The Role of the Maritime Community in Establishing a German Hydrogen Economy

- Management Summary -

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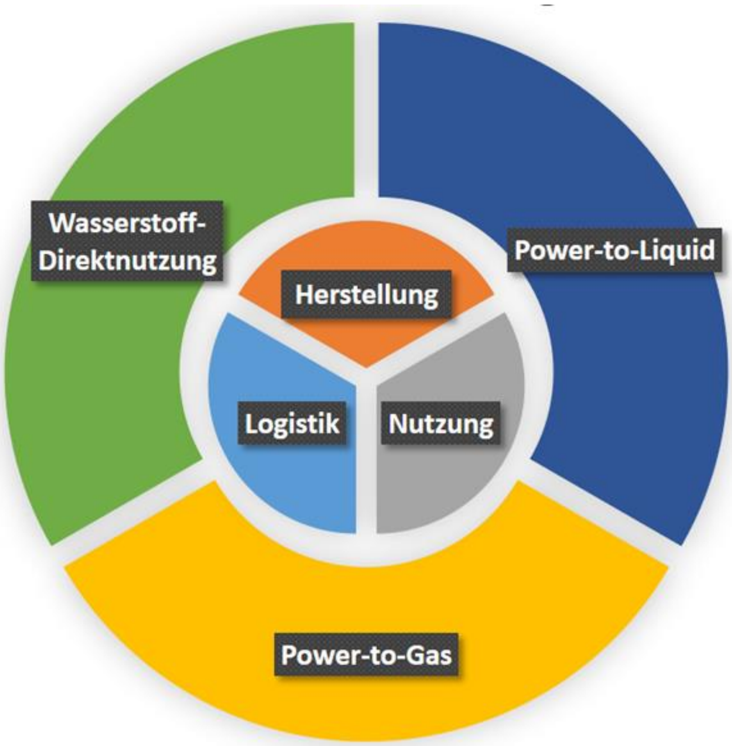

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The study commissioned by the German Maritime Centre focuses on the aspects “maritime industry as consumer” and “maritime industry for logistics” in connection with hydrogen technologies. It is based on various hydrogen strategies that formulate respective objectives, in particular the National Hydrogen Strategy of the German Federal Government, the European Hydrogen Strategy, and the North German Hydrogen Strategy. These strategies are ambitious, but indeed exceeded by the amendment to the German Climate Change Act which entered into force in summer 2021. In addition, the goals of the German Federal Government such as phasing out nuclear and coal-fired power for electricity generation depend on the availability of regeneratively generated electricity as well and are therefore in direct competition with the generation of green hydrogen, which is an additional challenge with regard to the successful achievement of the climate goals.

In the study, the technologies of electrolytic hydrogen production as well as power-to-gas and power-to-liquid production (hereinafter referred to as PtX energy carriers) are presented holistically with their process chains from production to consumption, and evaluated based on their efficiencies and greenhouse gas emissions. The examined PtX energy carriers are synthetic methane, methanol, ammonia and crude oil (e-crude). The properties and costs of the transport processes which take place between the stages of the process chains are examined separately. Different distances and transport technologies are considered and evaluated. The sources of electricity and water are taken into account as well. The detailed examination of the various hydrogen-based technologies indicates that only a combination of all approaches will ultimately lead to the successful achievement of the climate goals.

German domestic hydrogen production

According to various already published studies, the demand for hydrogen and PtX energy carriers in Germany is estimated to increase drastically in the coming decades. In this context, this study investigates the extent to which wind energy can be utilized in German coastal regions on the North Sea and the Baltic Sea to meet the German demand for hydrogen. The total nominal capacity currently installed in these regions onshore and offshore - 30.2 GW - would be sufficient to produce around 64 TWh of green hydrogen per year from electrolysis. In principle, that would be sufficient to meet the current German demand for fossil hydrogen. However, since this nominal capacity is already required for the generation of electricity for direct use, it is only available to a limited extent - if at all - for the production of green hydrogen. Consequently, additional nominal wind power capacities are required for this purpose.

In order to meet the forecasted demand for renewable electricity in Germany solely through offshore wind power in 2045, when the abovementioned amendment to the German Climate Change Act demands greenhouse gas neutrality, additional offshore wind farms the size of the German Federal State of Mecklenburg-Western Pomerania would be required, which exceeds the area of the German Exclusive Economic Zone in the North and Baltic Seas and thus is not feasible.

So, even with the greatest possible expansion of domestic regenerative electricity generation, there remain significant demands for importing climate-neutral energy carriers to Germany. In this context, domestic efforts should focus on hydrogen production for direct use, as hydrogen transport over long distances is associated with significantly greater effort compared to the transport of PtX energy carriers due to its low volumetric energy density. Domestically produced hydrogen can be stored in caverns and distributed through appropriate distribution networks. Nevertheless, new processes for cheaper and more efficient electricity generation and optimization of respective process chains are necessary in order to make the domestic hydrogen production competitive compared to imports.

Electricity from renewable sources will in the long term remain a scarce resource. It is therefore of vital importance that the production paths of hydrogen and PtX energy carriers are as efficient as possible. For this reason, the efficiency of related technologies, e.g. electrolysers, should be further optimized.

Imports of hydrogen and PtX energy carriers

Regarding required imports of climate-neutral energy carriers in the coming decades, a diversified utilisation of all relevant energy carriers will offer significant advantages compared to a concentration on particular energy carriers only. In general, the superior transportability of PtX energy carriers over large distances compared to hydrogen must be taken into account. The existing LNG and crude oil infrastructure can immediately be used for importing the respective PtX energy carriers, at least for a transitional phase. These imports will facilitate quick effects of greenhouse gas reductions, also on an intercontinental scale. Apart from that, hydrogen demands exceeding the amount of domestically produced hydrogen must be covered by imports. As a consequence, imports of both green hydrogen and PtX energy carriers will be an important pillar of a future German hydrogen society.

Import flows by vessel and pipeline

In order to ensure that the demand for hydrogen and PtX energy carriers can be met, the study examines respective imports by means of suitable transport vessels. For this purpose, a number of tankers for different energy carriers are examined and compared. Since it is considered beneficial to supplement the vessel import flows with pipelines, the results are compared with pipeline transport.

The results demonstrate that vessel transport is competitive compared to pipelines and becomes even more competitive with increasing transport distances. Another important aspect is that the construction of a pipeline implies a determination of a single export country and the respective transfer countries, thus creating long-term political and economic dependencies and potential risks. Vessel transport in contrast is quite flexible in the selection of the export country, since different countries and ports can be approached at relatively short notice. In this way, vessel transport ensures a flexible supply of Germany with climate-neutral energy carriers.

It is evident that the higher the energy density of the carrier substance, the cheaper the transport. In order to facilitate efficient transport flows, the sizes of the selected vessels must be in agreement to the quantities of the respective energy carrier offered by the exporting country.

The transport units needed for the transport of SLNG, synthetic methanol or e-crude already exist, namely LNG tankers commonly used today and large crude oil tankers (VLCC) used for the import of fossil crude oil. Synthetic ammonia as liquefied gas could in an initial phase be transported by existing vessels as well.

In the hydrogen sector, however, tankers for liquid hydrogen (LH2) with the required capacities currently do not exist. Technology for the construction of large-volume, highly efficient LH2 vessel tanks is not available as well. Furthermore, there is a lack of the hydrogen liquefaction systems which are needed to load respective LH2 tankers in a reasonable time. First pilot projects with small LH2 tankers are in place, but offer only insufficient transport volumes and should be developed to market maturity as soon as possible, such that transport units of different sizes for various application areas will be available when needed. At the same time, standardization and certification must consequently be advanced. The extensive research and development activities which are necessary to develop and successfully implement global hydrogen transport chains will require a close cooperation between industry and science in the future, facilitated by large investments in the coming decades. In that way, the shipbuilding industry, the hydrogen industry, shipping companies and, last but not least, research institutes will play an important role in the development of innovative tanker types, new fleet structures, and innovative concepts. It is important that these developments are driven forward in balance with hydrogen and PtX production and demand, ensuring the successful establishment of a hydrogen society in Germany.

The role of the German ports

The hydrogen strategies emphasize the importance of hydrogen hubs, which integrate production, distribution, and consumption of hydrogen and PtX energy carriers in one place. It is up to the hydrogen industry in cooperation with research organisations to define the characteristics of respective hubs, indicating necessary functionalities and required technological structures. In this regard, connections to efficient import, export, and distribution structures play an important role, which makes the German ports promising candidates to play this central role as hydrogen hubs.

As a first step, it is important to provide a sound estimate of the expected import quantities of hydrogen and PtX energy carriers. Based on this, it must be examined which import infrastructures and superstructures such as terminals, storage capacities, and hinterland connections are required in order to handle the expected quantities. Whenever applicable, the utilisation of existing infrastructure and superstructure should be continued for the sake of sustainability. For this purpose, it must be investigated to what extent, for example, existing import terminals for LNG, crude oil, products, or chemicals could be used for future handling of hydrogen or PtX energy carriers, or how these structures could be modified to meet the demands.

With regard to import of energy carriers through ports, respective handling, storage, and distribution is easiest in case of the PtX variants of fossil fuels. In this way, existing infrastructure for fossil LNG and crude oil such as refineries, filling stations, and distribution networks can in the future be used for synthetic methane and e-crude. In contrast, existing structures for synthetic methanol or synthetic ammonia are only suitable for handling the currently low demands - they are not sufficient for large-scale imports and must be significantly expanded. The largest deficits are related to the import of hydrogen, as currently no infrastructures and superstructures in Germany exist, which means that they have to be built from scratch. This consideration also leads to the abovementioned recommendation to concentrate domestic production of renewable energy carriers mainly on the generation of hydrogen for direct use, in order to focus imports on substances which imply less efforts for transportation.

Furthermore, existing regulations need to be revised or extended on international level in order to enable global large-scale imports and applications of hydrogen and PtX energy carriers in the maritime sector. This is an essential component for the ramp-up of a hydrogen economy, as regulatory gaps currently exist in this area. While the applicability of synthetic methane, synthetic heavy fuel oil, synthetic diesel fuel and synthetic methanol as a marine fuel is already covered by the regulations for the corresponding fossil fuels, there still is no regulation for the use of hydrogen as fuel in the maritime context. The use of ammonia as marine fuel is currently not permitted on all types of vessels and is explicitly prohibited for gas tankers in accordance with Chapter 16 of the IGC Code. In order to examine the use of these energy carriers as fuels for maritime applications, appropriate regulations must be drafted and put into force as soon as possible.

Establishing international partnerships

The analysis of global hotspots of hydrogen technologies has shown that numerous countries beyond Africa, the Middle East, and Australia have ambitions to export hydrogen-based energy carriers. In order to guarantee a reliable supply with hydrogen and PtX energy carriers and to ensure the competitiveness of the German seaports in this respect, political and economic efforts are necessary to establish energy partnerships with strategically favorable hydrogen exporting countries and to secure appropriate capacities. The port of Rotterdam, which competes with the German seaports, is currently very active in this area and has already established several direct partnerships to meet the demand.

In general, a diversified approach should be chosen, establishing partnerships with a number of different countries in order to avoid individual dependencies. The study considers various countries that are currently in discussion as possible sources for the import of hydrogen products to Germany or with which corresponding agreements have already been established. Representing different global export regions, Australia, Chile, Iceland, Canada, Morocco, Norway, and the United Arab Emirates are examined as examples, carrying out respective economic and greenhouse gas analyses.

Since other countries are pursuing decarbonisation and the development of a hydrogen society as well, Germany is in global competition with countries that also rely on the import of climate-neutral energy carriers. Hence, sound political foundations for future activities must be put in place. Especially in the areas of regulation, the establishment of energy partnerships, and the development of import infrastructures and superstructures, political decisions must be taken as soon as possible with regard to lengthy approval processes. This is a prerequisite for the successful establishment of a sustainable international hydrogen market with German participation, ensuring the import of the required amount of energy carriers into Germany, thus facilitating successful achievement of the hydrogen strategies' goals.

Hydrogen applications in the maritime sector

For maritime applications, the shipbuilding industry needs to develop innovative propulsion concepts utilizing different types of alternative fuels, thereby considering all feasible technological options. These new concepts have to be tested in practical use beyond the currently existing pilot projects. Both new concepts for combustion engines as well as fuel cell applications should be examined in order to determine optimal solutions. PtX energy carriers such as, for example, synthetic diesel fuel, synthetic methanol, and synthetic ammonia, as well as the direct use of hydrogen should be investigated in order to identify the best option for the various application areas.

New concepts for the application of hydrogen technologies in ports are required as well. It must be examined which propulsion concepts can be deployed for vehicles and handling equipment in the port area and beyond. Research in this area must consider all feasible technological options. An objective evaluation of the ecological impacts of different propulsion concepts is provided by life cycle analyzes.

The use of new fuels in shipping requires adaptations of existing bunker structures or the implementation of new ones. Although synthetic methane, synthetic heavy fuel oil, and synthetic diesel fuel can be integrated into existing bunker concepts without major adjustments, fuels such as synthetic methanol and synthetic ammonia already require significant modifications to the bunker structures. Liquid hydrogen, however, requires a completely new bunker concept and the construction of specialized infrastructures and superstructures and thus extensive research and development activities. As already mentioned above, the relevant international regulations will have to be revised as well.

Conclusion

Due to its central role in transport and application of climate-neutral energy carriers, the German maritime industry is of outstanding importance for the implementation of a Hydrogen Economy in Germany. In general, the expansion of renewable energies must be a cross-sectoral goal in order to provide sufficient electricity from renewable sources for the implementation of the required electrolysis capacities. It has been shown that neither the existing potentials nor the current plans are suitable to meet Germany's demand for hydrogen and PtX energy carriers. Vessel imports will therefore play a central role in establishing a German hydrogen society. Appropriate political framework conditions must be created as soon as possible to significantly support and promote these developments. The corresponding regulations need to be revised or expanded as well.

With regard to a possible technological leadership of Germany on a global scale, it is important for the German maritime industry to identify new opportunities at an early stage and to exploit them in a consequent manner. The investigation of the different hydrogen and PtX products, the underlying technologies, and the status of their development shows that both the direct use of hydrogen and the use of the various hydrogen-based PtX fuels will contribute to the decarbonization of Germany's economy, leading to a successful achievement of the climate goals. For this purpose, the different approaches should be implemented and examined in practical pilot and implementation projects in order to ensure their expedient application.

In the area of vessel transport, the superior transportability of PtX energy carriers over large distances compared to hydrogen must be taken into account. In particular, considering the transport of liquid hydrogen by vessel, it is evident that there still is considerable need for research and development in order to bring the required highly efficient tank technologies to market maturity. These circumstances must in particular be taken into account when developing the strategy for establishing a German Hydrogen Economy.