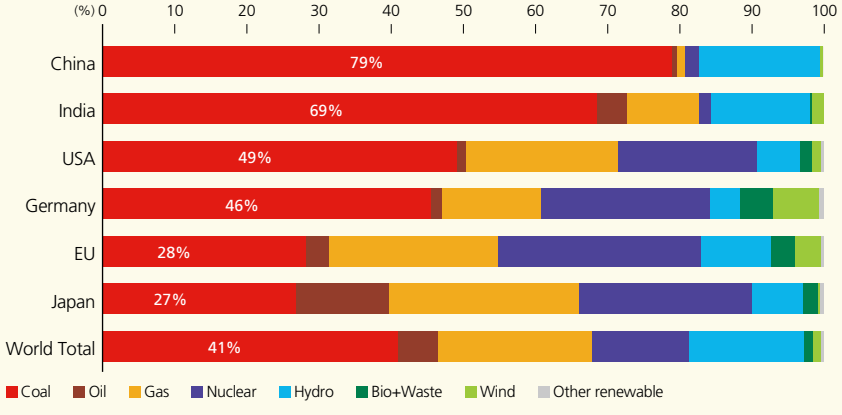
* A scenario that takes into account measures officially adopted as at mid-2010

**Estimated Global Energy-Derived $CO_2$ Emissions Volume by Emissions Source**




Source: Compiled from current policies scenario in *IEA World Energy Outlook 2010*

**Breakdown of Power Generation Volume by Power Source for Each Country/Region (2008)**




Source: *IEA World Energy Outlook 2010*, except for Germany, which is based on *IEA Electricity Information 2010*.

## Spreading J-POWER's Cutting-Edge Technologies throughout the World

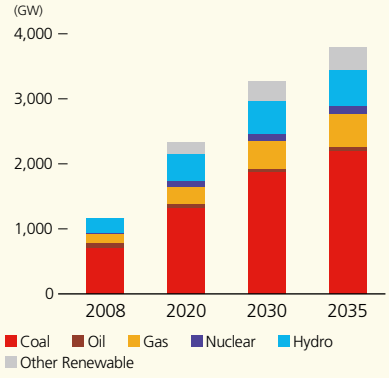
One effective way to reduce $CO_2$ emissions from coal-fired thermal power plants is by increasing generation efficiency. Were power generation made more efficient, this alone would reduce the amount of coal used and curb $CO_2$ emissions. Japanese coal-fired thermal power plants utilize the ultra-supercritical (USC) method, which raises steam turbine pressures and temperatures to extremely high levels, enabling them to realize a level of generating efficiency higher than at plants in Europe, the United States, and Asia. Active in developing these cutting-edge technologies under its own initiative and having championed their application, J-POWER is achieving the highest levels of efficient energy use.

J-POWER leverages Japan's accumulated expertise and technologies, while the widespread conversion to highly efficient coal-fired thermal power stations throughout the world holds major significance for the reduction of worldwide $CO_2$ emissions and the conservation of energy resources.

If Japan's best-performing coal-fired thermal power technologies were to be used globally at all newly built and existing coal-fired thermal power plants, it is estimated that, in 2030, the world's annual $CO_2$ emissions would be reduced by 1.87 billion tons. This is an amount that exceeds Japan's annual $CO_2$ emission volume, which was 1.15 billion tons in fiscal 2009.

Power demand is steadily increasing particularly elsewhere in Asia, and coal-fired thermal power generation is expected to play an ongoing major role in power supply. Both the amount of electricity generated at and the facility capacity of Asian coal-fired thermal power plants are projected to have doubled the current levels by 2030. As the coal-fired thermal power plants in other Asian countries are also of the conventional, comparatively less efficient subcritical type, a full-fledged switch to high-efficiency plants is under way. J-POWER is thus targeting contributions toward the simultaneous achievement of Asian growth and reduced environmental impact by means of Japanese clean coal technologies.

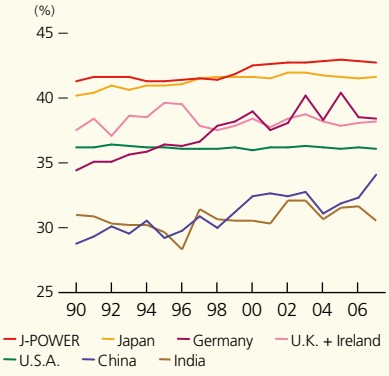
### Estimated Asian Power Plant Capacity by Power Source




Source: Compiled from current policies scenario in *IEA World Energy Outlook 2010*

### Trends in Average Thermal Efficiency of the World's Coal-Fired Thermal Power Plants

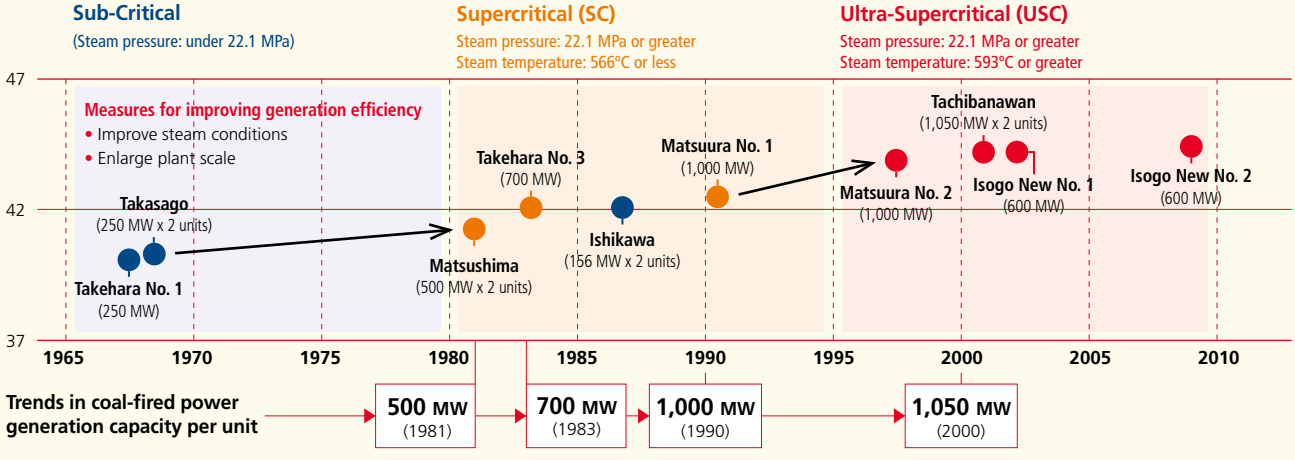
Gross efficiency (LHV)




Source: *Ecofys International Comparison of Fossil Power Efficiency and $CO_2$ Intensity 2010*

### Generation Efficiency of J-POWER Coal-Fired Thermal Power Stations

Designed Thermal Efficiency (%, gross efficiency, LHV basis)



**Specific J-POWER Initiatives 1**

# Replacing Older Thermal Power Plants with Cutting-Edge Facilities

In 1996, a project was launched to replace the two original 265 MW units at the Isogo Thermal Power Plant with state-of-the-art, coal-fired thermal facilities. The project was a means of complying with a City of Yokohama environmental improvement plan, improving the stability and reliability of power supply, and addressing problems associated with aging facilities. The New No. 1 (600 MW) went online in April 2002, followed by the New No. 2 (600 MW) in July 2009.

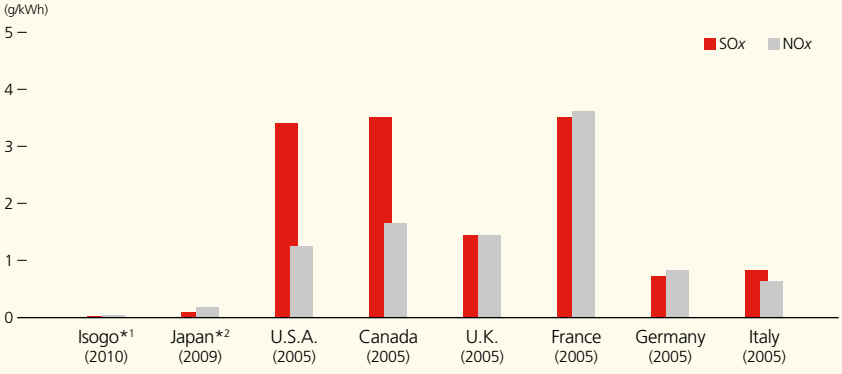
As the Isogo Thermal Power Plant is located in a major city, a pollution prevention agreement—the first of its kind in Japan—was signed with the City of Yokohama; focus was placed on environmental measures from early on, measures that included installing flue-gas desulfurizers. Replacing the first unit at the Isogo Thermal Power Plant brought together J-POWER's clean coal technologies and introduced USC, the highest standard for coal-fired thermal power with a main steam turbine pressure of 25 MPa, a steam temperature of 600°C, and a reheat steam temperature of 610°C.

J-POWER also worked on further improvements in thermal efficiency that were realized with New No. 2, which boasts a reheat steam temperature of 620°C, 10°C higher than No. 1. The Isogo Thermal Power Plant reduces sulfur oxide (SO*x*) and nitrogen oxide (NO*x*) emissions per unit of electricity generated to extremely small values compared with thermal power plants in other major industrial countries thanks to the installation of the latest environmental equipment. Isogo represents the highest standard of clean, coal-fired thermal power plant from the standpoints of both generation efficiency and environmental impact.

To maintain power supply capabilities during the Isogo Thermal Power Plant replacement project, an unprecedented "build, scrap, and build" approach was employed, which involved a number of innovations. The New No. 1 was constructed while the original power facilities were still in operation. When the New No. 1 went online, the old facilities were shut down and removed, and the New No. 2 was built in their place.

Following on from the Isogo Thermal Power Plant, J-POWER is already moving ahead with plans to replace the two units at the Takehara Thermal Power Plant in Hiroshima Prefecture—the 250 MW No. 1 commenced operations in 1967 and the 350 MW No. 2 in 1974—with a New No. 1 capable of producing 600 MW. The Company is completing environmental assessment procedures; the plans call for construction work to start in 2014 and for the New No. 1 to come online in 2020.

### International Comparison of SO*x* and NO*x* Emissions per Unit of Thermal Power Generation




Source: The Federation of Electric Power Companies of Japan

*1 Figures for Isogo are actual results for fiscal 2010

*2 10 major Japanese EPCOs and J-POWER

With the exception of the Isogo Thermal Power Plant, the graph shows units for a combination of coal-, oil-, and gas-fired thermal power generation.

Isogo Thermal Power Plant
(before replacement work)

Isogo Thermal Power Plant
(after replacement work)

Takehara Thermal Power Plant
(Hiroshima Prefecture)

## Aiming to Realize Zero Emissions

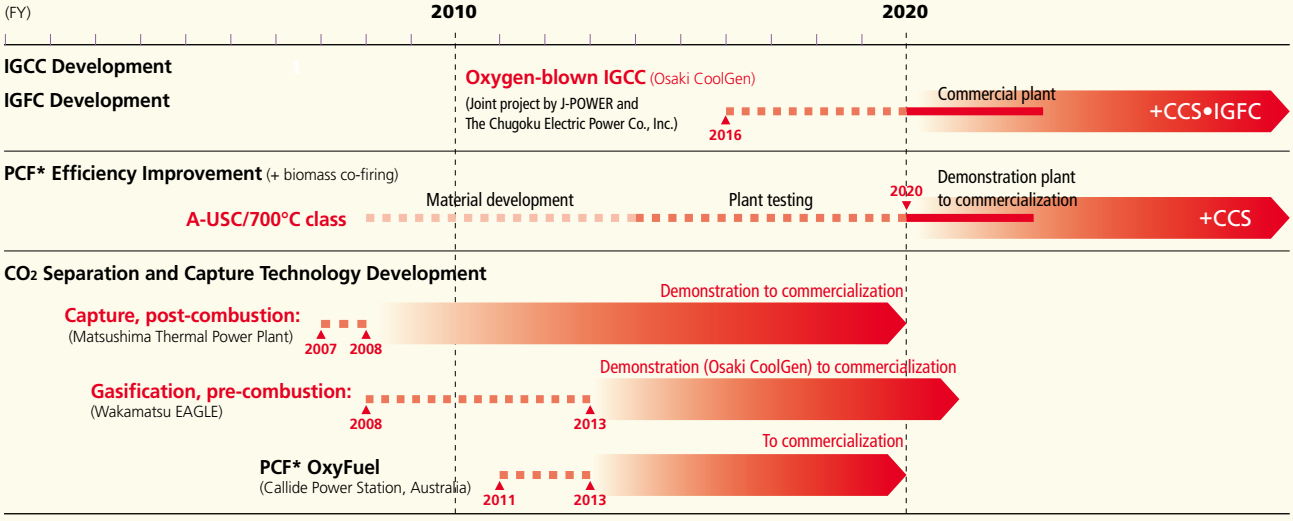
Aiming to further increase coal-fired power generation efficiency and realize low-carbon performance, J-POWER is engaged in the development of a variety of next-generation technologies and is making advances in the combined combustion utilization of biomass fuels.

With respect to our long-term initiatives, we are seeking to enable the practical application of oxygen-blown coal gasification technology, which is expected to provide the next generation of coal-fired thermal power generation. Establishing this revolutionary technology and applying it together with integrated coal gasification combined cycle (IGCC) and integrated coal gasification fuel cell combined cycle (IGFC) systems will dramatically increase generating efficiency and make it possible to substantially reduce $CO_2$ emissions.

In addition, we are developing advanced ultra-supercritical (A-USC) technologies that will further enhance the high efficiency of cutting-edge USC technology at the present time.

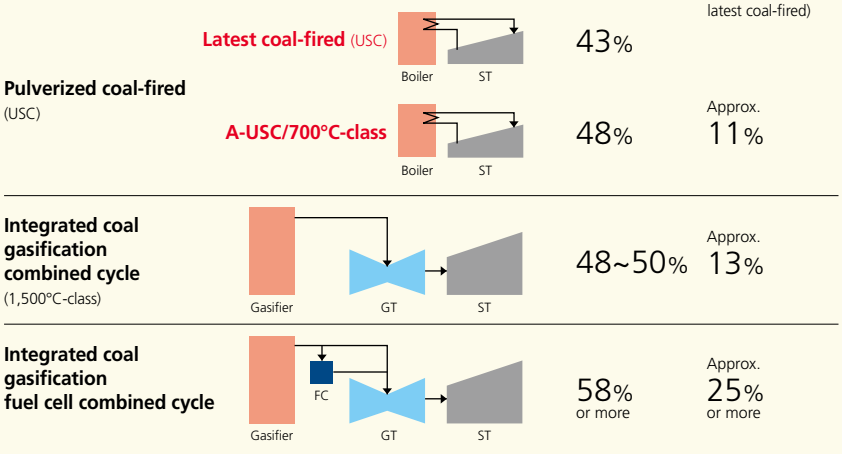
Ultimately, we will strive to realize innovative, zero-emission, coal-fired thermal power by combining IGCC and IGFC systems with $CO_2$ capture and storage (CCS) technologies.

### Development and Deployment Road Map for Clean Coal Technologies




*PCF: Pulverized coal-fired

### Coal-Fired Power Technology for the Next Generation




**Ultra-Supercritical (USC)**
Current cutting-edge technology for raising the efficiency of pulverized coal-fired thermal power. Utilizes a steam pressure of 24.1 MPa or greater with a steam temperature of 593°C or higher

**Advanced Ultra-Supercritical (A-USC)**
Raises thermal efficiency achievable with USC technology by utilizing a steam temperature of 700°C or higher

**Integrated Coal Gasification Combined Cycle (IGCC)**
An integrated power generation system with a twin-turbine configuration; the gas produced from burning coal is used as fuel to drive a gas turbine, the exhaust gases from which are used in a steam turbine

**Integrated Coal Gasification Fuel Cell Combined Cycle (IGFC)**
Adds fuel cells to both gas and steam turbines for a triply integrated power generation configuration

**Specific J-POWER Initiatives 2**

# Developing the Next Generation of Coal-Fired Thermal Power Technologies

## Large-Scale Demonstration Test of Oxygen-Blown IGCC Technology

Since Fiscal 2002, J-POWER's Wakamatsu Research Institute in Fukuoka Prefecture has been heavily involved in two EAGLE pilot programs to test multipurpose coal gasification and gas purification technologies with a view to using coal efficiently and reducing $CO_2$ emissions to zero. The aim of the EAGLE projects is to realize an IGCC system. This system converts coal into flammable carbon monoxide (CO) and hydrogen ($H_2$) by oxygen-blown gasification and uses this gas to power a gas turbine generator and, at the same time, uses the gas turbine's exhaust gases in a steam turbine. Because they generate a gas mainly composed of CO and $H_2$, a special characteristic of oxygen-blown coal gasification technologies is that they facilitate $CO_2$ separation and capture, which can be used in more varied applications. Through the EAGLE projects, J-POWER has achieved the world's highest cold gas efficiency and developed coal gasifiers adaptable to a wide range of coal types.

Leveraging the expertise and accomplishments obtained with the EAGLE projects, J-POWER made the decision to move ahead with a large-scale demonstration test—the Osaki CoolGen Project—designed to bring about the commercialization of IGCC and $CO_2$ separation and capture technologies. In 2009, J-POWER and Chugoku Electric Power Co., Inc., established a joint venture, Osaki CoolGen Corporation, to carry out the test, which entails the construction of a demonstration plant with a coal processing capacity of approximately 1,100 tons per day and a power generation capacity of roughly 170 MW. Starting in 2017, the test will investigate the reliability, economic efficiency, and ease of operation of a power generation system based on oxygen-blown IGCC technology. In addition, we will verify the applicability of conducting tests of the most recent $CO_2$ separation and capture technology. Based on these tests, we will be aiming to further increase efficiency with the IGFC system, which combines fuel cells with the oxygen-blown IGCC system. The aim of these technological developments is to bring to fruition the CoolGen Project* that was put before a national commission.

*The national CoolGen Project is a plan for experimental research aimed at realizing "zero-emission, coal-fired thermal power generation" through a combination of IGCC, IGFC, and CCS technologies.

EAGLE Pilot Test Facility (Fukuoka Prefecture)

## Development of $CO_2$ Separation and Capture Technology

Several countries are making progress with CCS surveys and trial projects. The CCS process involves separating and capturing $CO_2$ given off by large-scale emission sources and storing it permanently underground. Of the three distinct elements comprising CCS—$CO_2$ separation and capture, transport, and storage—J-POWER has focused primarily on the former because those technologies must be designed for use at power plants and because $CO_2$ separation and capture is the most cost-intensive component of the entire CCS process. Technologies for separating and capturing $CO_2$ from the gas produced by oxygen-blown coal gasification are believed to hold the most potential for future application. We demonstrated the effectiveness of a chemical absorption method associated with those technologies during one of the EAGLE pilot programs and are implementing a four-year demonstration test program for a physical absorption method that is scheduled to end in fiscal 2013.

J-POWER is also actively working to develop $CO_2$ separation and capture technologies for combustion exhaust from pulverized coal-fired thermal power, currently the most-common method of power generation from coal. In collaboration with Mitsubishi Heavy Industries Ltd., we conducted pilot trials using the chemical absorption method from 2007 to 2008 at our Matsushima Thermal Power Plant, in Nagasaki Prefecture. Additionally, we are a participant in the Callide Oxyfuel Project using the oxyfuel method, which is being carried out at the Callide A Power Plant in Queensland, Australia. Scheduled for implementation from 2011 to 2013, this joint Japanese-Australian project will be the first in the world to test an integrated CCS and underground storage system using the oxyfuel method at an existing power plant.

Callide A Power Plant (Australia)