# Sophisticated Use of Coal Energy with Green Technologies for Thermal Power Plants


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*With the attention to environmental problems growing in recent years, demand has grown to reduce the emission of $CO_2$ gas, which contributes largely to global warming. For thermal power plants, $CO_2$ emission is reduced by making power generation more efficient. Mitsubishi Heavy Industries, Ltd., (MHI) has improved power generation efficiency in conventional coal-fired thermal power plants by improving steam conditions and adopting advanced technologies. MHI is also improving the efficiency by using gas turbines and gas engines. This paper summarizes on sophisticated use of coal energy with green technologies for thermal power plants, i.e. advanced coal-fired ultra supercritical (USC) thermal power generation, integrated gasification combined cycle (IGCC), the blast furnace gas-fired gas turbine combined cycle, and gas engine power generation using coalmine methane.*


## 1. Introduction

Implementation of the Kyoto Protocol in February 16, 2005, calls for Japan to reduce $CO_2$ emission by 6 % until 2010 from that of 1990 level. Measures proposed to meet this target include expanded use of nuclear energy, renewable energy, clean coal technologies for higher efficiency, natural gas, and energy conservation. Coal, a cheap worldwide energy source, accounts for 20% of Japan's primary energy consumption. Some 20% of Japan's power is generated in coal-fired thermal power plants. Japan's fiscal 1990 power plant $CO_2$ emission intensity was 0.42 kg-$CO_2$/kWh, which was reduced to 0.38 kg-$CO_2$/kWh in 2001. The target set by the Federation of Electric Power Companies of Japan for fiscal 2010 is 0.34 kg-$CO_2$/kWh, 20% down from the 1990 emission level.

$CO_2$ generation per unit calorific power of coal is approximately 1.5 times that of natural gas. With the $CO_2$ emission unit in coal-fired thermal power generation is high at 0.88 kg-$CO_2$/kWh, making high-efficiency coal-fired power generation with less $CO_2$ emission is highly important. **Fig. 1** shows MHI's thermal power generation technologies, which includes improved steam conditions, diversified fuels, gas turbine, and gas engine applications.

## 2. Ultra supercritical pressure coal-fired thermal power plants

For conventional thermal power generation, high-temperature high-pressure steam shown in **Fig. 2** was promoted to increase the unit capacity and thermal efficiency of a power generation.

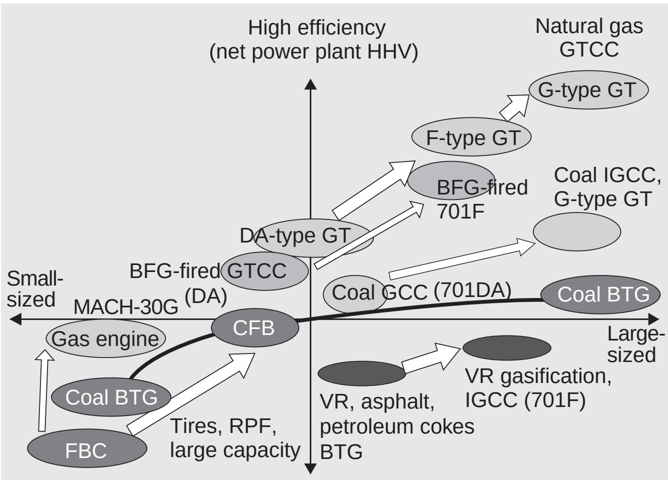


**Fig. 1 Thermal power generation technologies**

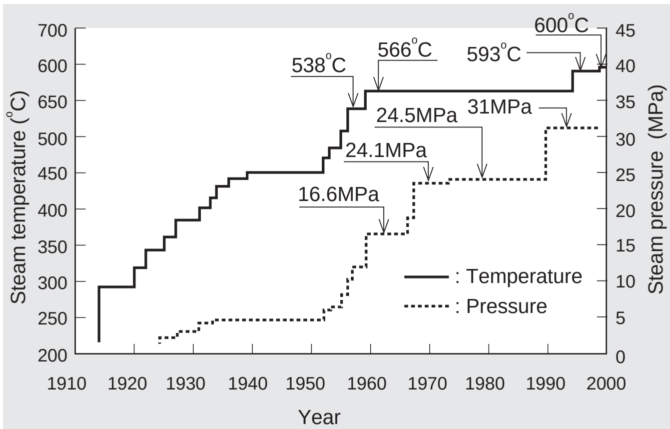


**Fig. 2 Changes in steam conditions in thermal power plant**


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For advanced coal-fired thermal power generation using ultra supercritical pressure conditions, the efficiency at generator terminal exceeds 45% (LHV base), enabling a 3% reduction in $CO_2$ emission as shown in **Fig. 3**.

**Fig. 4** shows Hirono Thermal Power Plant No. 5 of the Tokyo Electric Power Company, which started commercial operation in July 2004. The plant operates under the highest global standards for steam conditions i.e. 24.5 MPa x 600/600°C. The steam turbine of the plant shown in **Fig. 5** uses high-temperature materials and cooling structure to withstand high-temperature steam conditions, and uses sophisticated technologies such as a two-casing turbine — the first in a 600 MW class turbine, a 48-inch steel ISB, a new type of condenser, and a single-shell deaerator cum storage tank. The boiler in this plant uses vertical tube waterwall furnace with rifle tubes and materials withstanding high-temperature together with combustion technologies for reducing NOx and unburned combustible using an A-PM burner and the MRS pulverizer.

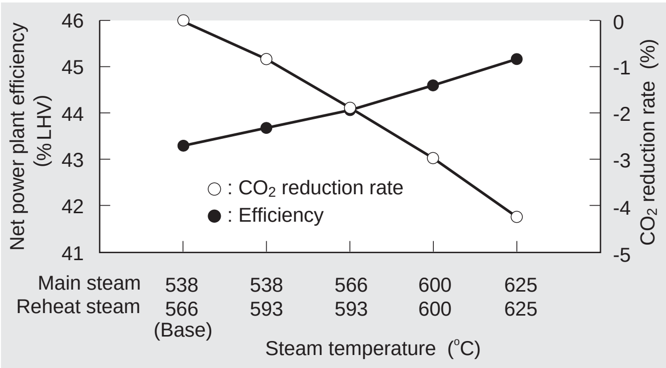


**Fig. 3 Steam condition and efficiency, steam condition and $CO_2$ reduction**

**Fig. 4 Hirono Thermal Power Plant No. 5, Tokyo Electric Power Company**

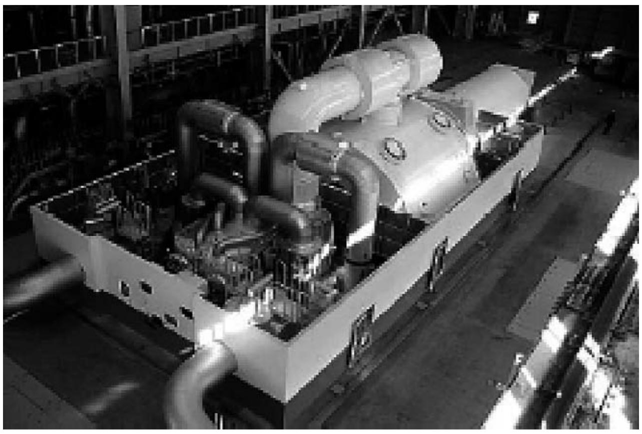

**Fig. 5 600 MW steam turbine of Hirono No. 5**

## 3. IGCC

Thermal efficiency has been drastically improved through high-temperature combustion in gas turbines, with power plant efficiency exceeding 50% in the latest power plant using a gas turbine with 1 500°C class combustion. Fuel used in commercial gas turbines for large-capacity power generation is confined to extremely clean fuels such as LNG and light oil. Coal containing a large amount of ash and alkaline metals cannot be used as it is in such turbines.

IGCC is a technology that gasifies coal into inflammable components such as CO and $H_2$ before it is combusted in the gas turbine. A large project with 300 MW-class oxygen-blown IGCC is already under way in overseas. All of these projects use $O_2$-blown gasification systems developed for chemical plants that lack the reliability of power generation equipment. In Japan, an air-blown IGCC with higher efficiency and reliability is being developed.

Compared to the oxygen-blown IGCC, the air-blown IGCC has high net power plant efficiency because it requires less auxiliary power . The air-blown type also has less latent heat loss than wet coal-feeding type using coal slurry because it feeds pulverized coal as in the case of coal-fired boiler. The principle of the air-blown coal gasifier is shown in **Fig. 6**.

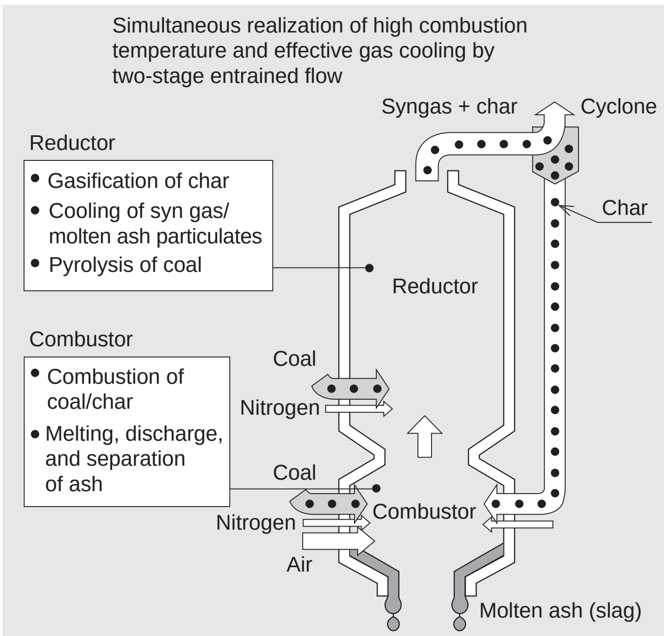


**Fig. 6 Principle of air-blown gasifier**

The Clean Coal Power R&D Co., Ltd, jointly established by electric power companies in Japan is currently constructing 250 MW-class IGCC demonstration plant at the Joban Joint Power Co. Ltd. Nakoso Power Station shown in **Fig. 7** under the government subsidy program. MHI supplies gasifiers, desulfurization, gas turbine, steam turbine, and HRSG plus civil engineering and construction work for this plant, which is scheduled to undergo verification testing in 2007.

The net power plant efficiency of the IGCC using the 1 500°C-class G-type gas turbine is 48–50% (LHV-base) and net power $CO_2$ emission is reduced by 15–20% that of a conventional coal-fired thermal power plant, yielding a $CO_2$ emission unit equivalent to that of a oil-fired thermal power plant.

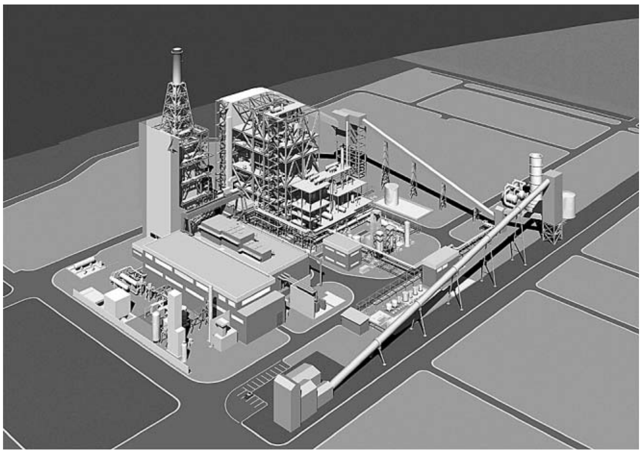

**Fig. 7  250 MW-class demonstration IGCC**

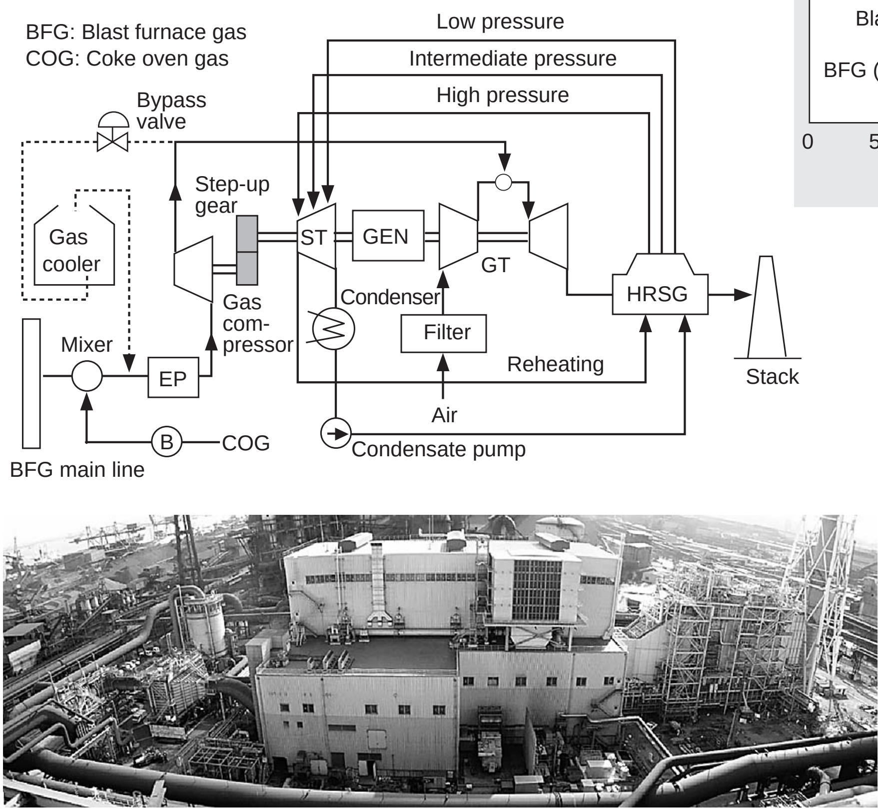


**Fig. 9  Blast furnace gas-fired combined system**

## 4. Blast furnace gas-fired gas turbine combined cycle plant

MHI uses by-product gas in refineries, blast furnace gas in iron mills, etc. as well as natural gas, as fuel for gas turbines (**Fig. 8**). The use of by-product gas as fuel in gas turbine is expected to expand the use of energy more effectively. Approximately 40% of the coal imported to Japan is consumed in iron mills, including the manufacture of coke, so improving energy efficiency in iron mills contributes greatly to reducing $CO_2$ emission.

MHI developed a blast furnace gas fired F-type gas turbine and commercialized the world's largest capacity blast furnace gas fired combined cycle plant in the 1 300°C-class shown in **Fig. 9**, whose commercial operation started in July 2004. This has helped to reduce $CO_2$ emission by 25% compared to conventional thermal power plants having the same power output.

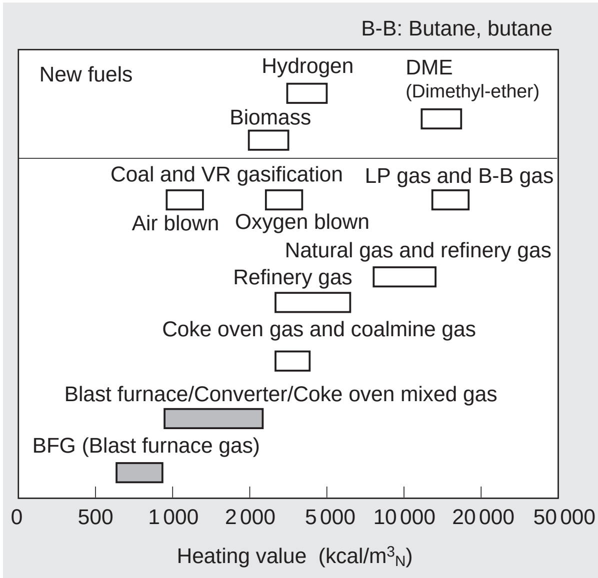


**Fig. 8  Diversification of gas turbine fuels**

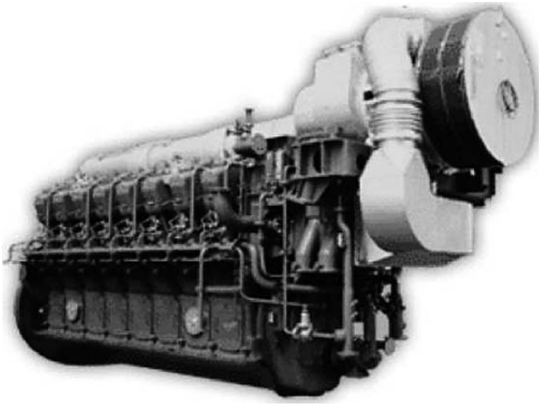

**Fig. 10 External view of MACH-30G**

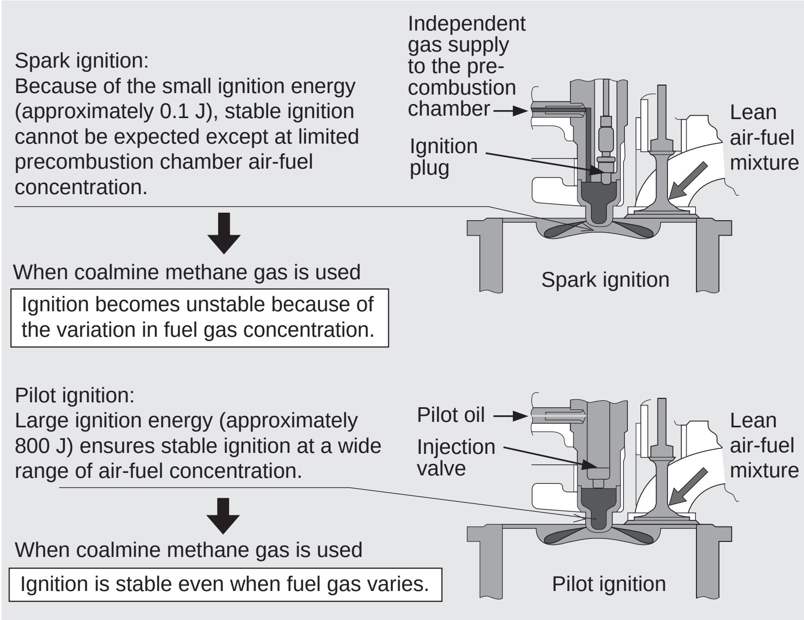


**Fig. 11 Comparison of gas engine ignition**
Use of pilot ignition corresponds to variation in gas concentration

Energy consumption per unit iron production in China is said to be 1.5 times higher than in Japanese iron mills. Energy-saving in Chinese iron mills has become important from the viewpoint of global environmental preservation. MHI is actively engaged in the diffusion of gas turbine combined cycle power plants using by-product gas such as blast furnace gas.

## 5. Gas engines using coalmine methane gas

Demand is growing for gas engines for power generation with less emission of NOx, dust, $CO_2$, etc. MHI developed a low NOx lean burn gas engine applying new technology, targeting the world's highest power generation efficiency. MHI commercialized the micropilot ignition MACH-30G in 5 000 kW-class engines using extremely small amounts of liquid fuel as the ignition source (**Fig. 10**). R & D is targeting the use of methane gas generated when coal is dug at coal mines for the micropilot ignition engine. The methane concentration in coalmine methane gas is approximately 30—50%, so approximately 90% of methane gas is released unused into the atmosphere. The greenhouse effect of methane gas is 21 times larger than that of $CO_2$, with the total emission in terms of $CO_2$ amounting approximately to 500 million t/year in the world, equaling 40% of total $CO_2$ emission a year in Japan. The effective use of coalmine methane gas could thus contribute greatly to preventing global warming.

In conventional engines, where spark ignition system is used and a mixture close to the theoretical air-fuel ratio is fed into the precombustion chamber, ignition becomes unstable when the fuel gas concentration varies excessively. For an engine using micropilot ignition, high ignition energy ensures stable ignition of lean air-fuel mixtures. In other words, micropilot ignition system ensures stable ignition even when the fuel gas goes through variation as in the case of coalmine methane gas. A comparison of pilot ignition vs. spark ignition is shown in **Fig. 11**.

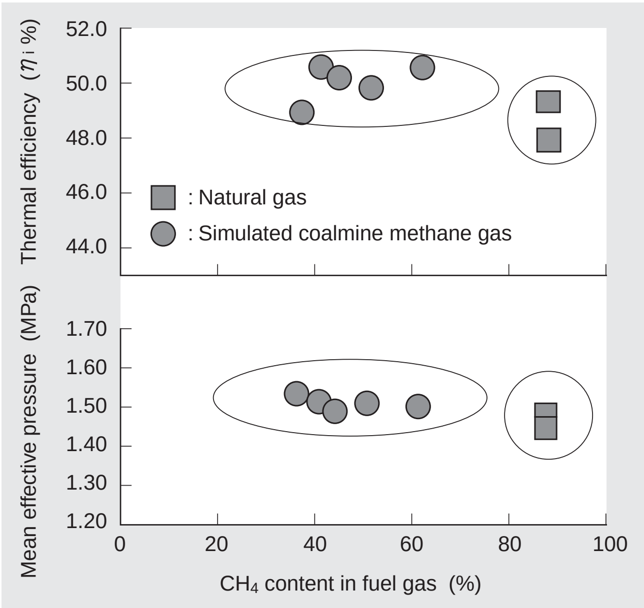


**Fig. 12 Test results of simulated coal bed methane gas**
Indicates comparison of methane concentration in fuel, thermal efficiency, and output. Combustion performance of coalmine methane gas is equivalent to that of natural gas.

MHI has clear, bright prospects of conducting high-power, high-efficiency, stable operation of gas engines using coalmine methane gas equivalent to that of using natural gas by using micropilot ignition shown in **Fig. 12**. MHI is continuing development and striving to commercialization of the gas engine.

## 6. Conclusions

Implementation of the Kyoto Protocol requires Japan to reduce $CO_2$ emission. The $CO_2$ emission per calorific value is higher for coal than for other fossil fuels. Approximately 23% of primary energy in nations worldwide, including Japan, depends on coal, and coal is expected to continue to be used as a prime source of energy.

Japan's coal use technology is among the top in the world, and MHI is determined to take active measures to improve efficiency in coal use technology, including the effective use of natural resources and reduction in $CO_2$ emission, and disseminating its use.

## References


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