

Looking ahead to the future of clean coal technology from the viewpoint of technical innovation in the coal industry, noted below are some very diverse technological trends that are crucial for society.

The first trend is that many different technologies or systems related to coal gasification are now under development. As an example, R&D on high-efficiency power generation systems, including the integrated coal gasification combined cycle (IGCC) and the integrated coal gasification fuel cell combined cycle (IGFC), has steadily progressed toward commercialization. Another example is conversion into liquid fuel or chemical raw materials that are clean and contain no impurities, such as methanol, DME and GTL. These technologies will lead to co-production systems, including co-generation, with a view to a zero-emission world.

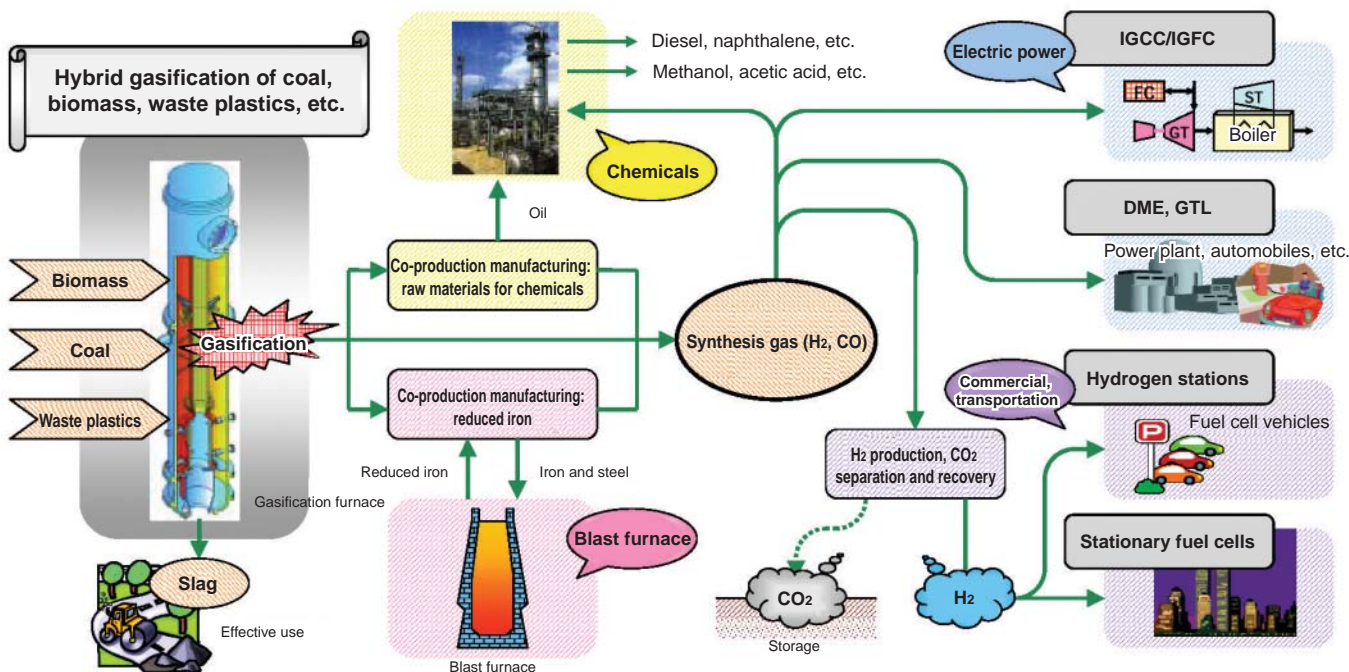
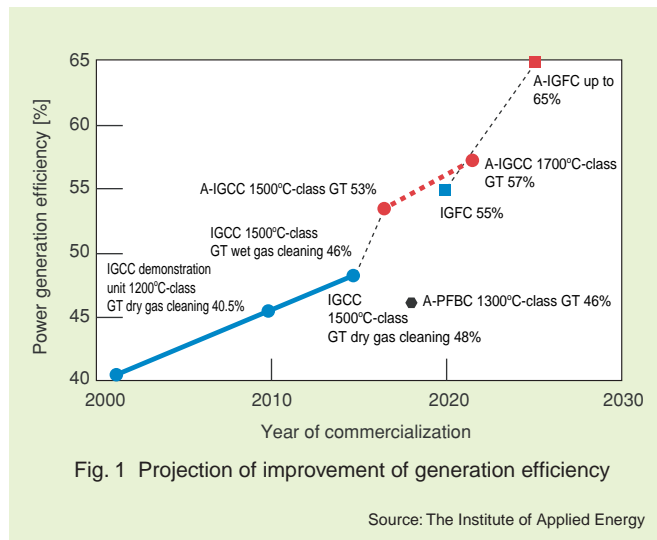
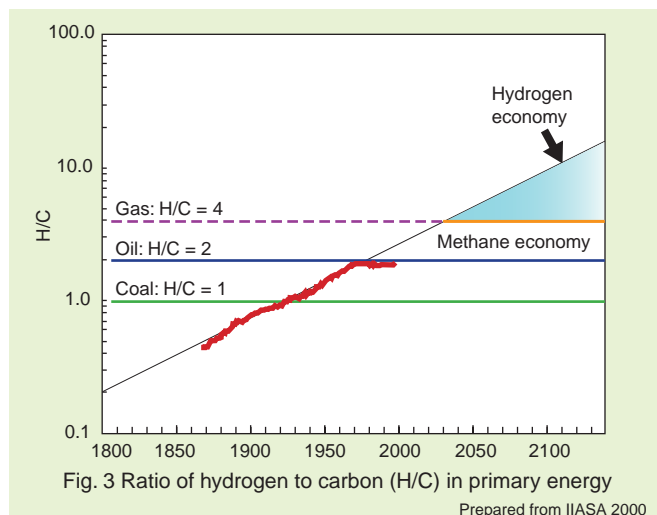


Fig. 2 Various CCT developments centering on coal gasification

The second trend is towards efforts to build a hydrogen energy society, which is the direction the energy sector is expected to move. According to the International Institute for Applied Systems Analysis 2000 (IIASA 2000), in terms of the "H/C (hydrogen/carbon)" ratio, global primary energy consumption was on a near-constant increase between the mid-1800's to around 1980. In and after 1980, the H/C ratio remained almost unchanged at around two due to an increase in oil consumption. As a whole, however, the pre-1980 trend is expected to resume, leading to a situation where, around 2030, the H/C ratio will equal four. In a society where the primary energy source is shifting from natural gas to hydrogen, energy consumption derived from carbon combustion will finally be discouraged. It is even predicted that coal energy will only be used for HyPr-RING (Hydrogen Production by



Reaction Integrated Novel Gasification process, where the H/C ratio is approximately one), and society will be forced to deal with CO₂ emissions resulting from the direct combustion of coal by heavily relying on CO₂ separation, recovery, sequestration and fixation. Thus, there are basically two important clean coal technology challenges. One is to develop a series of upstream technologies to separate, recover, sequester and store CO₂

generated through the direct combustion of coal and to collect crude oil and gases. The other is to build high-efficiency coal utilization technologies, including coal gasification, reforming and conversion technologies, so that the carbon component in coal can be used as fuel or as a feedstock for the chemical industry, thereby reducing CO₂ emissions generated through direct combustion.

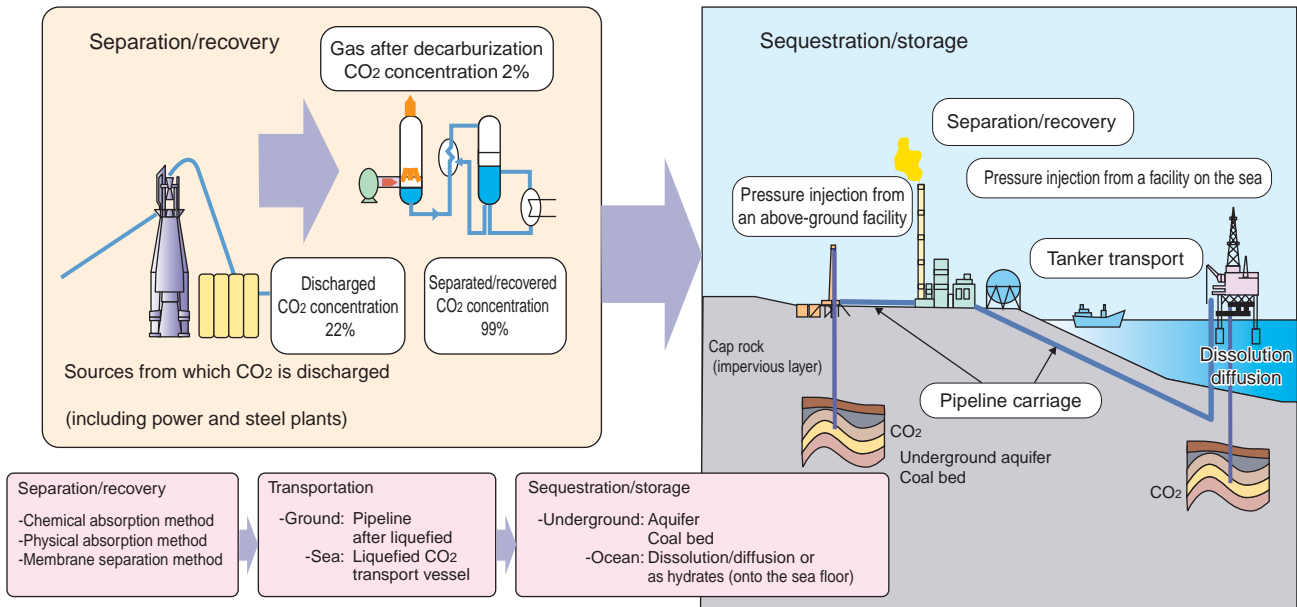


Fig. 4 CO₂ separation, recovery, sequestration, and storage

The third trend is exploiting coal technology's potential for technical development in association with innovative technologies such as environmental/energy technology, biotechnology, nanotechnology and information technology, which have been categorized as priority R&D target technologies in Japan.

Research and development of environmental/energy technology is focused on achieving a zero-emission society, mainly through the implementation of "CO₂ control," as mentioned earlier. The co-production system is regarded as the final target to be achieved through technical innovation.

Advances in biotechnology could also unlock methods for the fixation and effective utilization of CO₂. Furthermore, the

development of hyper-coal production technology may bring about novel techniques that allow advanced utilization of the carbon within coal. In fact, there exist some specific nanotechnology areas, such as nanocarbon fibers, where potential technical innovation is associated with coal.

The progress in information technology will certainly bring about innovative developments in the modeling and simulation of coal technologies.

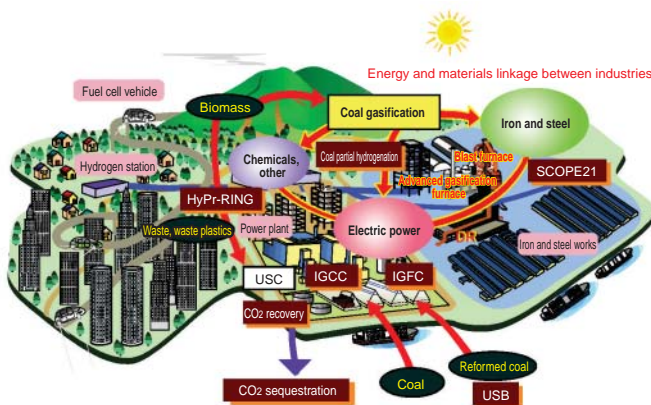


Fig. 5 Energy utilization in a future society supported by CCT (2030)

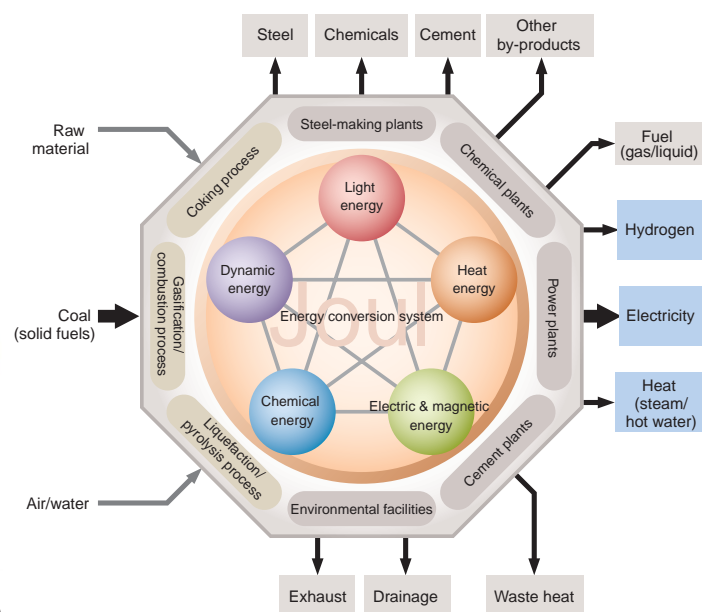


Fig. 6 Co-production system

The ultimate goal for co-production systems is zero emissions (or the discharge of purified water and steam).

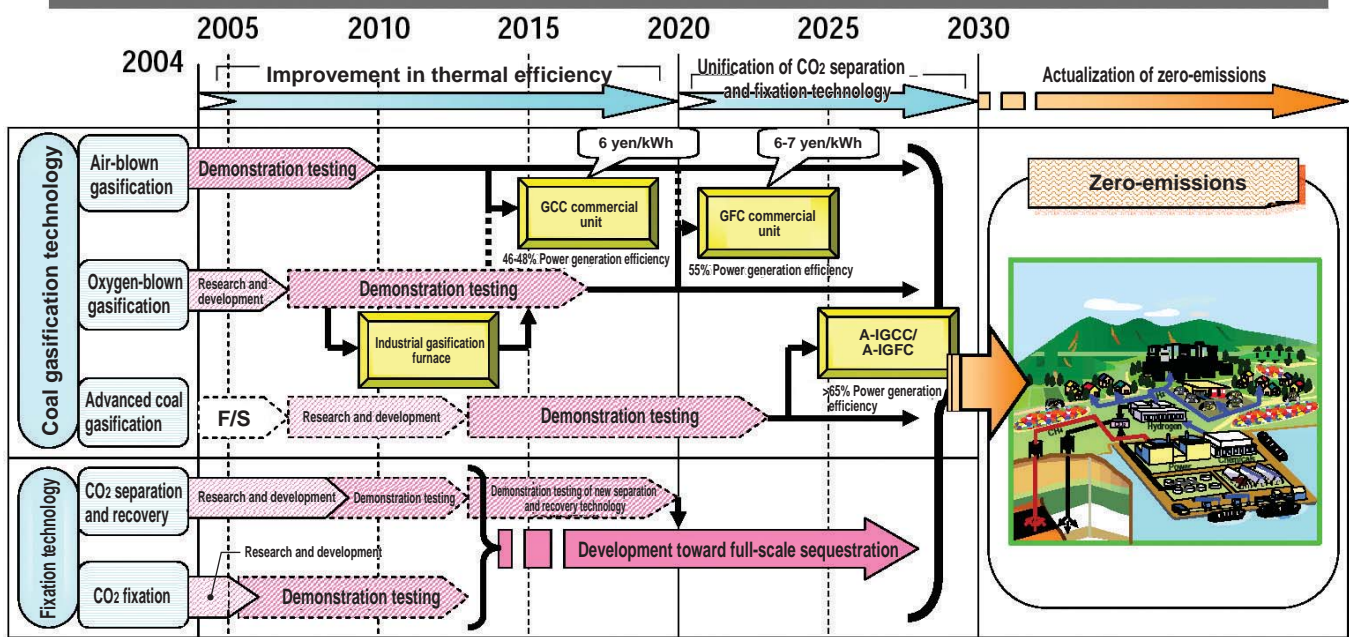
CCT plays an important role in steelmaking as well as in power generation. Coal is used in the steelmaking industry not only as an energy resource but also as a high-quality reducing agent, and is one of the raw materials used in steelmaking. A potential task to be assigned to well-established steelmaking processes, such as the blast-furnace process, is to achieve an innovative level of total coal utilization efficiency by using a co-production system, like DIOS (Direct Iron Ore Smelting reduction process), in order to simultaneously produce iron and synthetic gas, electric power, hydrogen/thermal energy, chemical feedstocks, etc., from steam coal for the steady implementation of improved environmental measures aimed at zero emissions.

As the world's largest coal importer and as the leader in CCT, Japan should remain active in international cooperation, including technical transfers and human resource development with developing countries, mainly in Asia. Such international activities will not only benefit countries that are trying to improve their economic growth by relying on coal energy, but also provide Japan itself with significant means to achieve a stable supply of energy. In addition, it will support efforts to utilize the Kyoto

Mechanisms, including the Clean Development Mechanism (CDM), which seek to address global environmental problems. Economic growth can only be achieved with a stable supply of energy, while environmental conservation is a challenge to be addressed by the whole world. The former is a limiting factor for the latter and vice versa. Throughout history, these two conflicting concerns have had the common fundamental problem of explosive population growth. Under these circumstances, efforts for environmental conservation, including controlling global warming with a goal of eliminating emissions, must be the top priority in the development of CCT in Japan. It is, therefore, essential to build an efficient, advanced coal energy utilization system with minimum impact on the global environment, which will require international cooperation.

Promotion of innovative CCT development toward eliminating emissions

With an aim to positioning coal as a source of CO₂-free energy by 2030, innovative CCT development will be promoted, including CO₂ fixation technology and next-generation high-efficiency gasification technology, toward the goal of eliminating emissions, while identifying the role of individual technologies in the overall scheme.



Current coal thermal generation unit price is assumed to be 5.9 yen/kWh, as estimated by The Federation of Electric Power Companies, Japan. : Commercialization