

Product and Technology Development in the Energy Solution & Marine Engineering Company

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Introduction

The goals of our medium- and long-term business policy, Group Vision 2030, are to realize a hydrogen society and to achieve carbon neutrality. To attain these goals, in April 2021 we established Energy Solution & Marine Engineering Company by merging Energy System and Plant Engineering Company and Ship & Offshore Structure Company. The integration of these two companies has enabled us to build a system to provide solutions for production, transport, storage, and use, which are required to build hydrogen supply chains in a comprehensive manner. In addition, this integration has resulted in synergies such as interaction and sharing of expertise among our existing businesses including power generation, waste treatment, and shipbuilding. Merging companies is and will continue to be highly significant for us.

1 Introduction to the company

(1) Company overview

Energy Solution & Marine Engineering Company has five business divisions and four plants. The divisions are Hydrogen and Carbon Neutral Business Division, Energy Solution Business Division, Plant Engineering Business Division, Marine Machinery Business Division, and Ship & Offshore Structure Business Division. The plants are the Kobe Works, the Sakaide Works, the Harima Works, and the Akashi Works.

The products of the various divisions are as listed in **Fig. 1**. Our strength is our ability to meet various customer needs by combining the wide range of products we deal in to realize synergies.

(2) Hydrogen business

In the area of storage, Hydrogen and Carbon Neutral Business Division is in charge of liquefied hydrogen tanks and hydrogen terminals. In area of transport, Ship & Offshore Structure Business Division is in charge of liquefied hydrogen carriers. We are advancing projects related to these products, which are the core of the hydrogen commercialization demonstration to be described later, towards commercialization in 2030.

In the area of production, the Energy Solution Business Division and Hydrogen and Carbon Neutral Business Division are in charge of hydrogen compressors and hydrogen liquefaction equipment. In the area of use, Energy Solution Business Division is in charge of and develops hydrogen gas turbines, hydrogen gas engines, and hydrogen boilers, whereas Marine Machinery Business Division is in charge of and develops marine hydrogen gas engines and MHFS (Marine Hydrogen Fuel Systems).

We launched our hydrogen business ahead of other companies. We will collaborate with diverse stakeholders to realize a hydrogen society by leveraging the technologies and the expertise that we have accumulated.

(3) Optimization by leveraging a production system comprising four plants

We are building a system under which four plants mutually leverage their strengths and compensate for each other's weaknesses to achieve efficient production in light of corporate integration. In particular, the Kobe, Sakaide, and Harima Works are planning to divide the manufacturing of large liquefied hydrogen tanks and vacuum insulated piping and to work together in the hydrogen business. To

Division	Product family	Plant	Main products
Hydrogen and Carbon Neutral Business Division	Liquefied hydrogen terminals Low-temperature tanks	Kobe Harima	<ul style="list-style-type: none"> • Liquefaction • Shipping bases • Receiving bases • Low-temperature tanks (for liquefied hydrogen, LNG, etc.) • Hydrogen liquefaction equipment
Energy Solution Business Division	Energy systems	Kobe Akashi	<ul style="list-style-type: none"> • Industrial gas turbines • Gas engines for power generation • Aerodynamic machinery • Distributed energy systems
	Power plants	Kobe Harima	<ul style="list-style-type: none"> • CCPPs (Combined Cycle Power Plants) • Thermal power • Exhaust heat boilers • Steam turbines
Marine Machinery Business Division	Naval ship equipment Marine machinery	Kobe Akashi Harima	<ul style="list-style-type: none"> • Naval ship equipment • System-related equipment • Marine propulsion machinery • Marine reciprocating engines
Plant Engineering Business Division	Industrial machinery	Kobe Harima	<ul style="list-style-type: none"> • Delivery plants • Shield excavators • Ash treatment plants • Shredder plants
	Environmental plants	Kobe	<ul style="list-style-type: none"> • Waste treatment plants
Ship & Offshore Structure Business Division	Naval ships, special purpose ships and merchant ships	Kobe Sakaide	<ul style="list-style-type: none"> • Submarines • High-speed crafts • LPG/NH₃ carriers • Liquefied hydrogen carriers

Fig. 1 Main products and plants of each division

fully implement the hydrogen commercialization demonstration, production system optimization is the most critical issue.

We aim to achieve a system in which the four plants are operated in an integrated way to further harness the strengths of each plant and to enable flexible adjustment between off-time and on-time. We will first subdivide the production processes at each plant and visualize each plant's capabilities, features, and operating status. Based on the results, we will prepare production plans to realize an efficient production system.

In addition, we will standardize education at manufacturing sites in order to develop multiskilled workers so that each worker can be in charge of more processes. These workers will move among the four plants depending on which plants are busy. This will level out the operating rates, raising the capabilities of the manufacturing departments.

Aiming to realize robust plants that can properly address future changes in the business environment with agility, in addition to the hydrogen business, we will apply this system to existing businesses as well.

2 Hydrogen Commercialization Demonstration

As part of concrete efforts to realize a carbon neutral society, we are working on a demonstration of a commercial-scale hydrogen supply chain with Japan Suiso Energy, Ltd., utilizing the Green Innovation Fund Project (GI Fund) of the New Energy and Industrial Technology Development Organization (NEDO). We have already

determined a candidate site. In FY2023, we will design a liquefied hydrogen carrier and start the FEED of liquefaction as well as shipping bases and receiving bases. Both the liquefied hydrogen carrier and the land liquefied hydrogen tank used in the commercialization demonstration will be large in scale; compared to a Japan-Australia pilot demonstration, the liquefied hydrogen carrier will have a load capacity 128 times larger, while the land liquefied hydrogen tank will have a storage capacity 20 times greater. To prepare for the use of multiple commercial chains, it is essential to achieve collaboration among the divisions and three plants, improvement of production capabilities, and streamlining for lead time reduction. Our current activities include efforts to establish a system in which three plants divide the manufacturing of 10,000-m³ spherical tanks and vacuum insulated piping for liquefied hydrogen shipping bases as well as efforts to develop manufacturing and inspection technologies, including automation and modularization construction methods. For the liquefied hydrogen carrier, we are making progress in processes, including verification of manufacturability and performance using a test tank as well as development of a hydrogen-powered propulsion system.

(1) Establishing a three-plant manufacturing system for 10,000-m³ spherical tanks

We plan to construct five 10,000-m³ spherical liquefied hydrogen tanks at the liquefied hydrogen shipping base and have built a general management system for the Harima Works, Kobe Works, and Sakaide Works to divide the manufacturing of these tanks.

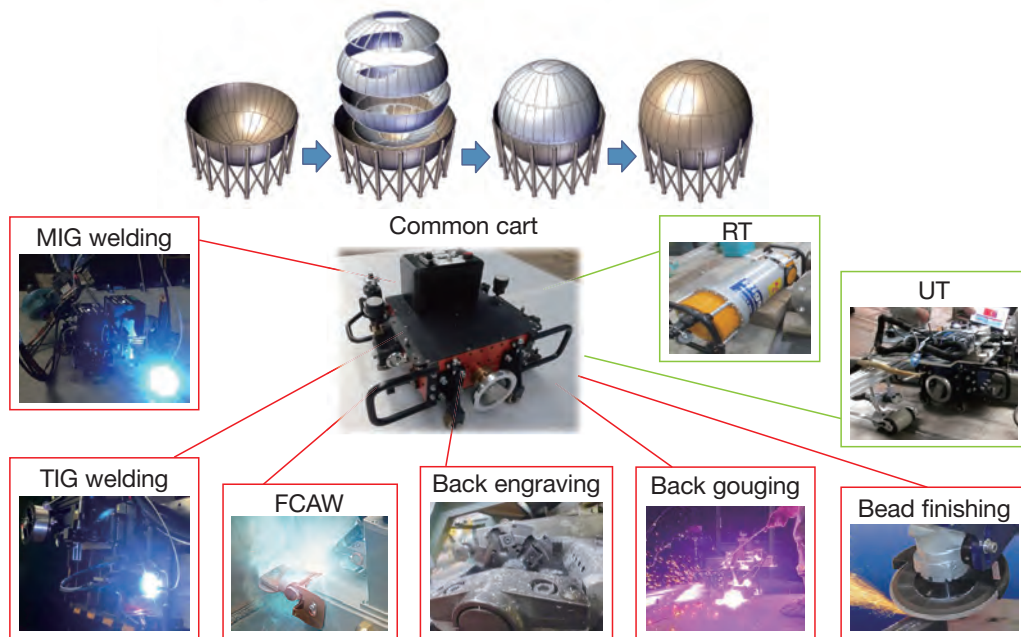


Fig. 2 Image diagram of technologies for improving the efficiency of the spherical tank module construction method

In particular, we have clarified the scopes of responsibility at the interfaces between the plants, defined procedures for transferring and managing necessary information, and built a mechanism for seamless operations.

We have also developed a construction method to finish the tanks at our three plants in Japan and to transport the finished tanks by ship in order to achieve advanced modularization and reduce delivery times, which are critical for conforming to processes in contracts for overseas construction work. In particular, the Sakaide and Kobe Works have also acquired ASME certification based on the Harima Works' experience acquiring the certification. To improve the efficiency of plant manufacturing, we have developed plate bending, cutting, and grooving methods as well as self-propelled automatic MIG/TIG welders and an automatic UT device. In addition, we have developed a safe marine transport method using barges and a method for realizing safe carry-in to shipping bases.

(2) Liquefied hydrogen carrier

Leveraging insights obtained from the Suiso Frontier, a world-first 1,250-m³ liquefied hydrogen carrier that we constructed, Ship & Offshore Structure Business Division is developing the basic design for a large liquefied hydrogen carrier with a cargo capacity of 160,000 m³, which is 128 times greater than the Suiso Frontier. We plan to complete construction of this carrier during the late 2020s and demonstrate long-distance mass transport of liquefied hydrogen.

As its propulsion system, this carrier employs a steam turbine plant consisting of a main boiler and a main turbine. Steam generated in the main boiler drives the main turbine, the force of which is transmitted to the propellers via the reduction gear in order to propel the carrier. The main boiler can be operated by hydrogen only, oil only, or hydrogen/oil mixed firing. Notably, this boiler achieves zero greenhouse gas (GHG) emissions when operated by hydrogen only. In this carrier, we also plan to install a dual fuel generator engine that can switch between hydrogen and oil for demonstration purposes.

Energy Solution Business Division is developing and designing the main boiler, main turbine, and dual fuel generator engine while developing the hydrogen-powered propulsion system in collaboration with Ship & Offshore Structure Business Division. We also plan to standardize and normalize the technologies.

3 Hydrogen and Carbon Neutral Business Division

On August 1, 2023, we carried out an organizational restructuring to efficiently and reliably execute carbon neutrality projects, and established Hydrogen and Carbon Neutral Business Division.

For hydrogen-related products, this division is in charge of liquefaction and loading terminals and unloading terminals, and it provides liquefied hydrogen tanks as its core product. The division is working to implement the hydrogen supply chain commercialization demonstration.

4 Energy Solution Business Division

The Energy Solution Business Division is in charge of hydrogen gas turbines, hydrogen gas engines for power generation, hydrogen boilers, and hydrogen compressors in the hydrogen business. The division is also developing CO₂ capture equipment towards the realization of a carbon neutral, carbon recycling society and has started a demonstration test in Japan.

(1) Hydrogen gas turbines

We have developed hydrogen gas turbines and hydrogen gas engines with hydrogen mixed firing and hydrogen combustion ahead of other companies in order to seamlessly support the transitional period from the start of hydrogen use up to the dawn of a full-fledged hydrogen society. For gas turbines, we have already established and started sale of a hydrogen mixed firing combustion technology. As for hydrogen combustors, we have completed the development and demonstration of some models and are working to deploy them across the entire lineup. Our hydrogen gas turbines enable existing natural gas generators to support hydrogen without needing to make significant alterations. We have already received orders for projects predicated on alteration to enable hydrogen support in Europe and for projects predicated on future hydrogen support in Japan.

(2) Hydrogen compressors

The high-efficiency centrifugal hydrogen compressor is equipment that is essential for increasing the size of hydrogen liquefiers and improving their liquefaction efficiency. We developed this equipment, which was selected for a GI Fund project as a product required to achieve the target hydrogen supply cost in 2050. We plan to test and evaluate various element technologies by the end of FY2022, to create prototypes in FY2023, and to

start operation in plants during FY2024. We will then increase the size and implement additional innovative technologies toward 2030. As high-efficiency centrifugal hydrogen compressors can be used not just in hydrogen liquefiers but in a wide range of applications, such as hydrogen pipelines and hydrogen fuel gas supply, we plan to launch products starting with frontier markets.

(3) CO₂ capture technologies

As CO₂ capture technologies are positioned as required elements in the “Roadmap for Carbon Recycling Technologies” created by the Ministry of Economy, Trade, and Industry, we have developed a CO₂ capture technology that employs the solid sorption method and started demonstration tests. In Japan, we have installed demonstration equipment at coal-fired power plants and elsewhere to start demonstration tests in order to evaluate applicability to coal combustion exhaust gas. We are also constructing demonstration equipment at the Dry Fork Power Plant in Wyoming in the U.S. We plan to monitor the environment of the surrounding region while capturing CO₂.

5 Plant Engineering Business Division

The Plant Engineering Business Division has thus far delivered social infrastructure equipment such as cement plants, fertilizer plants, handling systems, LNG tanks, and municipal waste treatment facilities. Upon the establishment of Hydrogen and Carbon Neutral Business Division in August 2023, key persons were assigned to it in order to build hydrogen supply chains by reliably leveraging the technologies we have accumulated through our hard-won experience. Meanwhile, Plant Engineering Business Division is developing businesses in the area of material recycling as well as developing labor-saving technologies for municipal waste treatment and other facilities.



Fig. 3 Recycling system for lithium-ion batteries

(1) Material recycling

Combustion ash generated when solid fuels are burned contains unburned carbon, which ought to have been combusted. Unburned carbon not only leads to energy loss but also hinders ash recycling. We have developed a dry processing system and equipment to remove unburned carbon in order to promote recycling and have received orders for commercial application.

In addition, we are developing lithium recycling technologies for lithium-ion batteries, the use of which is expected to increase. We are currently conducting a demonstration test in China.

(2) Labor-saving technologies

Responding to Japan's shrinking workforce is an urgent issue both in waste treatment facilities and recycling facilities. This issue must be addressed while considering how to guarantee safety and reliability as well as how to reduce operator workloads. Against this background, we have developed labor-saving operation technologies, including K-Repros, an AI-powered support system for hand-sorting recyclable waste.

We have also developed and launched the robot system Successor-G, which automatically performs remote operation of grinders in harsh environments exposed to powder dust and sparks.

We will continue to develop labor-saving technologies and broaden the range of applications.

6 Marine Machinery Business Division

The business of Marine Machinery Business Division encompasses a wide lineup, including core components of

propulsion systems for commercial ships and naval ships as well as system package products.

(1) Marine reciprocating engines

We have produced and delivered two-stroke and four-stroke reciprocating engines for over 110 years since 1911, when we began a technology partnership with MAN in Germany. In 2014, we developed the L30KG gas combustion engine as a private brand by leveraging our accumulated technologies. In response to increasing demand for GHG emissions reduction, we are focusing on LNG- and LPG-fueled gas engines, and we have started development of marine hydrogen gas engines to achieve carbon neutrality.

(2) Marine propulsion machinery

Over the years, we have delivered many propellers; our lineup includes controllable pitch propellers, side thrusters, and the Rexpeller azimuth thruster. We have expanded our business by sophisticating technologies with controllable pitch propellers, which require high propulsion performance, and expanding the application of these technologies to side and azimuth thrusters. In particular, we increased the number of delivered side thrusters mainly for container ships and have the highest global share as of 2022.

(3) Package products and system integration

As needs for package products, which combine a variety of components, and system integrators, which realize such products, have increased recently, we are working to integrate various propulsion systems, including environmentally friendly propulsion systems for

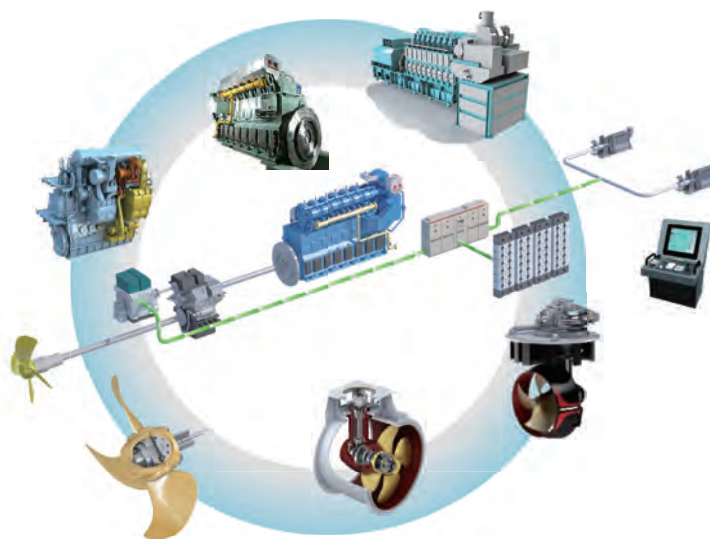


Fig. 4 Marine propulsion system products

commercial ships and hybrid propulsion systems for naval ships. In 2022, we delivered a battery propulsion system that is exclusively battery-powered; in 2023, we delivered a hybrid propulsion system that combines the L30KG gas engine with batteries.

We have also delivered the KICS integrated control system to operate propellers, rudders, and other equipment in an integrated manner for ferries, cable ships, and other vehicles. Needs for safety and manpower reduction have been increasing recently. In particular, there is demand for safety and crew manpower reduction during ship berthing/unberthing. Against this background, we have begun to develop a safe berthing/unberthing assist system based on our KICS technologies.

7 Ship & Offshore Structure Business Division

The main products of Ship & Offshore Structure Business Division are submarines and their product families based on related technologies, and merchant ships, especially focused on liquefied gas carriers.

(1) Submarines and related products

We have delivered a total of 30 submarines, including Oyashio, the first domestic submarine after World War II that was completed in 1960, and Hakugei, a state-of-the-art submarine. The new-type submarine has a long underwater endurance capability enabled by lithium-ion batteries and adopts leading-edge technologies, for example, a variety of automation systems as well as improved/increased surveillance and stealth capabilities. We have also developed products including SPICE, autonomous underwater vehicle, which uses underwater technologies we have accumulated by building submarines over the years, and new products for terrestrial use that are based on CO₂ capture technology used in submarines, which are closed spaces.

(2) Merchant ships

We have continued to provide high-quality ships based on cryogenic liquefied gas technologies ever since we delivered our first liquefied petroleum gas carrier (LPG carrier) in 1969 and our first liquefied natural gas carrier (LNG carrier) in 1981. As alternative fuels with low GHG emissions have recently been adopted one after the other around the world, our first LPG-fueled cargo ship in Japan is highly recognized by customers and we get continuous orders for the following ships. In addition, we have received numerous shipbuilding orders that incorporate new environmentally-friendly technologies, including LNG-/methanol-fueled ships, and we have built them through

joint venture shipyards in China, thereby maintaining high competitiveness.

In addition, we constructed the world's first liquefied hydrogen carrier by integrating shipbuilding technologies for liquefied gas carriers and in-house liquefied hydrogen technologies described above, and we completed a demonstration of liquefied hydrogen transportation by ship. As our next challenges, we are working to ensure stable mass supply of liquefied hydrogen and to enlarge the size of ships to achieve the reduction of transportation costs.

(3) Others

SOPass, ship operation support service, which leverages our insights into shipbuilding and cryogenic liquefied gas technology for the engineering of LNG carriers, has been recognized as valuable by customers who have introduced the service (mainly charterers of LNG carriers). We continue to enhance the functionality of the service to further optimize operations and reduce GHG emissions.

In addition, in 2020 we delivered our JETFOIL for the first time in 25 years. This is an ultra-high-speed passenger hydrofoil and flies over the water surface by dynamic lift generated by fully-submerged foils. JETFOIL plays an active part as essential infrastructure of transformation for remote islands in Japan. It is expected to contribute to society because momentum for constructing additional ships has been rising following the 2022 revision of the Japanese Remote Islands Development Act.

Conclusion

The Energy Solution & Marine Engineering Company has built a system to provide solutions for hydrogen supply chains in a comprehensive manner. We will contribute to realizing a hydrogen society and achieving carbon neutrality.

In addition, the company will realize synergies among Hydrogen and Carbon Neutral Business Division, Energy Solution Business Division, Plant Engineering Business Division, Marine Machinery Business Division, and Ship & Offshore Structure Business Division as well as the Kobe Works, the Sakaide Works, the Harima Works, and the Akashi Works in order to provide a wide range of products that meet customers' various needs.

We are committed to supporting a prosperous global society and contributing to the preservation of the global environment as a company that plays an important role in "ensuring a safe, secure, remote society" and "energy and environmental solutions" according to the future focus fields defined in our Group Vision 2030.