Zero Emissions from Fossil Fuel Power Generation

The use of renewable energy is currently expanding on a global scale. However, CO_2-free renewables and nuclear power alone are not sufficient to meet power demand in Japan or around the world. As such, significantly reducing the CO_2 emitted from power generation using fossil fuels, such as coal and natural gas (fossil fuel power generation), is essential to meeting the goals of the Paris Agreement and Japan's greenhouse gas reduction targets.

The J-POWER Group is implementing initiatives to achieve zero emissions from fossil fuel power generation with the aim of greatly reducing CO_2 emissions.

Social Issues

- Climate change
- Energy security
- Electricity shortages in emerging countries

Value That the J-POWER Group Provides

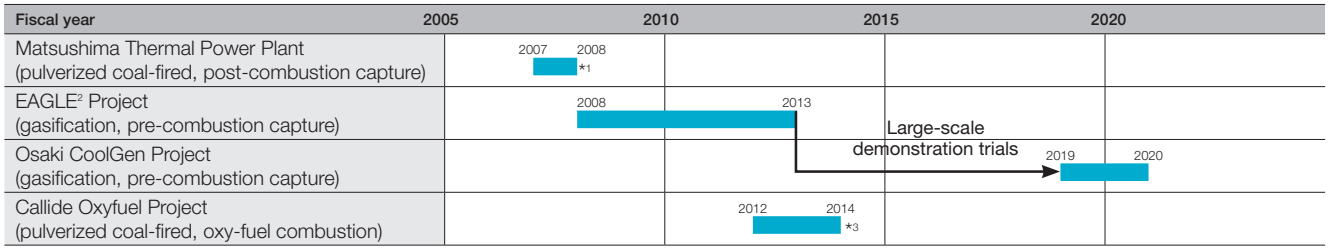
- Greatly reduces CO_2 emissions from fossil fuel power generation
- Contributes to energy security and resolving electricity shortages in emerging countries by enabling the continued use of coal-fired thermal power generation

CO_2 Separation, Capture, Utilization and Storage Initiatives

The J-POWER Group is developing CO_2 separation, capture, utilization and storage (CCUS) technologies as it aims for major reductions in the CO_2 emissions from fossil fuel power generation.

CO_2 Separation and Capture

The J-POWER Group has carried out significant testing related to the separation and capture of CO_2 emitted by coal-fired thermal power plants. Beginning in fiscal 2019, we have been conducting large-scale demonstration trials at the Osaki CoolGen Project.



1. Joint project with Mitsubishi Heavy Industries, Ltd. 2. Please refer to page 27 for details.
3. A public-private, Japanese-Australian joint project. The project conducted the world's first trials of an integrated process involving oxy-fuel and CCS at an actual power plant.

CO_2 Utilization and Storage

CO_2 that has been separated and captured can be put to use or stored underground.

Utilization

Methods of utilizing captured CO_2 include injecting it into depleted oil fields to increase crude oil production in a process known as enhanced oil recovery (EOR), using it directly as dry ice or in other forms, and using it as an input to manufacture chemicals, fuels, or other products.

The J-POWER Group is considering carbon recycling using CO_2 captured by the Osaki CoolGen Project. Specifically, we are looking at using it to increase the concentration of CO_2 in agricultural greenhouses to accelerate crop growth and improve productivity in addition to developing technology for using photosynthetic microalgae mass cultures to produce carbon-neutral jet fuel.

Storage

Storing a large amount of CO_2 deep underground has the potential to significantly reduce the escape of CO_2 to the atmosphere.

J-POWER took part in the Callide Oxyfuel Project, a project jointly conducted by the Japanese and Australian governments and private sectors, which conducted trials in 2014 in which separated and captured CO_2 from a coal-fired thermal power plant was stored underground in Australia.

Furthermore, Japan CCS Co., Ltd., in which J-POWER is an investor, conducted large-scale CCS demonstration trials in Tomakomai City, Hokkaido, under contract with the national government. Japan CCS began injecting CO_2 into underground reservoirs in fiscal 2016 and completed the injection of a cumulative 0.3 million tons of CO_2 in fiscal 2019.

Japan CCS is also surveying potential sites for CO_2 storage on behalf of the government.

Initiatives to Achieve Zero CO_2 Emissions

In addition to CCUS, to reduce the CO_2 itself that is produced during coal use, the J-POWER Group is advancing initiatives aimed at the commercialization of oxygen-blown integrated coal gasification combined cycle (IGCC)[1] and the R&D of high-efficiency power generation technologies, such as integrated coal gasification fuel cell combined cycle (IGFC)[2] technologies.

Oxygen-blown IGCC offers high thermal efficiency, helping reduce CO_2 emissions. In addition, the gases produced contain a high concentration of carbon monoxide (CO), which facilitates the efficient separation and capture of CO_2, so this generation technology is very well suited for CCUS.

Furthermore, at conventional coal-fired thermal power plants, we are not only introducing high-efficiency power generation technologies but also using biomass fuel mixed combustion to reduce carbon emissions. In addition to continuing the mixed combustion initiatives already in practice, we aim to realize up to 10% mixed combustion at the Takehara Thermal Power Plant New Unit No. 1, which commenced operations in June 2020.

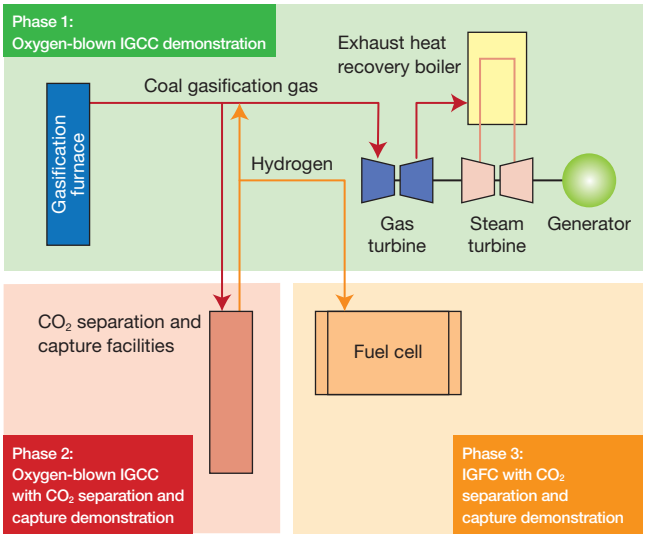
1. Integrated coal gasification combined cycle (IGCC): A combined cycle power generation system with a twin-turbine configuration, comprising a gas turbine driven by the combustion of gas produced by gasifying coal and a steam turbine driven by the exhaust gases from the gas turbine. Oxygen-blown refers to the use of oxygen in the coal gasification process.
2. Integrated coal gasification fuel cell combined cycle (IGFC): An integrated power generation system that combines IGCC with fuel cells and achieves the highest level of thermal efficiency from coal-fired thermal power

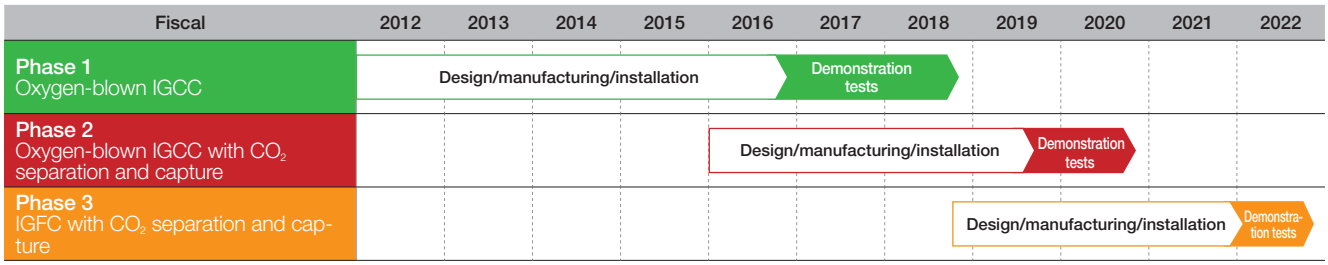
Osaki CoolGen Project

Beginning in fiscal 2002, J-POWER was engaged in the EAGLE[3] Project in collaboration with the New Energy and Industrial Technology Development Organization (NEDO), a national research and development body. This project was aimed at establishing technologies for realizing oxygen-blown IGCC.

Employing insights and results gleaned from the EAGLE Project, the Company has since been engaged in the Osaki CoolGen Project with support from NEDO and in collaboration with The Chugoku Electric Power Co., Inc. Phase 1 of this project, a demonstration test of oxygen-blown IGCC (166 MW capacity, with a coal consumption volume of 1,180 tons per day), was completed in February 2019. In Phase 2, launched in December 2019, we are adding CO_2 separation and capture facilities to conduct demonstration testing of IGCC with CO_2 separation and capture. After Phase 2 is completed, in Phase 3, we will use fuel cells to conduct further demonstration testing of IGFC with CO_2 separation and capture.

3. EAGLE: An oxygen-blown coal gasification project that was conducted at the Wakamatsu Research Institute. The name EAGLE is an acronym for coal Energy Application for Gas, Liquid & Electricity.





Osaki CoolGen Project demonstration test facilities (Osakikamijima-cho, Hiroshima Prefecture)

Osaki CoolGen Project—Main Achievements and Targets

Phase 1: Oxygen-Blown IGCC Demonstration

Achievements

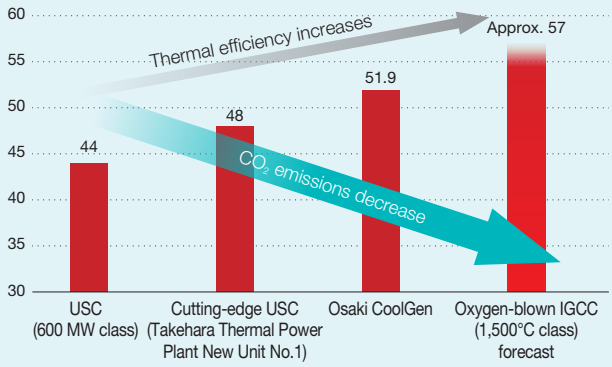
Steady Progress Toward Zero Emissions

■ Achieved 51.9% thermal efficiency (gross efficiency, LHV)
- Higher thermal efficiency than ultra-supercritical (USC) plants[1]
- Data obtained allowed us to estimate thermal efficiency of approximately 57% (gross efficiency, LHV) when these technologies are used with 1,500°C class gas turbines
- Increases in thermal efficiency are expected to lead to a reduction of CO_2 emissions in comparison with USC plants

1. Ultra-supercritical (USC): The current cutting-edge technology for pulverized coal-fired power generation (a conventional method of coal-fired thermal power generation in which finely crushed coal is combusted in a boiler)

Note: The graph at right is based on the thermal efficiency values for USC given in BAT reference materials published by the Ministry of Economy, Trade and Industry and Ministry of the Environment about cutting-edge power generation technologies already in use at commercial plants without economic or reliability issues as of January 2020.

Gross Thermal Efficiency (LHV) (%)

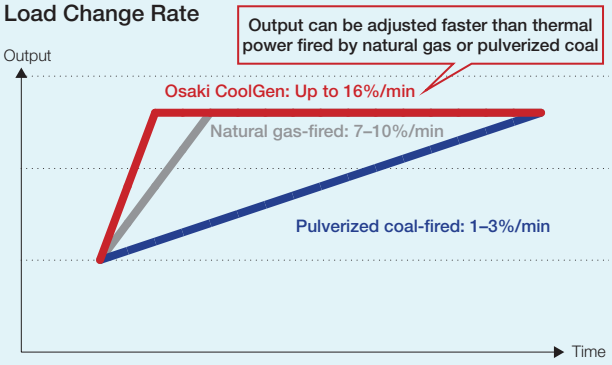


Facilitating the Adoption of Renewable Energy

■ Achieved load change rate[2] of up to 16% per minute
- Load change rate surpassing that of natural gas-fired thermal power generation
- Can be used to balance rapid fluctuations in output from renewables
- Expected to facilitate the adoption of renewable energy by alleviating instability in the power grid caused by the growing use of renewables

2. Load change rate: Ratio of output change to rated load per minute. A larger load change rate allows quicker output adjustment in response to changes in electricity demand.

Load Change Rate



Phase 2: Oxygen-Blown IGCC with CO_2 Separation and Capture Demonstration

Target

■ Gather data needed to design a new commercial plant (1,500°C class IGCC) that achieves 90% CO_2 capture while maintaining approximately 52% thermal efficiency (gross efficiency, LHV).

- Capture rate of CO_2 at separation and capture equipment: Over 90%
- Purity of captured CO_2: Over 99%

Phase 3: IGFC with CO_2 Separation and Capture Demonstration

Target

■ Gather data needed to design a commercial IGFC plant with CO_2 separation and capture (500 MW class) that achieves 90% CO_2 capture and approximately 66% thermal efficiency (gross efficiency, LHV).

Australian Brown Coal Hydrogen Pilot Test Project (HESC* Project)

Hydrogen produces no CO_2 when combusted, can be manufactured from a variety of energy sources, and can be stored and transported. By employing CCS technology at the manufacturing stage, hydrogen can be used as a CO_2-free form of energy. Therefore, for Japan, a nation poor in mineral resources, hydrogen technologies are promising as a means of promoting energy security and combating global warming.

Aiming to build and commercialize a CO_2-free hydrogen supply chain, J-POWER is participating in a pilot test project to produce hydrogen by gasifying Australian brown coal, an abundant, underutilized resource, and transport it to Japan. Within this project, J-POWER is handling the gasification of the brown coal (sponsored by NEDO) and the purification facilities for the hydrogen gas produced. The pilot test is scheduled to be carried out in 2020.

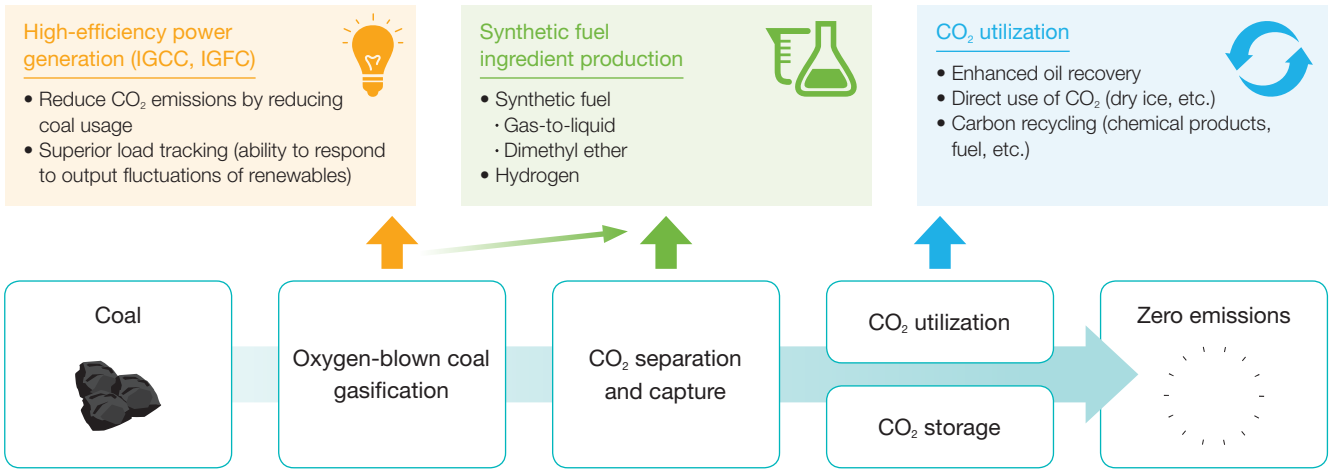
When this supply chain is commercialized, plans call for utilizing CCS to store the CO_2 produced during the manufacture of hydrogen from brown coal, avoiding its release to the atmosphere and thus achieving CO_2-free operations.

* HESC: Hydrogen Energy Supply Chain

Brown coal gasification furnace facilities under construction

Achieving both Zero Emissions in Coal Use and Diverse Uses of Coal

The J-POWER Group is advancing initiatives to achieve zero emissions from coal use. This will not only significantly reduce CO_2 emissions, but enable the use of coal in diverse applications outside of power generation, achieving zero emissions while more effectively using coal resources.



Reference: Initiatives to Reduce CO_2 in Japan

As one of Japan's electricity business operators, J-POWER takes part in the Electric Power Council for a Low Carbon Society and is contributing to the achievement of its targets.

GHG Reduction Target	• Reducing GHG by 26% in fiscal 2030 from fiscal 2013 level
Long-term Energy Supply and Demand Outlook (Energy Mix)	• The share of power generated by each power source in fiscal 2030 is estimated in line with the GHG reduction target • Thermal efficiency is estimated at high-efficiency generation levels (coal: USC, LNG: combined cycle)

Voluntary Initiative

The Electric Power Council for a Low Carbon Society (47 companies as of August 2019)

• Electricity business companies as a whole* aim for a carbon intensity in line with the energy mix (0.37 kg-CO_2/kWh at the user's end in fiscal 2030)

* Accounting for 94.3% of total electricity sales in Japan at the end of fiscal 2018

Governmental Policy Measures

Generators	Grid operators	Retailers
Energy Conservation Act • Newly built thermal power plants must employ the highest-efficiency technology in commercial operation (coal-fired thermal power: 42.0% [gross efficiency, HHV]). • Each generator must aim for the high efficiency energy mix premised for fiscal 2030 (overall thermal power: 44.3% [gross efficiency, HHV]).		**Energy Supply Structure Enhancement Act** • Each retailer must aim for a non-fossil power ratio of 44% or higher, the level estimated in the energy mix, in fiscal 2030.

Note: The number of members of the Electric Power Council for a Low Carbon Society and the electricity sales coverage rate given above are from the council's publications.