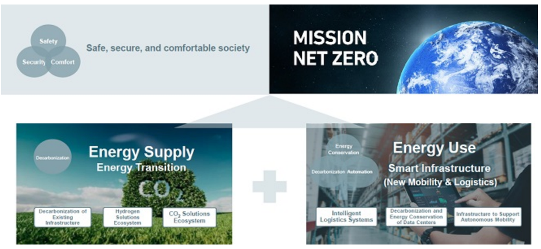
Carbon Neutral Initiatives for Works and Plants of MHI Group



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Mitsubishi Heavy Industries Ltd. Group (MHI Group) announced its Mission Net Zero goal in October 2021 to reduce CO_2 emissions from its business activities to Net Zero by 2040. This initiative targets Works and Plants, which are the main sources of emissions from business activities, and aims to minimize CO_2 emissions intensity on the demand side through a scientific approach, to materialize a feasible means to achieve that, and to realize an energy transition on the supply side. This report focuses on the minimization of CO_2 emissions intensity on the demand side and introduces an initiative example where an approximately 50% reduction was attained. MHI Group will use this initiative as a showcase to contribute to the achievement of carbon neutrality around the world by offering MHI Group's products and services "in total, from engineering to equipment installation and O&M".

1. Introduction

MHI Group business activities in 2021 had direct CO_2 emissions from Works/Plants and other facilities (corresponding to Scope 1, CO_2 emissions from the combustion of gas and other fuels) and indirect CO_2 emissions from the use of electricity in Works/Plants and offices (corresponding to Scope 2) that totaled 138,000 tons and 374,000 tons, respectively. In this way, MHI Group's production factories are the main CO_2 emissions source of its business activities. MHI Group has more than 20 production bases throughout Japan, and under the basic policy of 3E+S (Energy security, Economic efficiency, Environment, and Safety), the bases have been actively working on energy saving for their energy-intensive facilities such as boiler facilities, heat treatment furnaces, electric furnaces, heating and drying furnaces, steam utilization facilities and processes, and air conditioning facilities, in other words, global environmental conservation and CO_2 emissions reduction.

Figure 1 shows the roadmap toward Mission Net Zero, which is MHI Group's current goal. MHI Group aims to achieve carbon neutrality by 2040 by strengthening and accelerating the existing initiatives and actively introducing our own technologies, such as high-temperature heat pumps, hydrogen technology, and CCUS (Carbon dioxide Capture, Utilization, and Storage), to Works/Plants. In order to realize this, it is necessary to consider both the demand side, which consumes energy, and the supply side, which provides energy.

In addition to the above, MHI Group possesses a wide range of required technologies and products that contribute to carbon neutrality and is promoting technological development. By utilizing various product technologies such as heat pumps, engineering technologies, energy management technologies, and their basic technologies, and applying them to Works/Plants, MHI

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Group aims to achieve carbon neutrality and meet the demands of the international community, as well as to use this initiative as a showcase for "total services" from engineering to equipment installation and O&M and to contribute to the achievement of carbon neutrality around the world and the realization of a sustainable society.

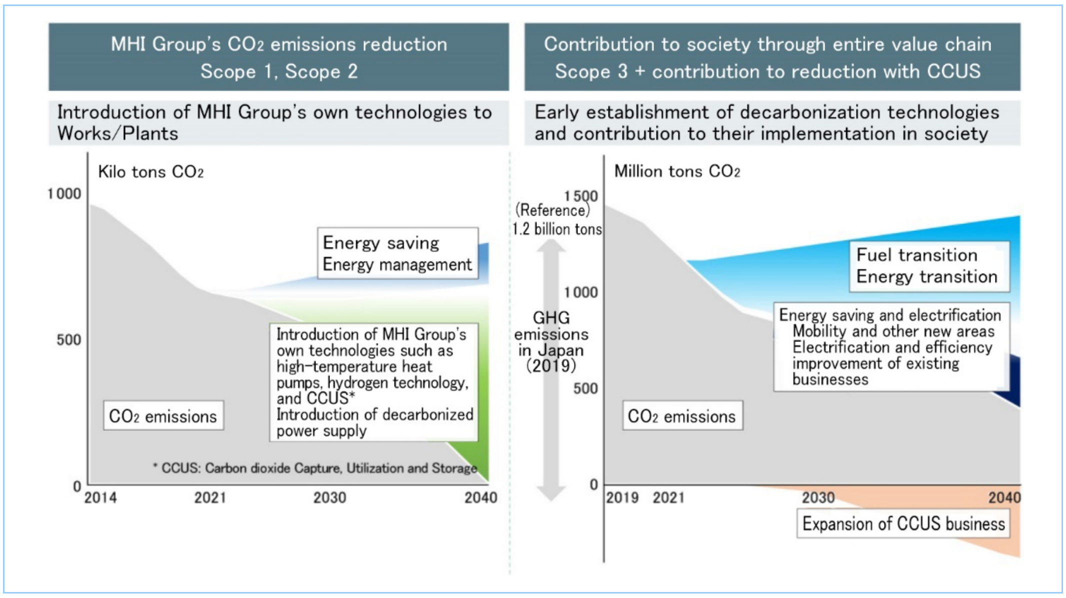

Figure 1 Roadmap toward Mission Net Zero

2. Concept and policy of initiative

Figure 2 shows the approach to be considered in proceeding with this initiative.

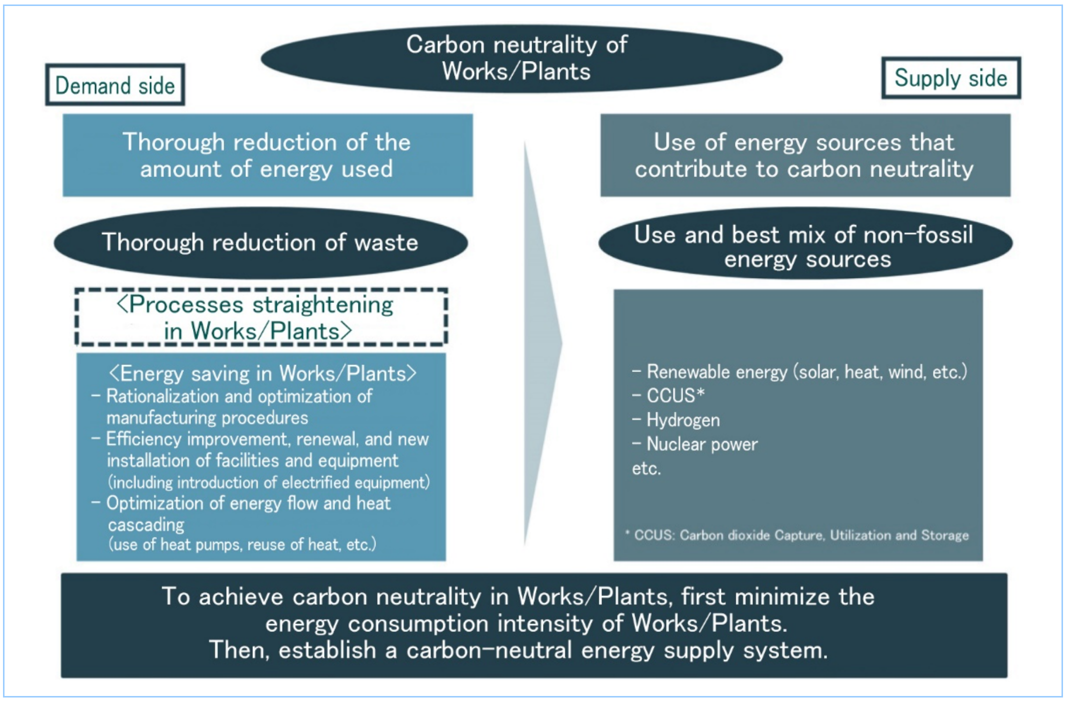

Figure 2 Consideration concept

It is necessary to consider the two sides of energy, the demand side, which uses electricity and fuel (heat), and the supply side, which produces them. On the demand side, it is necessary to eliminate waste and thoroughly reduce the amount of energy used. Rationalization and optimization of manufacturing procedures in product manufacturing as well as reduction and straightening of processes in Works/Plants are important. It is also important to optimize production planning and energy flow, promote heat cascading, and use heat pumps for reuse of heat. On the supply side, it is important how to use non-fossil energy sources and how to best mix them to meet the demand that has been optimized (minimized) by consideration on the demand side.

Therefore, we first minimized the CO_2 emissions intensity on the demand side, and then constructed a carbon-neutral energy supply system on the supply side.

Figure 3 shows a concrete approach to the consideration. Step 1 is to calculate the theoretical amount of energy that is truly necessary to achieve the required objectives in energy consumption processes in Works/Plants, including a review of the processes. The calculated value is an ideal value with zero losses, but it is a simple and easy-to-understand target value for minimizing the CO_2 emissions intensity. It is important how to attain the closest possible value to this ideal value, and the concrete measures to realize it are developed in Step 2. Step 3 is to consider the energy supply system using non-fossil energy while applying the concrete measures considered in Step 2.

Figure 4 shows a schematic view of CO_2 emissions reduction for achieving carbon neutrality through Step 1 to Step 3, which will minimize CO_2 emissions as well as capital investment for the introduction of non-fossil energy systems.

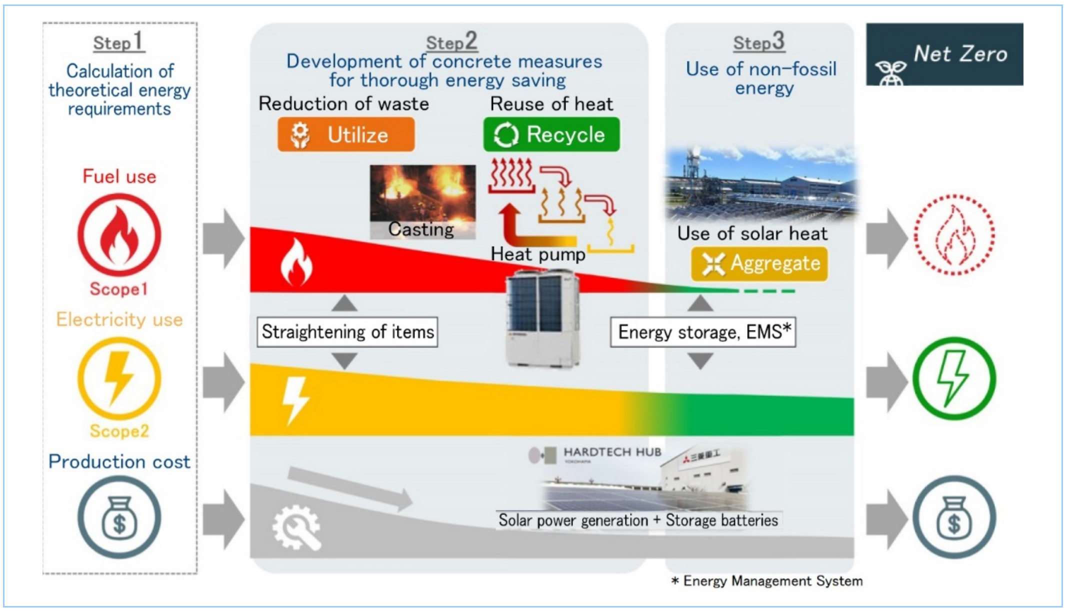

Figure 3 Consideration approach

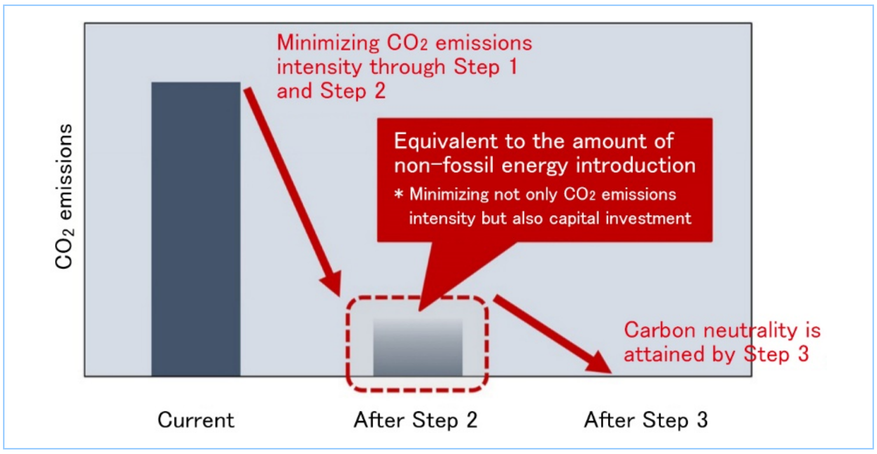

Figure 4 Schematic view of CO_2 emissions reduction toward achievement of carbon neutrality

3. Initiative example

In promoting these initiatives, we have selected a model factory from among our manufacturing bases for study and are working to minimize the CO_2 emissions intensity of the casting process at Foundry Center in Kobe Shipyard & Machinery Works Futami Plant, where the ratio of thermal energy is comparatively high.

Figure 5 shows an example of the casting process. In the casting process, a lot of energy is consumed in the drying process after mold making, the material melting process, the preheating process of the ladle that receives materials (i.e., molten metal) in the melting furnace and pours the molten metal into the mold, and the heat treatment process. This report introduces an initiative case for the ladle preheating process.

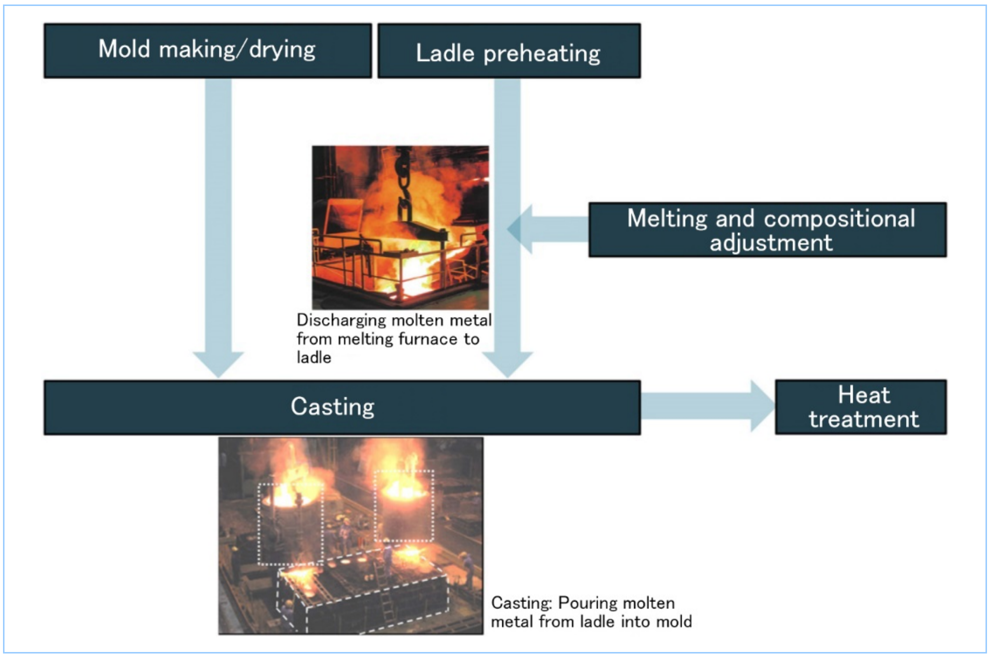

Figure 5 Example of casting process

Because of its application, the ladle is preheated to a high temperature by using a gas burner before molten metal is poured into it to avoid damage such as cracking caused by thermal shock when molten metal at a temperature of 1,500°C or higher is poured from the melting furnace, and to avoid solidification of molten metal due to temperature drops caused by heat radiation during the required setup time between processes, and other problems. The time required for this preheating is determined empirically based on past experience, and a lot of energy is consumed.

The key points to minimize the CO_2 emissions intensity of this process are to shorten the setup time to reduce the loss due to heat radiation and to predict the decrease in molten metal temperature due to heat radiation according to the ladle preheating time.

For shortening the setup time, work items and their purposes were thoroughly reviewed to reduce unnecessary and duplicated work and adopt measures that make it easier for operators to work (e.g., changing work positions). On the other hand, for predicting the decrease in molten metal temperature, the prediction accuracy was improved by making full use of our analysis technologies for heat transfer, etc., that have been developed for a wide range of products and verifying the analysis results with minimum data, such as the temperature measurement data necessary for the setup work. **Figure 6** shows a schematic diagram of estimating ladle preheating time based on the setup time and the molten metal temperature prediction result from heat transfer analysis, using the molten metal temperature required in the next process as the criterion. The ladle preheating time was optimized (shortened) based on this evaluation, and then verified in the actual process. As a result, it was confirmed that the ladle was not damaged during operation and the gas consumption required for preheating was successfully reduced by a significant amount of about 50%.

In each process, operating conditions such as temperature are organically related to the process conditions of the preceding and following processes. Moving forward, to minimize CO_2 emissions intensity at this Foundry Center, we will reexamine the manufacturing processes and operating conditions to optimize the casting process as a whole, rather than each process individually. Based on that, we will construct a system that can achieve carbon neutrality in the energy supply.

Although still under development and having uncertainties in cost and supply, there are several possible means and combinations instead of the use of conventional fossil fuels such as city gas, including the use of solar heat, heating with electric heaters powered by renewable energy, the use of hydrogen, ammonia fuel, and biomass, and the utilization of high-temperature heat pumps and heat cascading/storage aiming for zero factory waste heat. In addition, we will build an EMS

(Energy Management System) factory optimization tool that incorporates these uncertainties to reduce CO_2 emissions intensity by observing equipment operating conditions in real time during its operation, and also to reduce process waste, improve the equipment utilization rate, reduce costs, and shorten work lead times by comparing and analyzing Works/Plants production plans and actual results.

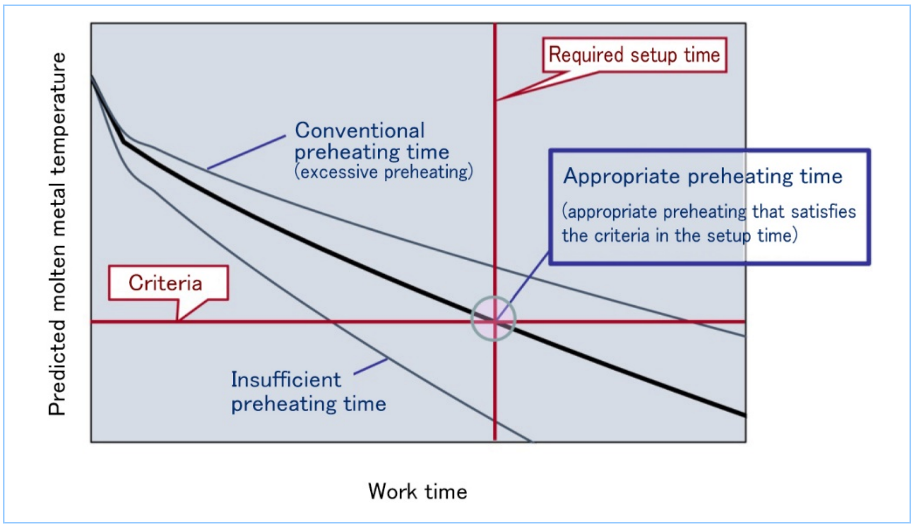

Figure 6 Schematic diagram of molten metal temperature prediction based on heat transfer analysis and ladle preheating time estimation

4. Conclusion and future prospect

In order to achieve carbon neutrality in Works/Plants, it is essential to minimize the CO_2 emissions intensity there and then make an energy transition in the energy supply system. This report focused on initiatives to minimize CO_2 emissions intensity and introduced an example case where such an initiative for a ladle preheating process in casting achieved a significant reduction of about 50% in CO_2 emissions intensity and was applied to an actual process. Consequently, the effectiveness of a method to derive the amount of energy that is truly necessary with a scientific approach and then consider concrete measures that can achieve it was demonstrated.

This example case started from the viewpoint of energy reduction, but the contribution of process review to shorten the setup time was significant. As shown in **Figure 7**, there is a high affinity between energy reduction, elimination of waste in processes, process straightening, and cost reduction and work lead time shortening as an effect obtained thereby. These are important perspectives to consider in the reduction of CO_2 emissions intensity.

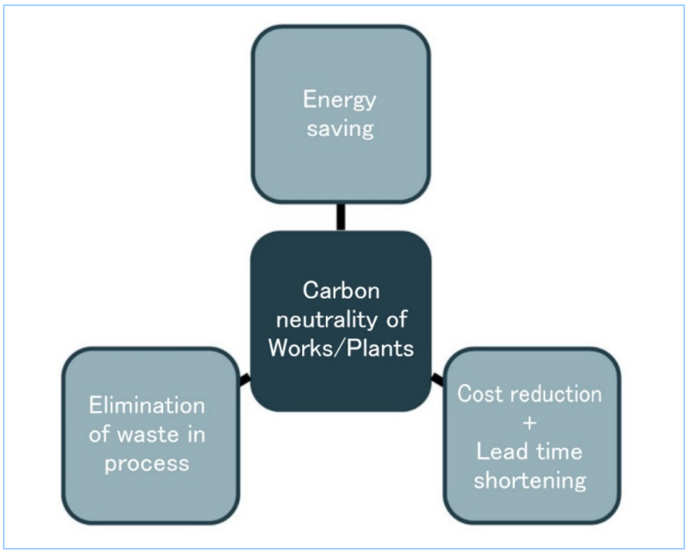

Figure 7 Affinity between energy, process straightening, cost reduction, and lead time

MHI Group has a wide variety of factories and energy consumption facilities. In the future, we will select a model factory for taking initiatives, after determining the effects of their expansion to other factories, and optimize the entire manufacturing process to minimize CO_2 emissions intensity while maximizing the results of the initiatives. After that, we will build a system that enables carbon neutrality in energy supply.

We believe we can achieve the carbon neutrality of MHI Group Works/Plants through these initiatives and respond to the demands of the international community. We will also use the results of these initiatives as a showcase to provide our customers with our products and services "in total, from engineering to equipment installation and O&M", thereby contributing to the achievement of carbon neutrality around the world and the realization of a sustainable society.