Core Technologies Supporting KOBELCO Group's Contributions to Green Society

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Abstract

Throughout its diverse business activities spanning materials, machinery, and electric power supply, KOBELCO Group has offered a wide range of technologies, products, and services that contribute to a green society. In pursuit of the challenge of realizing carbon neutrality by 2050, the KOBELCO Group is actively engaged in creating unique CO_2 reduction solutions by leveraging and combining the core technologies it has cultivated over time.

Introduction

Efforts to address climate change in developed countries have accelerated dramatically since the adoption of the Paris Agreement at COP21 in 2015 and the adoption of the SDGs at the UN Summit in the same year. Japan has also declared a goal of becoming carbon neutral by 2050, with its government's Green Growth Strategy stating that "the era of regarding global warming as a constraint or cost to economic growth has been superseded by an era in which it is regarded as an opportunity for growth internationally."

The KOBELCO Group has specified contributing to a green society as one of its materialities (key issues) and is consolidating its efforts to navigate climate change and resource recycling as part of "the challenge of realizing carbon neutrality". Although the KOBELCO Group's production processes emit a large amount of CO_2 the company has introduced a vast number of technologies, products, and services that greatly reduce CO_2 emissions. **Table 1** shows the KOBELCO Group's targets for 2030 and visions for 2050 as they relate to reducing CO_2 emissions in production processes and to contributing to reducing CO_2 emissions through technologies, products, and services.[1)] To achieve carbon neutrality by 2050, the KOBELCO Group aims to create new innovations that are unique to the company by combining the group's various businesses and technologies. This paper provides an overview of the KOBELCO Group's unique approach to contributing to a green society, including the core technologies that support it.

1. Efforts to reduce CO_2 emissions in the steelmaking process

Steel industry CO_2 emissions account for 40% of Japan's CO_2 emissions from the industrial sector (14% of Japan's total emissions).[2)] CO_2 reduction in the steelmaking process presents a major challenge along the path to the KOBELCO Group's achievement of carbon neutrality.[1)] As such, we are actively pursuing development of our own CO_2 reduction solutions.

1.1 Production of direct reduced iron via the MIDREX® Process

The essential technology behind the KOBELCO Group's unique CO_2 reduction solution is the MIDREX® Process, which uses natural gas as a reducing agent for direct reduction of iron ore.

Kobe Steel actively expanded its engineering business overseas in the 1970s, which led to the commissioning of an integrated steel plant in the Middle East, where natural gas is abundant. At that time, the MIDREX® Process was introduced as a means of producing DRI (direct reduced iron). The anticipated potential of the process drove Kobe Steel to acquire shares of Midrex Corporation in

Table 1 KOBELCO Group's targets for 2030 and vision for 2050[1)]

	2030 Targets	2050 Vision
Reduction of CO_2 emissions in production processes	**30-40%** (compared to fiscal 2013)	**Taking on the challenge of realizing carbon neutrality**
Contribution to reduction of CO_2 emissions through technologies, products, and services	**78 million tons**	**100 million tons or more**

1983. This period marked the dawn of the direct reduced iron plant industry. Kobe Steel's support in technological development helped perfect the process, leading to a multitude of milestone achievements within the sector. This process is now responsible for about 60% of the world's DRI (80% of the world's natural gas-based DRI).

Because the process doesn't use coal as a reducing agent, it has attracted increasing attention in recent years as an ironmaking process with low CO_2 emissions. Moreover, 100% H_2 reduction technology is already in the commercialization phase in the effort to further reduce CO_2 emissions.

1.2 Technology to utilize large amounts of direct reduced iron in blast furnaces

Although direct reduced iron (hereafter, "reduced iron") has mainly been used as a source of relatively pure iron for raw material in electric furnaces, Kobe Steel is actively pursuing the use of reduced iron in blast furnaces. In 2023, we demonstrated our technology for reducing the amount of coal used as a reducing agent by charging a large amount of HBI (Hot Briquetted Iron) produced by the MIDREX® Process into a working blast furnace at the Kakogawa Works. The result is a reduction of blast furnace CO_2 emissions of approximately 25% compared with conventional methods.[3)] This constitutes the world's highest level of CO_2 reduction of a large blast furnace in stable operation. Kobe Steel's unique blast furnace operation technology has enabled high-volume charging of HBI in blast furnaces. This technology has been refined over many years in pursuit of cost reduction amidst challenging operating parameters, or in other words, top-level operation in the blast furnace industry. Specifically, these technologies include center coke charging and all-pellet operation for thermal stabilization alongside economical raw materials and alteration of the reducing agent ratio (mass of reducing agent per ton of molten metal). Also embedded in the technologies are unique elements stemming from expansive expertise, such as ventilation control via burden distribution as well as evaluation methods for the actual machine. These unique findings have been exploited extensively to reduce CO_2 emissions in high-volume charging of HBI in blast furnaces. Achievements include an unprecedented degree of reduced iron charging in a blast furnace and a CO_2 emissions reduction level exceeding that of the typical competitors for the same amount of charging.

1.3 Core technologies supporting CO_2 reduction in ironmaking processes

One of the strengths of the MIDREX® Process is its flexibility to adapt the composition of reducing gas and the quality of reduced iron. This capability enables the process to meet the needs of customers around the world with different constraints. The core technologies of direct reduced iron production technology and thermal and fluid dynamics control technology covered in this special issue support optimization of process conditions to meet various needs.

Blast furnaces using a high-HBI blend are approaching the limit of stable operation. Innovations in AI-based prediction of furnace condition and sensing technology are essential to reduce CO_2 emissions, ensure stable operation, and mitigate cost increases in the future. This special issue also introduces core technologies that will support next-generation blast furnace operations, including process control technology, measurement technology under special conditions, and data-driven science and AI application technology.

2. Contributions to a green society through process equipment

Since the KOBELCO Group's manufacture of Japan's first high-pressure air compressor in 1915, it has commercialized a wide range of equipment indispensable to industrial processes in the oil refining, steelmaking, and gas and energy sectors, among others. The company's primary portfolio of process equipment encompasses industry-leading technologies including compressors, chillers, heat pumps, heat exchangers (e.g., vaporizers), electrolyzers, and glass-lined reactors. Moreover, the company continuously releases high-value-added products and services in response to environmental changes.

Major changes in industrial processes are to be anticipated for a green society. The KOBELCO Group leverages its experience and technological capabilities accumulated via its extensive history of process equipment development to respond flexibly to future process changes. Furthermore, the expertise in process engineering and operations management cultivated through the course of its engineering ventures positions the KOBELCO Group to become a major solutions provider for the next-generation energy and carbon recycling supply chains. This section introduces exemplary Kobe Steel process equipment and the KOBELCO Group's unique focus areas based on the combination of this equipment.

2.1 KOBELCO Group process equipment contributes to CO_2 reduction

The merit of Kobe Steel's process gas compressor segment is the capability of designing and manufacturing all major types of compression systems (screw, centrifugal, reciprocating). The demand for compressors for LNG carrier engine fuel is expected to increase against the backdrop of environmental regulations. Accordingly, our portfolio ranges from low-pressure screw compressors to high-pressure reciprocating compressors, providing highly suitable options for a wide range of needs.[4] In addition, to reduce energy consumption in CO_2 compressors used for carbon capture and storage (CCS), we developed an integrally geared centrifugal compressor for high-pressure CO_2. This development reduces power consumption compared with conventional single-shaft centrifugal compressors.[5]

Kobe Steel is also a top manufacturer of LNG vaporizers, having supplied many to companies all over the world. The need for effective use of cold energy to reduce energy consumption has increased recently. Accordingly, interest in the introduction of intermediate fluid type vaporizers (IFV), which are suitable for recovering cold energy during vaporization, is also increasing. Transitioning from LNG to liquid hydrogen fuel is part of the vision of a future carbon-neutral society, but no one had yet developed an IFV-type liquid hydrogen vaporizer. As such, Kobe Steel is demonstrating an IFV-type liquid hydrogen vaporizer that uses the technology it has refined for LNG vaporizers.[6]

In the 1990s, Kobelco Eco-Solutions Co., Ltd. (hereafter, SKS) developed and commercialized a water-electrolysis hydrogen generator (product name: HHOG [High-purity Hydrogen Oxygen Generator]) that produces high-purity hydrogen gas from tap water using a solid polymer electrolyte membrane (PEM). Initially, the main application of the HHOG was the on-site supply of industrial gases for metal heat treatment and the semiconductor and electronics industries. The HHOG's strength lies in its track record of the stable operation of over 200 units, a value that is among the highest in Japan. The demand for energy applications has recently seen rapid growth against the backdrop of carbon neutrality. The need for CO_2-free hydrogen (green hydrogen) that uses renewable energy as power for electrolysis is also expected to increase in the future. The challenge presented by using renewable energy is making the electrolysis of water track fluctuations in the electricity supply from renewable energy. The KOBELCO Group has successfully demonstrated the stable production of green hydrogen using renewable energy and the electrolysis of water in a project sponsored by the Ministry of the Environment.[7]

The KOBELCO Group will continue contributing to a green society through its feature-rich process equipment, which is necessary to drive the chemical and energy industries' processes toward carbon neutrality.

2.2 Demonstration of a hybrid-type hydrogen gas supply system that combines Kobe Steel's process equipment

The KOBELCO Group is promoting the demonstration of a hybrid-type hydrogen gas supply system developed to provide a stable and economical hydrogen supply for a carbon-neutral society.[8] This system combines the following three technologies in which the KOBELCO Group has great expertise:

① IFV-type cryogenic liquid hydrogen vaporizer
② Electrolyzed-water hydrogen production system using renewable energy
③ Operation management that monitors and controls creation and use

Specifically, as shown in **Fig. 1**, the hybrid-type hydrogen supply system comprises a liquid hydrogen vaporizer and a water-electrolysis hydrogen generator using renewable energy in parallel to minimize costs and mitigate the inherent instability of the supply of renewable energy.

In addition, the cold energy generated when liquid hydrogen is vaporized can be used to cool production plant equipment, air conditioning systems, heat pumps, and similar to improve customers' process efficiency and reduce energy consumption.

2.3 Core technologies supporting the development of process equipment that contributes to CO_2 reduction

As mentioned, process innovations in various industrial fields against the backdrop of carbon neutrality have changed the specifications required of process equipment. These innovations have also led to an increasing number of responses to unprecedented design specifications and operating conditions. However, a problem with process equipment can lead to the shutdown of industrial plants supporting the infrastructure of a green society; hence, high reliability and stability are essential. Energy efficiency is also important because process equipment accounts for a large proportion of

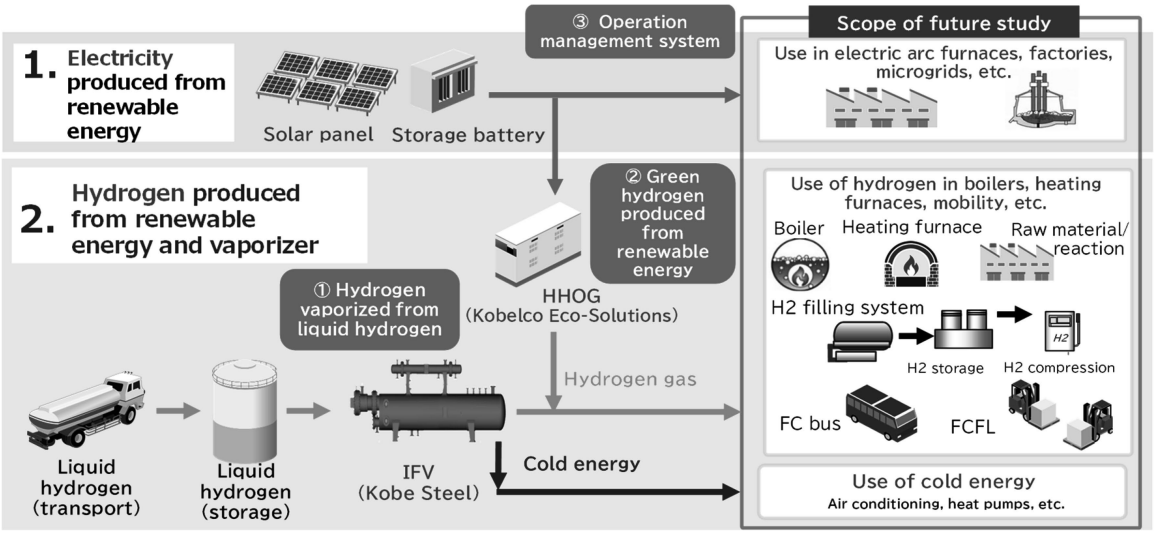

Fig. 1 Conceptual diagram of hybrid-type hydrogen gas supply system[8)]

a plant's energy consumption.

Process and equipment design, which are often based on past experience, must be optimized to fulfill necessary performance requirements in unexperienced conditions. This is accomplished by predicting the behavior of process equipment based on numerical analysis or by first performing an evaluation via component testing to compensate for a lack of historical data.

The thermal and fluid dynamics control technology; machine vibration, noise, and dynamics characteristics control technology; and adsorption and separation technology introduced in this special issue are all core technologies that are essential for responding to these challenges and are embedded in Kobe Steel's process equipment that contributes to a green society.

3. Initiatives and core technologies for reducing CO_2 emissions in the electric power business

The KOBELCO Group is taking on the challenge of realizing carbon neutrality of the electric power business and is strengthening its efforts to reduce CO_2 emissions.[1)] Steam generated by the Kobe Power Plant is used to supply heat to the surrounding area, and the possibility of supplying energy to the entire region is being investigated. The goal is to develop an urban thermal power generation plant with the world's most advanced environmental performance characteristics by using CO_2 reduction technologies such as biomass cofiring and ammonia cofiring.

Furthermore, the objective includes expansion of the share of ammonia cofiring in step with technological innovation to ultimately achieve ammonia-only cofiring. The Moka Power Plant is a high-efficiency CCGT plant (combined-cycle gas turbine) that generates a continuous and stable supply of power with low CO_2 emissions. Furthermore, the plant is considering using carbon-neutral city gas in the future.

The KOBELCO Group's technologies are also being used to reduce CO_2 emissions in the electric power business. One example is the use of local biomass at the Kobe Power Plant, which is progressing via collaboration between the engineering and electric power businesses. SKS, part of Kobe Steel's engineering segment, has a long history in water treatment and is working to reduce emissions through the effective use of sewage sludge via its technologies in this sector. In fiscal year 2021, the Kansai region commissioned SKS for one of Japan's largest sewage sludge fuel conversion projects.[9)] Using biomass fuel derived from sewage sludge as fuel for thermal power plants through cofiring contributes to reducing CO_2 emissions and recycling resources in the region.

Biomass shows great promise as a means of reducing CO_2 emissions because it can be used in existing thermal power generation facilities. However, it is necessary to first determine the inherent combustion characteristics of biomass and the effects of exhaust gas on catalytic performance. The KOBELCO Group possesses evaluation and analysis technologies that contribute to the safe and stable use of biomass. This unique core technology builds on past demonstration projects for low-grade coal utilization overseas.[10)]

The Kobe Power Plant is Japan's most environmentally accommodating urban power station. For more than 20 years, this plant has provided a stable supply of energy to the region

while placing the highest priority on environmental considerations. The various technologies developed over many years of environmentally conscious operation will be highly advantageous in the use of biomass and ammonia, which will contribute to CO_2 reduction.

This special issue introduces core technologies that have been supporting the electric power industry and that will contribute to future reductions in CO_2 emissions. Said technologies include carbon resource conversion and application technology, thermal and fluid dynamics control technology, and adsorption and desorption technology.

4. Recycling of by-products generated by the production process

To use finite resources effectively, the KOBELCO Group reduces the generation of waste, reuses secondary materials, and recycles by-products of the production process as resources for other uses (i.e., resource recycling).[1)]

The steel and aluminum sector generates a substantial amount of by-products. The reuse of steel slag is one of this sector's typical examples of recycling materials into a new product. Kobe Steel has a long history of producing steel slag products, with full-scale marketing of its slag products to external customers beginning in 1976. The company has since produced roadbed materials, fine blast furnace slag aggregate for concrete, ground granulated blast furnace slag, and civil engineering materials. The slag recycling process necessitates preprocessing in accordance with the environmental and quality standards of the given application. The KOBELCO Group's trusted slag products are subjected to stringent quality control standards.[11)]

One example lies in the steel slag from converter and hot-metal dephosphorization furnaces, which is primarily recycled as roadbed material for asphalt pavement. Calcium oxide (CaO) in the slag may react with moisture after asphalt is laid and expand, causing asphalt uplift. Hence, the slag is treated via steam aging to reform hydrates before shipment, thereby reducing expansion after asphalt is laid.

Kobe Steel practices a unique resource recycling flow that spans across different materials businesses (steel and aluminum alloy). Arc furnace ash from the aluminum melting process at the main aluminum sheet plant, Moka Works (Tochigi Prefecture), is recycled as a secondary material (desulfurizer) in the steelmaking process at the main steel plant, Kakogawa Works (Hyogo Prefecture).[12)] Desulfurization slag from the steelmaking process is recycled again in the upstream ironmaking process (sintering ore) and eventually becomes blast furnace slag, which is sold externally as a high-value-added cement material. Recycling between industries often involves downcycling, in which product value decreases. However, a unique resource circulation flow such as the one described capitalizes on the diversity of businesses and processes to enable upcycling for increased value added.

The KOBELCO Group is also developing a CO_2 fixation process (a type of CCUS technology - carbon capture, utilization, and storage) using steel slag. This process utilizes the free lime (CaO) in steel slag, which is an undesirable substance for the aforementioned roadbed material applications. In the fixation process under development, CaO is first selectively extracted from spent steel slag using a proprietary solvent. Reacting this CaO-containing solvent with exhaust gas from industrial plants also stabilizes CO_2 in the exhaust gas as high-purity calcium carbonate ($CaCO_3$). As such, this process contributes to both resource recycling of steel slag (suppression of roadbed material expansion) and curtailment of global warming (CO_2 fixation).[13)] Advanced technological development is currently underway.

Conclusions

This paper outlines the CO_2 reduction solutions fostered by the KOBELCO Group's technologies, products, and services in terms of contributing to a green society, which is a materiality for the KOBELCO Group. Achieving both carbon neutrality and our vision requires the development of new innovations, at the heart of which is the KOBELCO Group's diverse group of core technologies detailed in this special issue.

Individual core technologies as well as combinations thereof have enabled all the examples of contributing to a green society presented in this paper. The unique technological assets cultivated by the KOBELCO Group through the group's diverse businesses have opened up substantial possibilities. Specifically, they have enabled both the concepts for new products and services based on combined technologies introduced in this paper as well as the diversity of technologies covered in this special issue. Moreover, these concepts and technologies will certainly serve as the KOBELCO Group's strength in resolving difficult challenges.

The KOBELCO's Mission, in line with the group's corporate vision, is to provide solution to the needs of society, by making the best use of the talents of our employees and our technologies. We aspire to

enhance and combine our core technologies to create new value that contributes to a green society.

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