CARBON-NEUTRAL INDUSTRIAL COMPLEXES ADVANCING IN EUROPE

— DUTCH AND BELGIAN CASE STUDIES SUGGEST POTENTIAL FOR DEVELOPMENT IN JAPAN —

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SUMMARY

- In response to the crisis in Ukraine, European countries are aiming to achieve the NDCs announced at COP26, while seeking to phase out energy dependence on Russia. This will require a reduction in carbon dioxide emissions throughout industrial complexes.
- Major efforts include (1) establishing hydrogen-related and decarbonization infrastructure such as carbon dioxide capture and storage (CCS), (2) introducing efficient decarbonization infrastructure by utilizing existing infrastructure, and (3) promoting corporate participation through subsidies and other initiatives.
- In Japan, carbon neutralization of industrial complexes is also being considered. In this context, the Port of Rotterdam and the Port of Antwerp-Bruges are instructive examples: the Port of Rotterdam is considering a mechanism to import 4 megatons of hydrogen in the form of ammonia and the like by 2030, and the Port of Antwerp-Bruges is looking into the export of carbon dioxide.

1. SIGNIFICANCE OF DECARBONIZATION EFFORTS THROUGHOUT INDUSTRIAL COMPLEXES

Following COP26 on October 31 to November 13, 2021, countries have announced their nationally determined contributions (NDCs) and have begun working toward achieving their decarbonization targets. The crisis in Ukraine was initially thought to prompt a return to fossil fuels, but European countries, which had been heavily dependent on Russia for energy, are now working to secure alternatives to fossil fuels and save energy in the short term, while promoting renewable energy in the medium to long term, in line with REPowerEU.[1] The subsequent G7 also announced the aim to decarbonize power sources by 2035, an indication that the trend toward decarbonization has not changed, especially in Western countries. Heavy industries such as steel, chemicals, and cement, which make up industrial complexes, account for about a quarter of the world's carbon dioxide emissions arising from industry. Achieving the target requires reducing carbon dioxide emissions from throughout such complexes.

2. STATUS OF CARBON-NEUTRAL INDUSTRIAL COMPLEX EFFORTS IN EUROPE

Large-scale industrial complexes in Europe pursuing carbon neutrality are primarily engaging in the following efforts.

[1] REPowerEU is a policy aimed at phasing out EU dependence on Russian fossil fuels by 2030 in response to the crisis in Ukraine. The European Commission released an overview on March 8, 2022 and a detailed policy document on May 18, 2022.

(1) Establishment of hydrogen-related, CCS, and other decarbonization infrastructure

Hydrogen is heated and used directly as a fuel for power generation and transportation, but it also has various applications. For example, it can serve as a raw material for synthetic fuels and sustainable aviation fuels (SAF) and be used in the production of chemicals such as ammonia and monomers, as well as in the manufacture of metals. Hydrogen-related infrastructure includes production, import, storage, and pipeline facilities.

With regard to CCS, the EU's efforts are not limited to capturing and storing carbon dioxide emitted from industrial complexes and surrounding areas. It is also working on carbon dioxide capture, utilization, and storage (CCUS), in which carbon is utilized for the production of methanol and chemical products and others. Related infrastructure includes transportation pipelines and liquefied gas storage facilities.

(2) Introduction and use of efficient decarbonized infrastructure leveraging existing infrastructure

Existing infrastructure is being efficiently utilized. One example is converting petroleum refineries to biofuel and SAF refineries, as petroleum products such as gasoline, diesel, and aviation fuels are no longer necessary due to decarbonization. Another example is using natural gas pipelines as hydrogen-mixed gas pipes.

(3) Promotion of corporate participation through subsidies and other initiatives

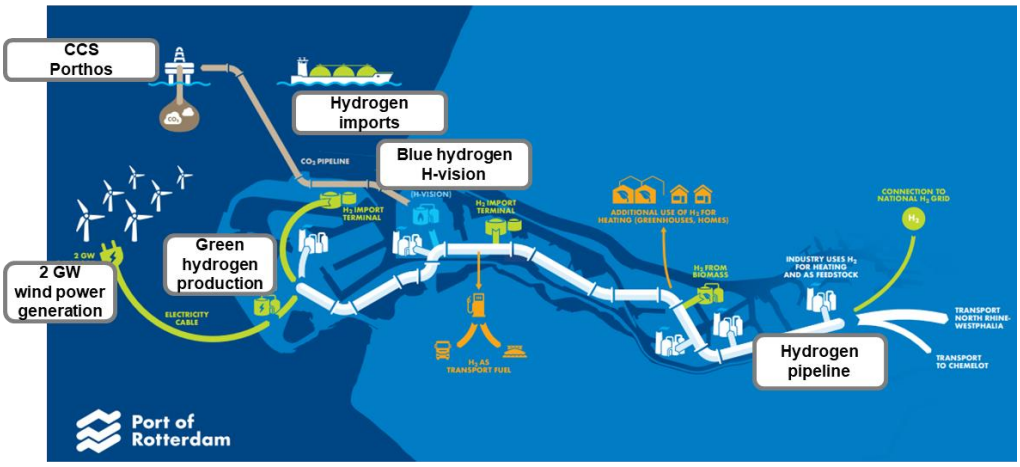
The EU, local governments, and other bodies provide subsidies to promote investment and technology adoption through corporate participation. This also consolidates companies and other organizations that want to overcome regulations such as the EU Emissions Trading Scheme (EU-ETS)[2] by increasing the convenience of hydrogen, CCS, and other decarbonizing infrastructure.

Examples of major efforts are described below.

2-1. Port of Rotterdam, Netherlands

The Port of Rotterdam, which handles the largest cargo volume in Europe, aims to decarbonize by 2050 through measures such as CCS, hydrogen, and other infrastructure (Figure 1) and the use of bio-materials and fuels.

Figure 1 CCS, hydrogen, and other infrastructure at the Port of Rotterdam



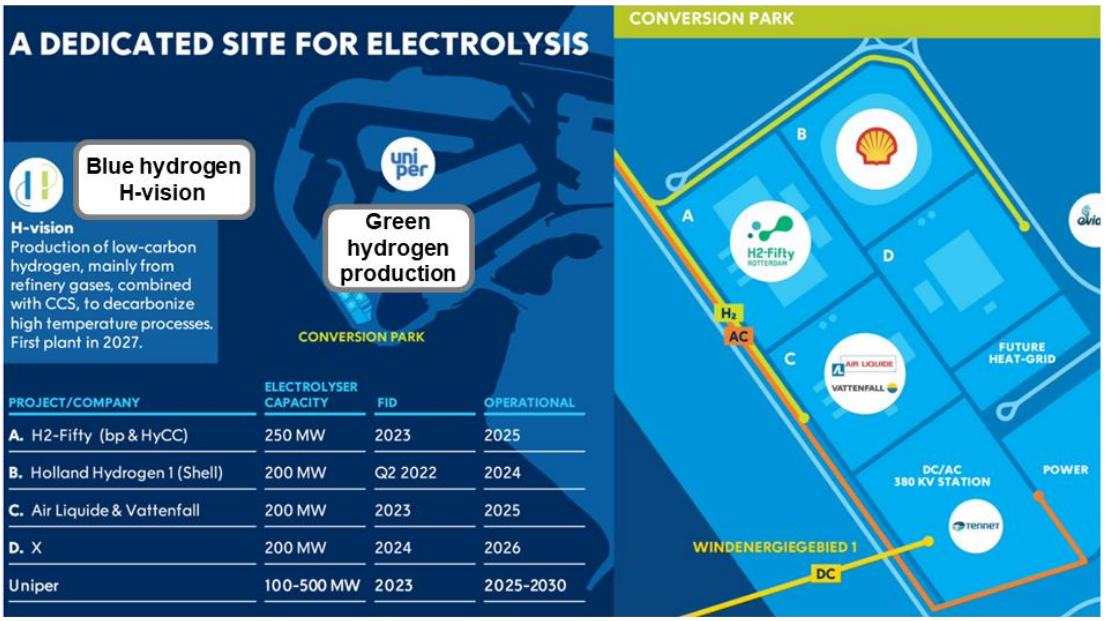
Source: Port of Rotterdam website "Hydrogen-economy-in-Rotterdam starts with backbone" https://www.portofrotterdam.com/sites/default/files/2021-06/hydrogen-economy-in-rotterdam-handout.pdf (accessed October 20, 2022)

[2] The EU-ETS sets emission allowances for facilities that emit greenhouse gases (GHGs) in the region and requires GHG emissions to be kept within those allowances or the purchase of additional allowances. The currently applicable sectors are thermal and other power generation, steel, cement, oil refining, and other energy-intensive industries. The emission cap has been reduced by 2.2% each year, but reduction by 4.2% is now under consideration.

In this regard, Porthos[3] is considered the main CCS infrastructure. Porthos is a project that involves transporting carbon dioxide through a pipeline approximately 20 km offshore in the North Sea and storing an annual volume of 2.5 megatons of it in empty gas fields more than 3 km deep, for a total of approximately 37 megatons. Owned by a joint venture company funded by the Rotterdam Port Authority and other investors, the project will be put into operation in around 2024 by Air Liquide (France), Air Products and Chemicals (US), ExxonMobil (US), and Shell (UK). In addition, the company has received a subsidy of 120 million euros from the EU through the CEF (an EU funding instrument)[4] and a subsidy of 2.1 billion euros from the Dutch government through SDE++ (Dutch government subsidy to promote the reduction of greenhouse gas emissions).[5]

Regarding hydrogen infrastructure, a mechanism is being considered to produce 0.6 megatons per year and import 4 megatons per year by 2030 (40% of REPowerEU's 2030 import target for the entire EU). The main initiatives in terms of production include H-vision,[6] which produces blue hydrogen from fossil fuels, and production of green hydrogen from renewable energy using electrolyzers (Figure 2). Through H-vision, more than 10 stakeholders in the hydrogen value chain, including Rotterdam Port Authority, Air Liquide, bp (UK), EBN (oil company owned by the Dutch Government), and ExxonMobil, will pipe residual gas collected at oil refineries and other sites to plants to produce hydrogen. The carbon dioxide emitted will be treated with CCS or used in the production of basic chemicals such as methanol, so that the process can be decarbonized. The plan is to complete 750 MW capacity by 2027, increasing to 1,500 MW by 2032. Shell, bp and others will operate 850 MW of electrolyzer hydrogen production by around 2026, and Uniper (Germany) is aiming to scale up to 500 MW by 2030[7] with the assistance of IPCEI Hy2Use.[8]

Figure 2 Hydrogen production at the Port of Rotterdam



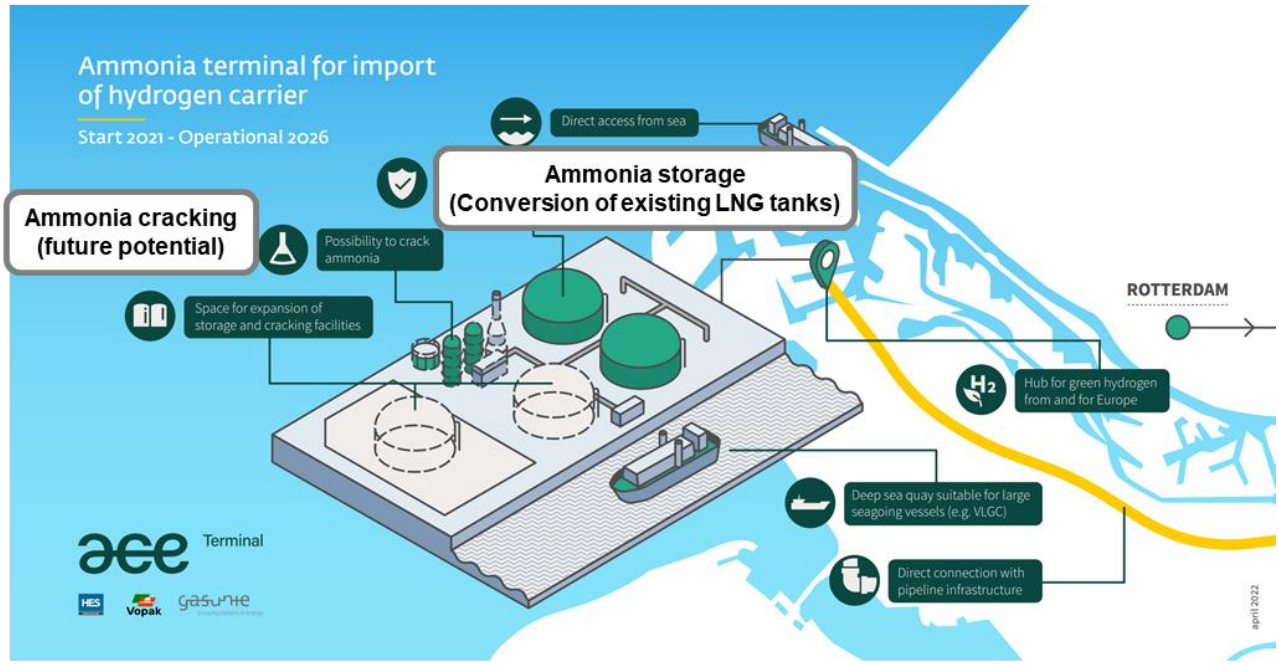
PROJECT/COMPANY	ELECTROLYSER CAPACITY	FID	OPERATIONAL
A. H2-Fifty (bp & HyCC)	250 MW	2023	2025
B. Holland Hydrogen 1 (Shell)	200 MW	Q2 2022	2024
C. Air Liquide & Vattenfall	200 MW	2023	2025
D. X	200 MW	2024	2026
Uniper	100-500 MW	2023	2025-2030

Source: Port of Rotterdam website "A new energy system"
https://www.portofrotterdam.com/en/port-future/energy-transition/a-new-energy-system
(accessed October 20, 2022)

[3] https://www.porthosco2.nl/en/project/
[4] The Connecting Europe Facility (CEF) is an EU funding instrument to promote growth, employment, and competitiveness through infrastructure investment in Europe. Since January 2014, it has provided approximately 30 billion euros in funding (23.7 billion euros for transportation, 4.6 billion euros for energy, and 500 million euros for telecommunications).
[5] Stimulation of Sustainable Energy Production and Climate Transition (SDE++) has a budget of 13 billion euros for 2022.
[6] https://www.h-vision.nl/en
[7] https://www.portofrotterdam.com/en/news-and-press-releases/uniper-contracted-technip-energies-as-feed-contractor-for-h2maasvlakte
[8] IPCEI Hy2Use is a project by which 13 EU member states (Austria, Belgium, Denmark, Finland, France, Greece, Italy, the Netherlands, Poland, Portugal, Slovakia, Spain, and Sweden) support the construction of related infrastructure in the hydrogen value chain. Thirteen countries plan to provide up to 5.2 billion euros in public funds.

With respect to imports, Gasunie (a Dutch state-owned gas company) and others are aiming to upgrade existing LNG storage tanks to import terminals for ammonia, a hydrogen-derived compound, by 2026 (Figure 3). In addition, OCI (a Dutch manufacturer and distributor of fertilizers, chemicals, and other nitrogen products) plans to increase the volume of ammonia handled by import terminals in 2023 to 1.2 million tons per year, three times that of 2022 and equivalent to the annual consumption in Japan.

Figure 3 Ammonia import terminal (ACE terminal)



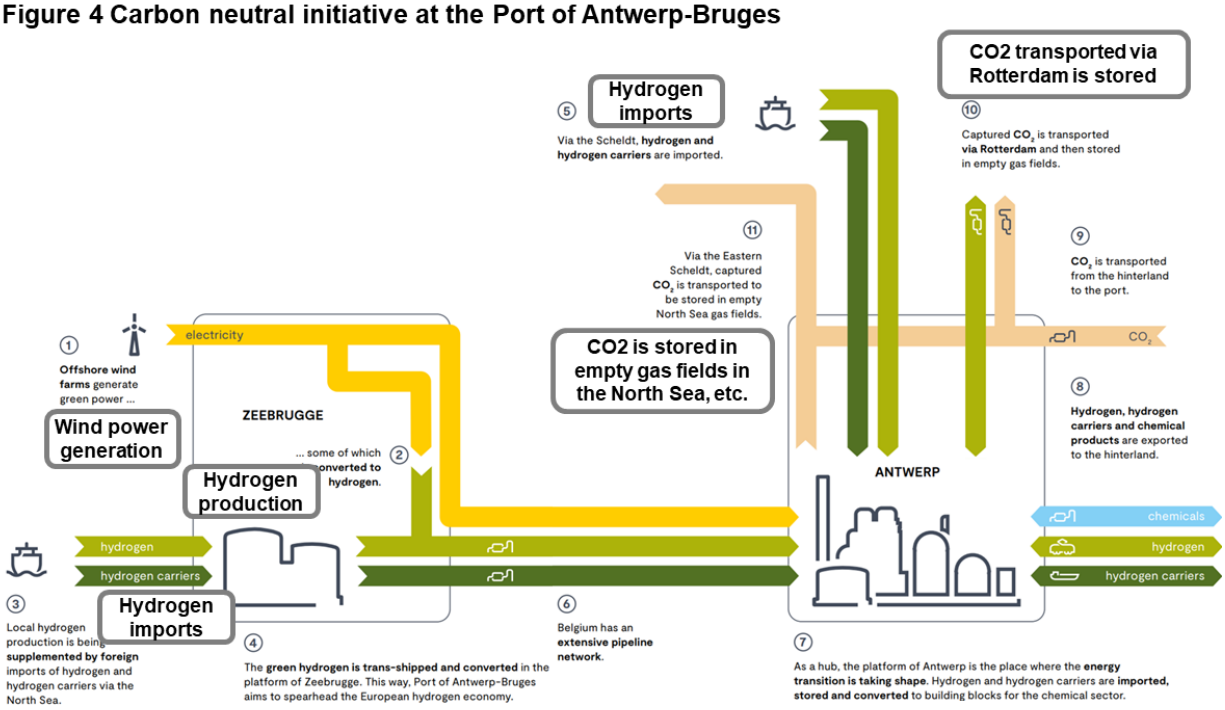
Source: Port of Rotterdam website "Development of import terminal for hydrogen carrier in port of Rotterdam" https://www.portofrotterdam.com/en/news-and-press-releases/development-of-import-terminal-for-hydrogen-carrier-in-port-of-rotterdam (accessed October 20, 2022)

As for the use of bio-materials and fuels, Shell announced in 2021 that it would convert its former Pernis Refinery into a biofuel facility with 820,000 tons per year of SAF, renewable diesel, and other biofuels. The carbon dioxide emitted will be treated with CCS. In addition, the Finnish energy giant Neste, which currently has the largest production capacity for renewable products in Europe, plans to approximately double its capacity to 2.7 million tons per year by 2026. It will produce 1.2 million tons of SAF as well as renewable diesel, polymers, and renewable raw materials for chemicals.

2-2. Port of Antwerp-Bruges (Belgium)

The Port of Antwerp-Bruges in Belgium was created by the 2022 merger of the Port of Antwerp, which forms one of Europe's largest petrochemical clusters, and the Port of Zeebrugge, Europe's largest port handling finished vehicles. The new port is working to become carbon neutral (Figure 4). Major efforts include the introduction of infrastructure such as hydrogen, CCS, CCUS, and renewable energy.

Figure 4 Carbon neutral initiative at the Port of Antwerp-Bruges

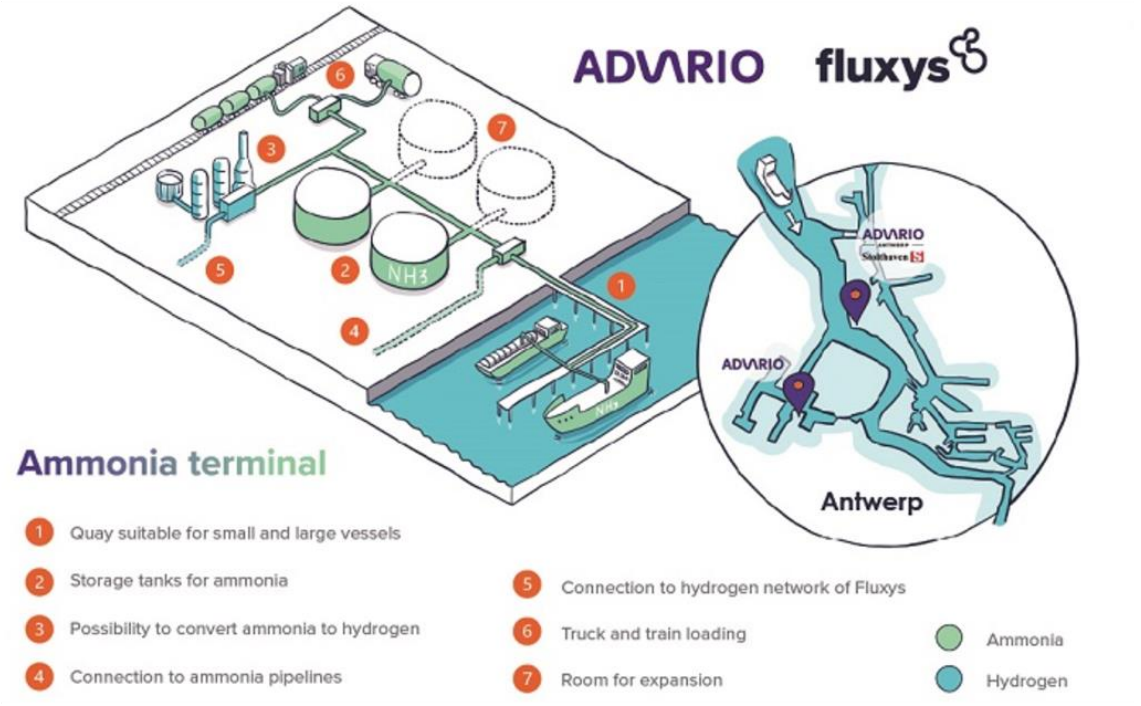


Source: Port-of-Antwerp-Bruges website "The green home port of Europe" https://media.portofantwerpbruges.com/m/122baaae59492c7f/original/Port-of-Antwerp-Bruges.pdf?_gl=1*kkkop0*_ga*MTE0MzEzNDIwMy45NDM1ODg5NjAw*_ga_DTC7EP43ET*MTY2NDc2NTYwOS41LjEuMTY2NDc2NTkwNy45LjAuMA. (accessed October 20, 2022)

Anticipating that it will not be able to provide sufficient quantities of hydrogen through local production, the port has signed a memorandum for the procurement of green hydrogen with Chile and Canada. In addition, with a grant from VLAIO (an organization that supports entrepreneurs and encourages growth and innovation in the Flanders region),[9] the former ports of Antwerp and Zeebrugge, along with major industrial players, are studying possible ways to import hydrogen from Australia, South America, the Middle East, Southern Europe, and other areas.[10] The study compares currently established transport technologies for liquid hydrogen, hydrogen-derived compounds (methane, methanol, and ammonia), and a liquid organic hydrogen carrier (dibenzyltoluene). The results have shown that hydrogen-derived compounds are more cost-effective for medium- to long-range transport. Subsequently, Fluxys and Advario (energy infrastructure companies based in Belgium and the Netherlands, respectively) announced plans in August 2022 to build a green ammonia import terminal (Figure 5) at the Port of Antwerp-Bruges. The terminal is scheduled to begin operations in 2027, and the imported ammonia will be used as a raw material for fertilizer and as fuel in the shipping industry.

[9] Flanders Innovation & Entrepreneurship, https://www.vlaio.be/en/about-us/let-us-introduce-ourselves
[10] https://flux50.com/news-events/news/the-hydrogen-import-coalition-is-ready-to-take-the-next-step-towards-the-belgian-hydrogen-economy

Figure 5 Port of Antwerp-Bruges ammonia import terminal



Source : fluxys press release "Driving Europe's hydrogen strategy:Fluxys and Advario join forces to develop a green ammonia import terminal at the Port of Antwerp-Bruges"
https://www.fluxys.com/en/press-releases/fluxys-group/2022/220831_press_fluxys_advario_green_ammonia (accessed October 20, 2022)

The Antwerp@C project[11] to store carbon dioxide and the Power to Methanol Antwerp project[12] to produce a low-carbon methanol fuel from carbon dioxide are initiatives in CCS and CCUS. The Antwerp@C project has been subsidized by the EU with about 9 million euros through the CEF. Air Liquide, BASF (Germany), ExxonMobil, TotalEnergies (France), and others are jointly conducting a feasibility study with the port authority. In contrast to the case of Porthos in Rotterdam, there are no CCS facilities in the vicinity. Therefore, the plan is to build a carbon dioxide liquefaction and storage facility and transport it by ship to Norway and the UK or by overland pipeline to Rotterdam and other locations.

The Power to Methanol project in Antwerp is being studied jointly by the port authority and major industrial players. The plan is to produce methanol from green hydrogen and carbon dioxide stored through CCS, and this methanol is being considered for use as, for example, fuel for transport vessels in the industrial complex.

3. POTENTIAL DEVELOPMENTS IN JAPAN

In Japan, major industrial complexes such as Kashima, Chiba, Kawasaki, Yokkaichi, Sakai, Mizushima, Shunan, and Oita are considering going carbon neutral. With a port where large tankers can dock, each complex has LNG pipelines, LNG storage facilities, and oil refineries within it, and existing facilities can be converted. However, at present, there are issues with the economics of hydrogen production and CCS. In this respect, Japan can learn from the cases of the Port of Rotterdam and the Port of Antwerp-Bruges: the Port of Rotterdam is considering a mechanism to import 4 megatons of hydrogen in the form of ammonia and the like by 2030, and the Port of Antwerp-Bruges is looking into the export of carbon dioxide.

Business opportunities are expected to be created in related projects, including the expansion of ammonia import facilities, carbon dioxide pipelines, liquefaction and storage facilities, and transportation facilities. In the future, we expect to see carbon neutrality in new hydrogen production processes that do not produce carbon

[11] https://newsroom.portofantwerpbruges.com/the-antwerpc-project-takes-a-major-next-step-towards-halving-co2-footprint
[12] https://powertomethanolantwerp.com/

dioxide even when natural gas is used, such as turquoise hydrogen,[13] and in new technologies such as economical floating offshore wind turbines and nuclear fusion power generation.

[13] Turquoise hydrogen is the carbon and hydrogen obtained from the thermal cracking of methane, the main component of LNG. This process does not produce carbon dioxide and has recently attracted attention as an effective hydrogen production technology for decarbonization.