A New "Hydrogen Road," Connecting Hydrogen Production and Consumption Sites

Interest in hydrogen energy as a game-changing tool for realizing a decarbonized society is on the rise around the world. Hydrogen can be stored for long periods and transported great distances, and it emits no CO_2 when used. Furthermore, hydrogen can be produced from a variety of resources. Hydrogen is therefore a highly promising source of clean energy, capable of helping counter global warming and resource depletion—two major environmental problems—if used as fuel for vehicles or power generation. Kawasaki is advancing the development of technologies for the entire hydrogen supply chain, encompassing production, transportation, storage, and utilization, aiming to quickly realize a hydrogen-powered society.

Kawasaki Hydrogen Road

Working toward a Sustainable, Decarbonized Society

The Long-Awaited Demonstration of a Hydrogen Supply Chain Spanning Japan and Australia[1]

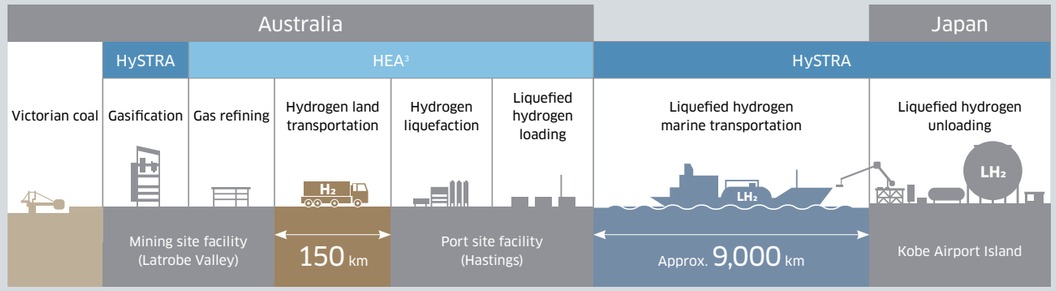
Kawasaki aims to build a large-scale international hydrogen supply chain in which Victorian coal—an underutilized resource—from Latrobe Valley in Victoria, Australia, is used to produce hydrogen that is then liquefied and transported by sea to Japan using a specialized liquefied hydrogen carrier. Aiming to commercialize a hydrogen supply chain around 2030, Kawasaki has been working in collaboration with partner companies and with the support of the Japanese and Australian governments to demonstrate a hydrogen supply chain connecting Australia and Japan. With the construction and manufacturing of the facilities and equipment necessary for the demonstration finally sufficiently advanced, 2020 marked the long-awaited start of demonstration operations.

In July 2020, commissioning began at the hydrogen liquefaction and loading facilities built at the Port of Hastings in Victoria.

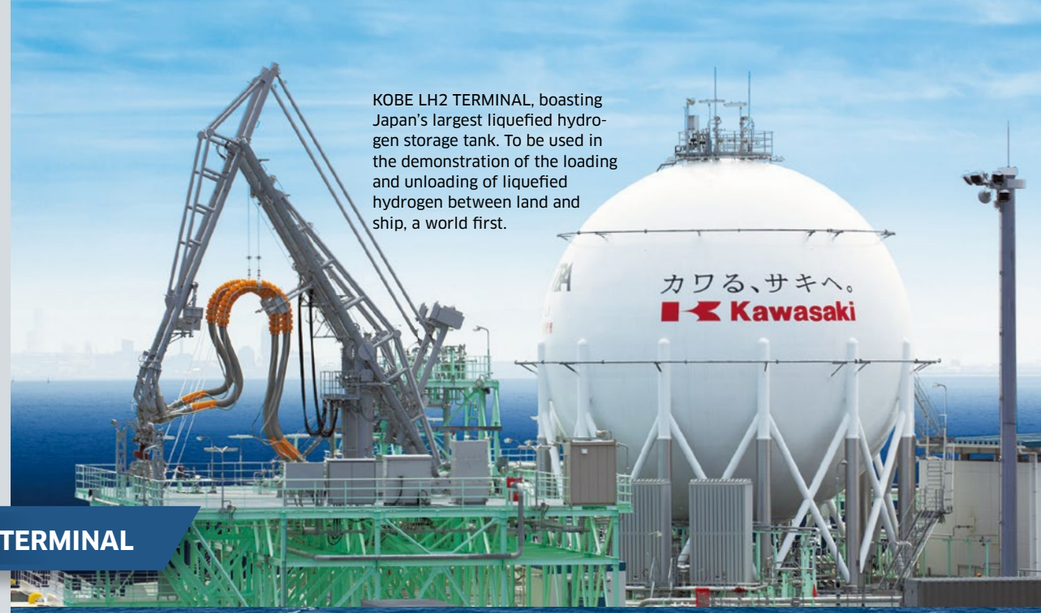
The SUISO FRONTIER, the world's first liquefied hydrogen carrier, launched in December 2019, completed its sea trial, the final phase of testing, on open water, in October 2020. The carrier is now undergoing final equipment adjustments and other preparations for delivery to HySTRA,[2] the organization implementing the demonstration. It will then be used in demonstrations of ship-to-shore transfer of liquefied hydrogen at KOBE LH2 TERMINAL, a liquefied hydrogen receiving terminal on Kobe Airport Island.

Furthermore, a round trip between Kobe and the Port of Hastings carrying liquefied hydrogen is planned for 2021.

1. The Demonstration Project for Establishment of Mass Hydrogen Marine Transportation Supply Chain Derived from Unused Brown Coal subsidized by the New Energy and Industrial Technology Development Organization (NEDO)
2. HySTRA: The CO_2-free Hydrogen Energy Supply-chain Technology Research Association
3. HEA: Hydrogen Engineering Australia (wholly owned subsidiary of Kawasaki)



Voyage distance: Approx. 9,000 km
Voyage duration: 16 days



KOBE LH2 TERMINAL, boasting Japan's largest liquefied hydrogen storage tank. To be used in the demonstration of the loading and unloading of liquefied hydrogen between land and ship, a world first.

KOBE LH2 TERMINAL

The liquefied hydrogen carrier, developed based on LNG carrier technology and onshore liquefied hydrogen transportation and storage technologies, will keep liquefied hydrogen at -253°C, carrying it approximately 9,000 km from Australia to Japan.

Liquefied hydrogen carrier *SUISO FRONTIER* nears completion

Start of commissioning at hydrogen liquefaction and loading facilities at the Port of Hastings in Australia

Here, hydrogen will be liquefied and loaded onto the liquefied hydrogen carrier. At -253°C, the liquefied hydrogen's bulk is just one eight-hundredth its volume as a gas, dramatically improving carrying efficiency.

2019 Building a hydrogen supply chain 2020 Start of demonstration 2021 Commercializing a hydrogen supply chain 2030 Working toward a Sustainable, Decarbonized Society

Roadmap for Creating Clean Energy

As it aims to contribute to the development of a hydrogen-powered society, Kawasaki is pursuing its goal of becoming a supplier of comprehensive system packages associated with liquefied hydrogen infrastructure by 2030 via the provision of hydrogen liquefaction and loading and unloading facilities, liquefied hydrogen carriers and hydrogen-fueled gas turbines. To achieve this goal, we are working with partner companies to develop key hydrogen supply chain technologies. These technologies include those associated the production of hydrogen from renewable energy and from Victorian coal in Australia, with the aim of making profitable use of this underutilized resource, as well as hydrogen liquefaction technologies. With regard to the transportation of hydrogen, our large-capacity carrier ships are expected to play an essential role along with our loading and unloading facilities. Furthermore, we will support the storage of liquefied hydrogen as well as hydrogen utilization via power generation employing gas turbines optimized for this fuel.

Applying CO_2 capture and storage (CCS) technologies at the production stage when obtaining hydrogen from fossil fuels enables the use of hydrogen as a source of clean energy by controlling CO_2 emissions all the way from production to utilization. Once established, the hydrogen supply chain that Kawasaki is building will be able to stably supply large quantities of clean energy while considerably reducing CO_2 emissions. We have steadily advanced the construction of facilities for the demonstration of this supply chain and begun research and development aimed at scaling up these facilities for commercial use. We are making steady progress, including the commencement of demonstration testing, toward greater efficiency and convenience in heat and electricity supply via pure hydrogen combustion.

Goal for fiscal 2021	• Complete the demonstration of a hydrogen supply chain spanning Japan and Australia
Fiscal 2019 achievements	• Launched a small liquefied hydrogen carrier, built a liquefied hydrogen receiving terminal in Kobe, and built liquefaction and loading facilities in Australia, aiming to implement supply chain demonstration • Began demonstration testing aimed at increasing the efficiency and convenience of heat and power supply from the mixed combustion of natural gas and the combustion of pure hydrogen in an urban area of Kobe

Making the Hydrogen Road Possible with Kawasaki Technology | Production | Transportation | Storage | Utilization

Production

Large-scale hydrogen-fueled power generation requires a large quantity of hydrogen. Kawasaki is the first in Japan to develop an industrial hydrogen liquefaction system that employs only domestic technologies. In addition to producing hydrogen from Victorian coal, an underutilized resource, we have made it possible to easily handle a large volume of hydrogen by using cryogenic (-253°C) liquefaction to reduce its bulk to one eight-hundredth its volume as a gas.

Sales of a Hydrogen Liquefier, a First Among Japanese Manufacturers

In June 2020, Kawasaki was the first Japanese manufacturer to commence sales of a hydrogen liquefier. Boasting industry-leading liquefaction efficiency, the hydrogen liquefier has demonstrated its performance and reliability through continuous operation for over 3,000 hours and various functional tests.

This hydrogen liquefier can produce five tons of liquefied hydrogen per day (enough to fuel more than 1,000 fuel cell vehicles) and is capable of producing 99.999% pure liquefied hydrogen. Going forward, as the use of hydrogen spreads, Kawasaki plans to expand its lineup of hydrogen liquefiers.

Transportation

Based on LNG carrier technology and onshore liquefied hydrogen transportation and storage technologies, Kawasaki is advancing the development of liquefied hydrogen carriers, which will keep liquefied hydrogen at -253°C to carry it safely and efficiently to Japan.[1]

Launch of the World's First Hydrogen Carrier

In December 2019, Kawasaki launched the world's first liquefied hydrogen carrier, the *SUISO FRONTIER*. Having completed its sea trial in October 2020, the carrier is now undergoing final equipment adjustments and other preparations for delivery. It is scheduled to take a round trip between Japan and Australia carrying liquefied hydrogen in 2021. Working toward commercialization, we have begun the development of large liquefied hydrogen carriers that can carry even larger volumes of liquefied hydrogen.

Storage

The development of storage tanks and transportation containers for liquefied hydrogen is essential to promoting the utilization of hydrogen in Japan. Kawasaki boasts a long track record in the handling of liquefied hydrogen used as rocket fuel. At Kobe Airport Island, we have now completed the construction of the largest liquefied hydrogen storage tank in Japan, which will boast vacuum insulated walls and a capacity of 2,500 m³.[1]

Liquefied Hydrogen Storage Tank for Marine Transport Installed on Liquefied Hydrogen Carrier

In March 2020, we installed a liquefied hydrogen storage tank for marine transport on the liquefied hydrogen carrier *SUISO FRONTIER*. Kawasaki leveraged its expertise in cryogenic equipment manufacturing, accumulated through the building of onshore liquefied hydrogen storage tanks and LNG storage tanks, to achieve ultra-high thermal insulation performance. This tank will enable the safe marine transport of large volumes of liquefied hydrogen over long distances.

Utilization

One effective use of hydrogen energy is electricity generation via hydrogen gas turbines. With the aim of commercializing power generation gas turbines that reduce environmental burden, we developed a unique combustion method employing a mix of 40% natural gas and 60% hydrogen. Furthermore, we developed technology that allows the fuel mix to be freely adjusted—from 100% natural gas to 100% hydrogen—without interrupting the power supply. We completed the demonstration of this technology on Kobe City's Port Island.[2]

Successful Technology Verification of Dry Low-NOx Hydrogen Combustion-Powered Gas Turbine

Kawasaki began demonstration testing of a dry low-NOx(nitrogen oxide) hydrogen combustion-powered gas turbine with its partners in May 2020, achieving the world's first successful verification of the technology.[3] The turbine's combustor, developed by Kawasaki, uses micro-mix combustion technology. The dry combustion method improves electrical efficiency over traditional methods and reduces NOx emissions. Kawasaki will continue verification operations until the end of fiscal 2020, stably generating power from dry hydrogen combustion while verifying performance, including electrical efficiency and the reduction in environmental burden.

1. The Demonstration Project for Establishment of Mass Hydrogen Marine Transportation Supply Chain Derived from Unused Brown Coal subsidized by NEDO
2. The Smart Community Technology Development Project Utilizing Hydrogen Cogeneration Systems subsidized by NEDO: The project succeeded in the world's first cogeneration via 100% hydrogen combustion in an urban area in April 2018
3. The Development and Demonstration Project for Low-NOx Hydrogen-fueled Gas Turbine Combustion Technology subsidized by NEDO