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Green Hydrogen Hub Europe

Hamburg as a hub for hydrogen imports to Germany and Europe

An economic policy strategy by the Ministry of Economy and Innovation

(Behörde für Wirtschaft und Innovation)

Hamburg, February 2022

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1 Objectives

In view of advancing climate change, Hamburg is at the beginning of a transformation process to a decarbonised future. Solutions must be found in wide areas of economic activity to reduce greenhouse gas emissions and thus limit global warming. In the Paris Climate Agreement, the international community committed to keeping greenhouse gas emissions significantly below 2 degrees Celsius and preferably at 1.5 degrees Celsius in comparison to the pre-industrial era. The Hamburg Senate is committed to these goals and is developing its policy accordingly. In order to achieve these goals, with the first revision of the Hamburg Climate Action Plan at the end of 2019, the Senate committed to reduce CO_2 emissions in Hamburg by 55 per cent by 2030 compared to 1990, and to reach climate neutrality by 2050.[1] However, when the Senate concluded its coalition agreement in June 2020, it established that the aspirations of the Climate Plan reduction goals are not sufficient and need to be revised as part of the 2022 reporting.[2]

Each administrative department of the Senate is responsible for making a contribution to complying with the Hamburg Climate Plan. In the field of economic policy, a crucial factor for achieving the reduction goals lies primarily in decarbonising industry, the ports, shipping, heavy goods transport and aviation, given that these offer considerable potential savings for greenhouse

[1] First revision of the Hamburg Climate Plan [...], Hamburger Bürgerschaft, Document 21/19200, 03.12.2019.
[2] "Koalitionsvertrag über die Zusammenarbeit in der 22. Legislaturperiode der Hamburgischen Bürgerschaft zwischen der SPD, Landesorganisation Hamburg und Bündnis 90/Die Grünen, Landesverband Hamburg", https://www.hamburg.de/senatsthemen/koalitionsvertrag/, last accessed on 21.01.2022.

gasses.[3] A key technology in this is green hydrogen[4] whose market ramp-up is also being treated as a priority in the current national coalition agreement.[5] The use of green hydrogen not only avoids CO_2 emissions in all scenarios where a switch is made from grey to green hydrogen. It can also be used to exploit decarbonisation potential in (industrial) sectors where the direct use of green electricity is not possible, making hydrogen the only decarbonisation option, such as in metallurgy and the chemical industry. Besides avoiding CO_2 emissions, the use of green hydrogen can help to safeguard jobs in the industries concerned and generate new added value potential at the location.

With the increasing market ramp-up of a green hydrogen economy, demand for green hydrogen will continue to rise rapidly over the next few years. In its National Hydrogen Strategy published in June 2020, the German Federal Government predicts a hydrogen demand in Germany of around 90 to 110 terawatt hours (TWh) per year by 2030.[6] If it is assumed that this demand is distributed across the individual federal states in proportion to current energy consumption, then around 4 TWh per year would fall to Hamburg alone – without the additional (North) German demand, which could be met by transshipment in the Port of Hamburg.[7] Results from a recent survey of Hamburg's largest industrial companies, which currently account for around a third of the entire

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[3] For more detailed information see, e.g. the study "Klimaneutrales Deutschland 2045 – Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann", compiled by Prognos AG, Öko-Institut e.V., Wuppertal Institut für Klima, Umwelt, Energie gGmbH on behalf of the Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende, 2021, https://www.agora-verkehrswende.de/fileadmin/Projekte/2021/KNDE_2045_Langfassung/KNDE2045_Langfassung.pdf. Towards a Climate-Neutral Germany by 2045 How Germany can reach its climate targets before 2050: Executive summary: https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021_04_KNDE45/A-EW_213_KNDE2045_Summary_EN_WEB.pdf

[4] On what is known as the "hydrogen colour theory", see the glossary of the National Hydrogen Strategy, June 2020, https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6.

[5] Coalition agreement 2021-2025 between the SPD, Bündnis 90 / Die Grünen and FDP "Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit", https://www.spd.de/koalitionsvertrag2021/, last accessed on 21.01.2022.

[6] The National Hydrogen Strategy, June 2020, https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6.

[7] Depending on proportional primary energy demand in 2019 (Hamburg approx. 508 PJ, Germany approx. 12.805 PJ)

consumption of natural gas in Hamburg, even predict that demand for green hydrogen by 2030 will total around 7.6 TWh/a, comprising industrial uses (approx. 5.7 TWh/a) and the mobility sector (approx. 1.9 TWh/a[8] solely for the transport flows directly associated with goods transshipment in the port). The Hamburg Metropolitan Region with its over 5 million inhabitants is likely to produce an additional demand for hydrogen. In order to meet the growing demands, Hamburg already has some small electrolysers in operation and larger plants (for example in Moorburg) are at the planning stage, meaning that by 2030 there will be a green electrolyser output of around 550 MW[9] and therefore a hydrogen production capacity of around 2.2 TWh/a.

According to current information, the shortfall between demand and production capacity cannot be met either regionally or nationally, even if there is an increased expansion of both renewable energies as electricity sources and the production capacity for green hydrogen. As a result, consumers in Hamburg and throughout Germany will be reliant on imports[10] in order not to hinder the ramp-up of the hydrogen economy from the buyers' side, therefore blocking the decarbonisation of the entire economy. A number of studies assume that in 2030 – taking account of current national expansion targets for energy and hydrogen generation – between 43 and 70 per cent of the national hydrogen demand will need to be met through imports.[11]

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[8] Container transshipment measured in TEU (20-foot standard container) was around 5.5 million TEU in the Corona crisis year; of this, 50.4 per cent was forwarded by lorry (https://www.hafen-hamburg.de/de/statistiken/containerumschlag/ and https://www.hafen-hamburg.de/de/statistiken/modal-split/, last accessed on 14.09.2021). Assumption: by 2030, 20 per cent of lorries will run on hydrogen and will be fuelled in Hamburg for 1,000 kilometres at a consumption rate of 10 kilogrammes hydrogen (at 350 bar) per 100 kilometres (data from Clean Logistics).

[9] With an efficiency of 65% and 6,000 full load hours of operation per year

[10] "Die Rolle der maritimen Wirtschaft bei der Etablierung einer deutschen Wasserstoffwirtschaft", Institut für Seeverkehrswirtschaft und Logistik, on behalf of the Deutsches Maritimes Zentrum e.V., 09.11.2021, https://www.dmz-maritim.de/wp-content/uploads/2021/11/Studie-Wasserstoff_2021.pdf.

[11] "Metastudie Wasserstoff – Auswertung von Energiesystemstudien", study on behalf of the German German National Hydrogen Council (Nationalen Wasserstoffrat), Wietschel, M.; Zheng, L.; Arens, M.; Hebling, C.; Ranzmeyer, O.; Schaadt, A.; Hank, C.; Sternberg, A.; Herkel, S.; Kost, C.; Ragwitz, M.; Herrmann, U.; Pfluger, B., Fraunhofer ISI, Fraunhofer ISE, Fraunhofer IEG (Eds.) Karlsruhe, Freiburg, Cottbus, 2021.

The Ministry of Economy and Innovation which is responsible for the port economy and industry is pursuing the ambitious aim of having a large proportion of these future hydrogen imports to Germany take place via Hamburg. Onshore imports will largely take place via pipelines[12] as it is likely that this method can meet a large proportion of the national hydrogen demand in the medium term. Parallel to this, plans for marine import need to be developed.[13] The significant quantities of hydrogen anticipated for transshipment provide an excellent opportunity to guarantee that the Port of Hamburg will continue be a leading global location and will remain one of the pillars of the city's economic development.

In Hamburg the potential of green hydrogen – both for decarbonising industry and for the future of the Port of Hamburg – was recognised early on, and for a number of years the location has been developing into a hydrogen stronghold in Europe, where the entire hydrogen value chain is represented. Unlike other locations, Hamburg has backed green hydrogen, even in the market ramp-up phase. Through the strategy presented here, the Ministry of Economy and Innovation aims to consolidate this position over the coming years and make a vital contribution to the development of the location into the Green Hydrogen Hub for Germany and Europe. Hamburg plans to become a reliable partner for hydrogen exporting countries and a landing point for European and non-European hydrogen imports via pipeline and ship, while developing into a hydrogen distribution centre both for the large number of industrial buyers in the Port of Hamburg and for Germany and many neighbouring European countries. This requires the implementation of a range of tasks during the current legislative period that are described in the following chapters as action points. Some of these action points involve financial burdens for the institutions concerned, for which resources need to be acquired in order to operationalise the strategy.

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[12] See Section 5.3 for details of hydrogen imports via pipeline.
[13] See Section 5.4 for details of hydrogen transport via ship.

The administrative strategy presented here is based on the fundamental principles and scope of action of the National Hydrogen Strategy[14] as well as the Hydrogen Strategy for North Germany.[15] Both strategy papers point out the need for imports along with the necessary infrastructure, but do not specify what actual next steps are required in this connection. This paper aims to provide the Hamburg government and administration with the stimulus for a course of action to decarbonise and transform the Port and industry, taking account of the hydrogen strategy of the European Union[16], the implications arising from the national coalition agreement[17] and the actions of the other North German federal states. In addition, this strategy aims to provide political support and guidance for potential investors, import companies and consumers, thus making an important contribution to planning and investment security. However, it is primarily intended to form a foundation to ensure that hydrogen imports will be available in sufficient quantity from around 2030 so that the decarbonisation potential offered by the use of green hydrogen, particularly for the port economy and the industries located there, can be used to the full and Hamburg can therefore reach its climate change objectives.

2 Hamburg: Hydrogen Hub for Germany and Europe

Hamburg is ideally suited to be a hydrogen hub, first of all on account of its harbour. Measured by annual container handling, the Port of Hamburg is the largest sea port in Germany and the third

[14] The National Hydrogen Strategy, June 2020, https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6.

[15] "Hydrogen Strategy for North Germany", 07.11.2019, https://www.hamburg.de/contentblob/13874168/e484c76e44486905abd9220bbdd64a8f/data/hydrogen-strategy-for-north-germany.pdf.

[16] "A hydrogen strategy for a climate-neutral Europe", 08.07.2020, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

[17] Coalition agreement 2021-2025 between the SPD, Bündnis 90 / Die Grünen and FDP, "Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit", https://www.spd.de/koalitionsvertrag2021/, last accessed on 21.01.2022.

largest in Europe[18], whose existing container handling and storage capacities (bulk goods) could be ideal for landing marine hydrogen imports. Moreover, the aim will be to construct new highly specialised plant in the port for receiving hydrogen via ship. Hamburg will in future be connected to a European and national hydrogen pipeline network so that hydrogen can be imported from all over Europe and be distributed to the city as well as to Germany and Europe. In Hamburg itself, the planned Hamburg Hydrogen Industry Network (HH-WIN) south of the River Elbe will enable a user-friendly link between local consumers, producers and the marine import infrastructures with the national pipeline network.[19]

Hamburg's excellent infrastructure and geographical position allow rapid and cost-effective onward distribution of green hydrogen to Germany and Europe. For instance, Hamburg and its ports are situated right next to the busiest man-made waterway in the world, the Kiel Canal, allowing rapid transport of hydrogen from Scandinavia. Moreover, the direct connection to the inland waterways could be expedient, once the technical requirements for hydrogen transport on barges have been met. This will enable the onward distribution of hydrogen via the canal and river network to the south and to Central Germany all the way to Czech Republic. The Port of Hamburg also has an outstanding rail infrastructure – with a total of around 300 kilometres of railway, the Port of Hamburg is one of the largest rail ports in Europe and currently transports as many containers by rail as Bremen, Antwerp and Rotterdam combined – enabling the rapid onward transport of hydrogen in all directions. Added to this, Hamburg has excellent connections to the national motorways A1, A7, A23, A24 and A20 as well as prospectively the A26, permitting hydrogen to be distributed on the road network by tanker.[20] The ports of Stade and Brunsbüttel on the Lower Elbe immediately downstream of the Port of Hamburg also have potential for handling marine hydrogen imports. This offers opportunities for cooperation in supplying North Germany

[18] "Top 20 Containerhäfen", Port of Hamburg, https://www.hafen-hamburg.de/de/statistiken/top-20-containerhaefen/, last accessed on 21.01.2022.
[19] Compare details of import via pipeline in Section 5.3.
[20] All-purpose Port Hamburg, Port of Hamburg – Gateway to the world https://www.hafen-hamburg.de/en/portofhamburg/port-of-hamburg/? last accessed on 21.01.2022.

with green hydrogen – if it is assumed that all available capacity will be required to meet future demand.

Large amounts of the imported hydrogen will be used directly by the Port in future. After all, the Hamburg Metropolitan Region is the third largest industrial location in Germany and one of the most important industrial areas in Europe. In the Port alone there are around 22 larger industrial enterprises operating mainly in oil refining, metal production, supply and disposal, boat and shipbuilding and the construction industry. According to the survey mentioned under "Objectives", by 2030 these enterprises will probably have a significant green hydrogen demand of around 5.7 TWa/a. Even the traffic flows directly connected to goods handling in the Port, particularly lorry transport, will have a notable hydrogen demand of around 1.9 TWh/a by 2030.[21]

Both government and industry are committed to developing and running an excellent import infrastructure as well as ensuring the development of a competitive, self-supporting hydrogen economy that represents the entire value chain. For instance, Hamburg promotes and supports the joint plans by Shell and Mitsubishi Heavy Industries as well as municipal Wärme Hamburg to generate green hydrogen on the site of the former Moorburg coal-fired power station in the Port of Hamburg. Plans are focused on a large electrolyser scalable up to 500 Megawatts (MW) with an initial output of 100 MW, primarily to supply local industry from 2025.[22] The city also supports plans by Gasnetz Hamburg GmbH to set up the previously-mentioned Hamburg Hydrogen Industry Network.[23] Both projects along with six other hydrogen projects from Hamburg were selected for funding at national level as part of the Important Projects of Common European Interest on Hydrogen Technologies and Systems (IPCEI hydrogen)[24] and will be implemented with

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[21] See page 4.

[22] "Wasserstoffprojekt Hamburg-Moorburg – Vier Partner unterzeichnen Absichtserklärung über 100 Megawatt Elektrolyse, 22.01.2021, https://www.hamburg.de/pressearchiv-fhh/14847126/2021-01-21-bukea-wasserstoffprojekt-am-standort-moorburg/, last accessed on 21.01.2022.

[23] See Section 5.3 for more detail on the HH-WIN project

[24] See Chapter 4 for more detail on the IPCEI Hydrogen programme

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financial support from the federal state of Hamburg and the German Federal Government. In addition, at the start of 2021 the existing Renewable Energy Hamburg (Erneuerbare Energien Hamburg, EEHH) cluster was expanded to include the priority area of the hydrogen economy. As part of this priority area, the EEHH in partnership with the Ministry of Economy and Innovation (BWI) will prioritise the development of a network in the Hamburg Metropolitan Region, thus creating a platform for the exchange of information and creation of synergies between the various stakeholders in the hydrogen economy and adjoining sectors.[25] Hamburg's strength in establishing strategic, sustained cooperation in important economic fields between industry, science and government is particularly relevant for the ramp-up of a green hydrogen economy. It is necessary for economic transformation that business, technology and policy develop in harmony.

In order to enhance innovation capability, the Federal Ministry of Transport and Digital Infrastructure (BMVI) is also planning a funded technology and innovation centre (ITZ-Nord) for hydrogen technology for the aviation and shipping sectors in North Germany at locations in Bremen/Bremerhaven, Hamburg and Stade. The plan focuses on developing and integrating fuel cell systems and the relevant components, on hybridisation, refuelling concepts and the use of green hydrogen and its derivatives (PtX fuels). Competencies for standardisation need to be integrated through the close involvement of classification societies.[26]

Action point no. 1

North German demand analysis

The import of green hydrogen via Hamburg should be aimed primarily at meeting the demands of the Hamburg economy and the Metropolitan Region. However, the potential additional

[25] "Erneuerbare Energien Hamburg – Das Branchennetzwerk für Zukunftsenergien", https://www.erneuerbare-energien-hamburg.de/de/ueber-uns/eehh.html, last accessed on 21.01.2022.

[26] "Der Norden bekommt ein Wasserstofftechnologiezentrum für Luft und Schifffahrt – Erfolg für gemeinsames Konzept aus Bremen/Bremerhaven, Hamburg und Stade", press release by the Federal Ministry of Transport and Digital Infrastructure, 02.09.2021, https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2021/102c-scheuer-standortentscheidung-innovations-technologiezentrum-norden.html?nn=12830, last accessed on 21.01.2022.

requirements of North Germany need to be considered as a whole. Up until now, there has been no precise overview of what needs actually exist in the north that cannot be met via production in the North German federal states. The Staff Section for the Hydrogen Economy (SW) of the BWI along with the EEHH Cluster and Hamburg Invest have been tasked with surveying these needs by 2023, as well as the potential quantities that can be produced in the north and the resulting gaps in demand, so enabling, e.g. expansion of the infrastructure in line with demand. This survey will collate the results of the working groups that were set up for each action area of the Hydrogen Strategy for North Germany, as well as the work of additional stakeholders in North Germany, including other potential import harbours or large logistics companies.

3 Areas of application and manufacturing costs for green hydrogen

In exploiting decarbonisation potentials, green hydrogen will play an important role for many (industrial) companies in Hamburg, especially in situations where direct electrification and the potential decarbonisation via electricity procurement is not practical. Use should be made of green hydrogen especially in the (industrial) fields of metallurgy (e.g. steel manufacture or iron production), refining (for example of petroleum, production of synthetic fuels), the production of cement and glass, and in the chemicals industry (for example, the production of methanol and ammonia or the manufacture of nitrogen fertilisers). In addition there is great potential for its use in heavy goods transport by road, in the maritime sector (port ferries, cruise ships and container ships), in aviation[27] and in rail transport.[28] Even though this strategy paper is focused on the economic location of Hamburg, when calculating the demand for the required import quantities of green hydrogen, a cross-departmental approach must be adopted in future. Demand for green

[27] It is planned to use hydrogen directly for short and medium distances and synthetic fuels (PtL) for long distances.
[28] What needs to be decided in this case is whether routes which have not been electrified should be decarbonised by expanding overhead lines (re-electrification) or through the use of alternative drives, i.e. fuel cell trains.

hydrogen could arise depending on how things develop, e.g. in the area of heat production for the building sector or for other modes of transport not previously mentioned.

Due to the current relatively high cost of green hydrogen, this kind of volume should only to be assumed if enough cheap green hydrogen is available – e.g. from imports.[29] One point to bear in mind is that the different sectors in which hydrogen can be used sometimes have very different requirements. This affects the supply as well as transport and therefore the import options. For instance, most industrial processes (for example in metallurgy or the production of cement and glass) require gaseous hydrogen in order to integrate it in the production processes. In contrast, many mobility applications (for example in aviation, but also potentially in shipping and in heavy goods transport by road) require liquid hydrogen or hydrogen derivatives.

It should be noted that the use of green hydrogen entails manufacturing costs which are currently well above that of the costs for producing grey and blue hydrogen (see Figure 1).[30] For instance, in 2020 the manufacturing costs of green hydrogen in Germany were around 5.50 euros/kg or 165 euros/MWh. In comparison to this, in 2020 the costs for grey hydrogen produced from natural gas were around 1.50 euros/kg or 45 euros/MWh and for blue hydrogen around 2.10 euros/kg or 63 euros/MWh. Even if it can be assumed that these costs can be significantly reduced over the next few years or decades (forecasts here go from around 3.00-4.00 euros/kg in 2030 and 2.00-3.00 euros/kg in 2050), initially high costs for converting the national economy to the use of green hydrogen are to be expected. Added to the higher production costs is the fact that there is a limit to the potential quantity of cheap green hydrogen that can be produced in Germany and that, in the long term, we will therefore be reliant on imports which are in turn linked to additional costs.[31]

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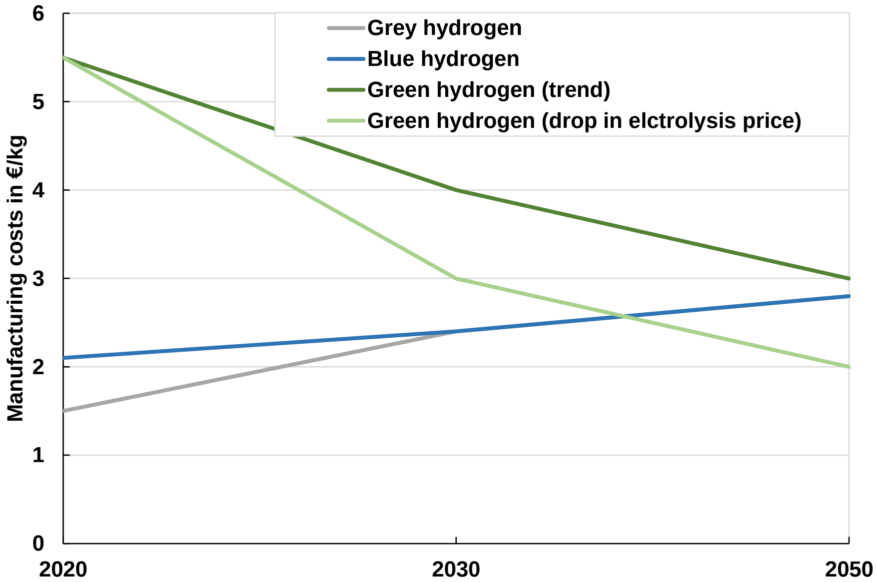
[29] Kopernikus-Projekt Ariadne: Deutschland auf dem Weg zur Klimaneutralität 2045. Szenarien und Pfade im Modellvergleich. Oktober 2021, Potsdam.

[30] On what is known as the "hydrogen colour theory", see the glossary of the National Hydrogen Strategy, June 2020, https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6.

[31] "Produktionskosten von Wasserstoff nach Wasserstofftyp in Deutschland im Jahr 2019 und Prognosen für die Jahre 2030 und 2050", Statista https://de.statista.com/statistik/daten/studie/1195863/umfrage/produktionskosten-von-wasserstoff-nach-wasserstofftyp-in-deutschland/, last accessed on 21.01.2022.

As there has been little green hydrogen available from commercial sources up to now, all the cost estimates in this strategy are associated with corresponding uncertainties – this applies in particular to the projections of future production costs. In order to guarantee an efficient and cost-effective hydrogen supply, there is a need for further research and development along the entire supply chain, i.e. from hydrogen generation via transport to temporary storage and recovery.



<u>Figure 1</u>: Forecast for manufacturing costs for green, blue and grey hydrogen in Germany for 2020, 2030 and 2050 (assumption for 2030: CO_2 price 100 €/t, natural gas price constant; assumption for 2050: CO_2 price 100 €/t, natural gas price constant, additional carbon import tax of 100 €/t CO_2).[32]

[32] "Produktionskosten von Wasserstoff nach Wasserstofftyp in Deutschland im Jahr 2019 und Prognosen für die Jahre 2030 und 2050", Statista https://de.statista.com/statistik/daten/studie/1195863/umfrage/produktionskosten-von-wasserstoff-nach-wasserstofftyp-in-deutschland/, last accessed on 21.01.2022.

4 Market ramp-up

As for the next few years green hydrogen will not be economically competitive compared to comparable energy carriers using grey hydrogen[33] or natural gas without state intervention, the market for green hydrogen cannot develop by relying on market forces alone. However, a market ramp-up is essential in order to be able to use the decarbonisation potential of green hydrogen for industry. This means it requires state support. This is provided in two main ways: first via investment support programmes that aim to promote innovative and future-oriented projects along the entire hydrogen value chain and, second, through state funding in areas where the market does not yet function adequately under the current circumstances. In both cases it is important that the funding is allocated for a fixed term in order to avoid lock-in effects.

There are investment support programmes at both the European and national level. At European level the main programme of note is the above-mentioned IPCEI Hydrogen programme that was begun in December 2020 by 22 EU member states and Norway. This programme supports projects that make a decisive contribution to implementing the National Hydrogen Strategy and to reaching the Paris Climate Goals. It allows funding of important highly innovative projects that are of overriding European interest, as an exception to the general prohibition on state aid[34] that applies in the EU. Funds for this come from the national budgets.[35] In Germany the hydrogen projects are coordinated by the Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie, BMWi) and the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Digitales und Verkehr, BMDV). At the point when this strategy was completed, both ministries had selected 62 major hydrogen projects for state funding

[33] See Chapter 3.
[34] See Article 107 of the Treaty on the Functioning of the European Union (TFEU).
[35] FAQ on the Important Project of Common European Interest (IPCEI), Federal Ministry for Economic Affairs and Energy, https://www.bmwi.de/Redaktion/DE/FAQ/IPCEI/faq-ipcei.html, last accessed on 21.01.2022.

out of more than 230 project outlines submitted.[36] Eight projects from Hamburg were selected for funding, covering the entire value chain from hydrogen production via distribution all the way to use in industry and the mobility sector.[37]

At national level there are also funding programmes for hydrogen projects along the entire value chain. One example is the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP), with which the Federal Ministry of Transport and Digital Infrastructure (BMDV) wants to achieve such goals as making hydrogen and fuel cell technology competitive in the transport sector and energy market by the middle of the next decade.[38] Another funding programme to mention is the Industrial Decarbonisation Programme by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, BMUV). This programme provides funding for projects in energy-intensive industries with the objective of reducing process-related greenhouse gas emissions, which cannot be avoided or only avoided with difficulty using the current state-of-the-art.[39] It is clear that the current funding scenario places particular emphasis on hydrogen applications. The FHH has therefore already suggested to the planning committees of the German Federal Government, that the existing funding framework – especially the 2016-2026 follow-up programme to the NIP (what is known as NIP II) – should focus not only on hydrogen in the context of drive technology, but also on the entire value chain, particularly transport.

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[36] "BMWi und BMVI bringen 62 Wasserstoff-Großprojekte auf den Weg", joint press release by the BMWi and BMVI, 28.05.2021, https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/05/20210528-bmwi-und-bmvi-bringen-wasserstoff-grossprojekte-auf-den-weg.html#:~:text=Die%20F%C3%B6rderung%20der%20deutschen%20Vorhaben%20erfolgt%20im%20Rahmen,Dezember%202020%20im%20Rahmen%20der%20deutschen%20EU%20, last accessed on 21.01.2022.

[37] "IPCEI-Wasserstoff-Prozess – Hamburg soll Hochburg der Wasserstoffwirtschaft im Norden werden", Press release, BWI, 28.05.2021, https://www.hamburg.de/pressearchiv-fhh/15103962/2021-05-28-bwi-bukea-wasserstoffwirtschaft/, last accessed on 21.01.2022.

[38] "Elektromobilität mit Wasserstoff/Brennstoffzelle", Bundesministerium für Verkehr und digitale Infrastruktur, https://www.bmvi.de/SharedDocs/DE/Artikel/G/elektromobilitaet-mit-wasserstoff.html, last accessed on 21.01.2022.

[39] "Dekarbonisierung in der Industrie", Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, https://www.bmu.de/programm/dekarbonisierung-in-der-industrie#:~:text=Das%20Bundesumweltministerium%20(BMU)%20f%C3%B6rdert%20Projekte,weitgehend%20und%20dauerhaft%20zu%20reduzieren, last accessed on 21.01.2022.

State funding must also be directed to those areas where the market does not function adequately in the current economic environment. A key area of this type is the trade in green hydrogen. It can be assumed that the purchase price for green hydrogen and its derivatives will lie above the achievable market price in Germany in the short term. This difference will be unlikely to enable an agreement between hydrogen producers and consumers for the foreseeable future, even if both sides are keen to get this trade rapidly underway. In view of this, the German Federal Government has announced that it will develop a pilot programme under the National Hydrogen Strategy for what are known as Carbon Contracts for Difference, which initially applies primarily to the steel and chemicals industries with process-related emissions. The German Federal Government is therefore guaranteeing to fund the difference between the actual mitigation costs arising from the more expensive greenhouse-gas-neutral technologies and the price of emission certificates for the CO_2 emissions from production. If in future the price of the emission certificates rises above the contractually regulated CO_2 price (and therefore the mitigation costs of the technology), the companies are obliged to pay the difference to the Federal Government. This type of programme should result in investment protection and incentives that favour climate protection projects, which in turn provide indirect incentives for the production of hydrogen, thus contributing to the market ramp-up of hydrogen technologies. If the pilot phase is successful, this instrument could also be used for other industrial sectors.

As part of the implementation of the National Hydrogen Strategy, the German Federal Government has also initiated the funding mechanism H2Global[40], based on the above-mentioned Contracts for Difference approach. The concept, developed under the lead of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in partnership with the Deutsche Wasserstoff- und Brennstoffzellen-Verband (DWV), the German Hydrogen and Fuel Cell Association, provides for the temporary offsetting of the difference between the purchase price (production plus transport costs) and the sales price (corresponding to at least the minimum market price for fossil hydrogen)

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[40] "H2Global – Die globale Energiewende gestalten", https://h2-global.de/, last accessed on 21.01.2022.

for green hydrogen and its derivatives through government funds. This will both stimulate the demand for green hydrogen in Germany and create an incentive for private investment in the necessary infrastructure, not only here in Germany but also in the producer countries outside the EU internal market. H2Global will be implemented via a civil law foundation that was established in June 2021 and was initially dependent on the Hamburg GFA Consulting Group (conversion to an independent foundation is planned to take place soon). The entire operational implementation of H2Global is being managed by Hamburg. The FHH is funding and supporting the process, particularly in view of the announcement in the current coalition agreement by the Government parties of their wish to develop H2Global in Europe and provide the corresponding financial support.[41]

Action point no. 2

European market ramp-up

Siting the initially dependent H2Global Foundation in Hamburg gave an important signal for Hamburg to become the future green hydrogen hub for Germany and Europe. The BWI will continue to provide funding and support for the activities of the H2Global Foundation. Consideration will also be given to implementing a similar funding instrument within Europe.

Action point no. 3

Funding opportunities for hydrogen projects

As long as the market ramp-up of a green hydrogen economy is still underway, companies and institutions will be largely dependent on state funding for their hydrogen importing projects. The BWI, along with the EEHH Cluster in partnership with hySOLUTIONS will demonstrate funding

[41] Coalition agreement 2021-2025 between the SPD, Bündnis 90 / Die Grünen and FDP, "Mehr Fortschritt wagen – Bündnis für Freiheit, Gerechtigkeit und Nachhaltigkeit", https://www.spd.de/koalitionsvertrag2021/, last accessed on 21.01.2022.

opportunities to companies in the Hamburg location and provide them with support in accessing these, thus pursuing proactive funding management.

5 Action areas for importing hydrogen

This chapter will present the most important action areas for the hydrogen imports required for the market ramp-up from the producing countries to Hamburg along the value chain.

5.1 International cooperation and partnerships

The German Hydrogen Action Plan 2021-2025 produced by the National Hydrogen Council[42] states that the hydrogen imports required to meet the domestic demand up to 2030 will come from Europe and, in the period after 2030, also from supply regions with a need for infrastructural development – in other words, from other regions of the world.[43] In order to guarantee that sufficient hydrogen can always be imported to Germany, both the German Federal Government and the FHH need to establish international cooperation agreements and partnerships with potential European and non-European hydrogen exporting countries.

The German Federal Government is therefore already involved in developing new international partnerships with countries that have high capacities or potential for hydrogen production due to the ready availability of renewable energies. For example, at the end of August 2021, a

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[42] The National Hydrogen Council was established by the Federal Government on 10 June 2020 in the context of approving the National Hydrogen Strategy. Its members, taken from industry, science and civil society, support the Federal Government in further detailing and implementing the National Hydrogen Strategy. The 2021-2025 German Hydrogen Action Plan is designed to fulfil this task. It summaries the discussions and analyses of the German National Hydrogen Council and draws conclusions for the next legislative period from its recommendations for action (cf. preface to the German Action Plan 2021-2025).

[43] "Wasserstoff Aktionsplan Deutschland 2021-2025", Nationaler Wasserstoffrat, July 2021, https://www.now-gmbh.de/wp-content/uploads/2021/06/NWR_Aktionsplan_Wasserstoff_2021-2025.pdf.

memorandum of understanding was signed with Namibia to develop a German-Namibian hydrogen partnership.[44] The Federal Government is also keen that existing energy partnerships with potential hydrogen exporting countries will increasingly involve hydrogen (derivatives) in the agreement. For instance, in mid-June 2021, an agreement was made with Australia as an ongoing commitment between the two countries for stronger cooperation on technical innovation, research and development, in order to develop a global hydrogen industry.[45] The basis for developing new partnerships or the transformation of existing ones will include international atlases of potential, which will be compiled and updated to record economically, environmentally and socially suitable sites for the production and export of green hydrogen.[46] An example of this is the "Potential atlas of green hydrogen" for western and southern Africa, presented in May 2021.[47] In all international partnerships, the Federal Government is dedicated to ensuring that the production of green hydrogen supports local markets and local decarbonisation. Employment effects should be created both in Germany and the partner countries and will in turn create long-term growth.[48]

Hamburg is also taking action to secure adequate imports of hydrogen in the international context and is largely following the actions of the Federal Government. As a traditional port city, Hamburg has always had excellent trade and economic relationships all over the world. These relationships

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44 "Karliczek: Deutschland und Namibia schließen Wasserstoff-Partnerschaft", Press release 172/2021, Bundesministerium für Bildung und Forschung, 25.08.2021, https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/2021/08/250821-Namibia-Wasserstoff.html, last accessed on 21.01.2022.

45 "Wasserstoff-Vereinbarung zwischen Deutschland und Australien", Press release 205, Die Bundesregierung, 13.06.2021, https://www.bundesregierung.de/breg-de/aktuelles/wasserstoff-vereinbarung-zwischen-deutschland-und-australien-1928188, last accessed on 21.01.2022.

46 "Wasserstoff Aktionsplan Deutschland 2021-2025", Nationaler Wasserstoffrat, July 2021, https://www.now-gmbh.de/wp-content/uploads/2021/06/NWR_Aktionsplan_Wasserstoff_2021-2025.pdf.

47 "Potenzialatlas Wasserstoff: Afrika könnte Energieversorger der Welt werden", Bundesministerium für Bildung und Forschung, 20.05.2021, https://www.bmbf.de/bmbf/de/home/_documents/potenzialatlas-wasserstoff-afr-ergieversorger-der-welt-werden.html, last accessed on 21.01.2022.

48 "Bekanntmachung der Förderrichtlinie für internationale Wasserstoffprojekte im Rahmen der Nationalen Wasserstoffstrategie und des Konjunkturprogramms: Corona-Folgen bekämpfen, Wohlstand sichern, Zukunftsfähigkeit stärken", Bundesministerium für Wirtschaft und Energie, Bundesministerium für Bildung und Forschung, BAnz AT 04.10.2021 B1.

with countries that already produce and export green hydrogen or will do so in future need to be developed or expanded as part of a successful import strategy. Hamburg has therefore decided to initially focus on prioritising import agreements with countries in Northern Europe, the MENA region and South America, which are clearly committed to renewably generated hydrogen. The aim is to establish reliable long-term relationships on an equal footing that bring benefits to both sides. This cooperation can for instance promote local value creation and economic stakeholders in the exporting countries as well as create jobs there.[49] Hamburg intends to promote this cooperation particularly via specific projects between partners from Hamburg and the exporting regions as well as via reciprocal memorandums of understanding. These political agreements are also intended to develop the supportive framework for expanding business relationships between manufacturers, buyers and the logistics companies involved in the transport and distribution. This will provide real support for the ramp-up of the import-based hydrogen economy, aligned to the business models of the partners. How this functions will be determined by the specific partnership. In addition to general issues such as certification, operational safety and knowledge sharing on particular technologies, for European partnerships dealing with the European legislation is a top priority, while for non-European partnerships a key issue is global target setting, for instance through H2Global. Compliance with the different dimensions of sustainability will also play an increasingly important role in future, both in the importing and exporting countries (see Section 5.6). In cooperation with the German Federal Government, Hamburg wishes to coordinate the relationships to the individual destinations based on this import strategy and the national import strategy. Discussions are currently underway with the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the German Federal Foreign Office, with the participation of the contracted service providers (Gesellschaft für Internationale Zusammenarbeit (GIZ), Guidehouse und adelphi). These are based on the idea that the various international contacts amongst the specified service providers as well as the EEHH Cluster on the Hamburg side should be combined, prioritised and looked at in a logical manner.

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[49] The National Hydrogen Strategy, June 2020, https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=6.

A number of Hamburg stakeholders are cooperating on the development and expansion of international partnerships with (potential) hydrogen exporting countries. The Staff Section for the Hydrogen Economy (SW) of the BWI in close consultation and partnership with the ministry responsible for energy policy (Ministry for Environment, Climate, Energy and Agriculture, BUKEA) and the Senate Chancellery are the lead stakeholders for coordinating the international hydrogen activities, for initiating and implementing the international import agreements and for initialising and supporting projects and business partnerships. Support is also provided to the Section by the EEHH Cluster. The Cluster provides additional competencies, experience and an existing and diverse network in the field of renewable energies. Along with the Staff Section for the Hydrogen Economy, it ensures a close link between government, industry and science. Additional stakeholders who contribute to raising the international visibility of the Hamburg hydrogen location are the external representations of the FHH and the HamburgAmbassadors. The HamburgAmbassadors are an international network of individuals with close links to the Hanseatic city, who live permanently abroad and hold an important position in industry, culture or society there. They strengthen international awareness of Hamburg and support the preparations for foreign activities through their contact networks.[50]

Action point no. 4

International partnerships

In order to develop sufficient production opportunities for green hydrogen abroad and guarantee adequate imports of hydrogen, the BWI in close cooperation with BUKEA and the Senate Chancellery as well as suitable companies will negotiate, prepare and conclude memorandums of understanding for green hydrogen with selected exporting countries, assisted by the relevant

[50] Internationales "HamburgAmbassadors", https://www.hamburg.de/international/ambassadors/, last accessed on 21.01.2022.

Federal Ministries. By the end of the legislative period it is planned to conclude qualified MoUs on the import of green hydrogen with at least six additional countries or regions.

5.2 Transporting hydrogen

Hydrogen can currently be transported in condensed gaseous (GH_2) or liquid (LH_2) form, using the energy carrier ammonia (NH_3) or methanol (MeOH) as well as using a liquid organic hydrogen carrier (LOHC).[51] The large-scale import of these energy carriers to Germany will take place mainly by ship and pipeline.[52] [53] Both of these types of transport need to be developed in parallel as, in terms of cost, they are suitable for different carrier media and transport distances (see Figure 2). Transporting gaseous hydrogen or ammonia via pipeline is the most cost-effective method up to a distance of around 1,500 kilometres, due to the construction costs of new hydrogen pipelines in comparison to that of special tankers and export and import terminals. For larger distances than this, the transport costs of LOHCs or liquefied ammonia by ship are lower. In comparison, transporting liquid hydrogen by ship incurs the highest costs. However, this last-mentioned transport method is cheaper for distances in excess of around 3,750 kilometres than gaseous transport via pipeline. Alternative transport options for importing hydrogen still need to be examined. In order to achieve the maximum reduction in greenhouse gas emissions by using green hydrogen, the entire supply chain needs to be developed to be as sustainable as possible. Besides the most efficient hydrogen production from renewable electricity, this also involves sustainable import (efficient conditioning, transport methods with the most climate neutral drives

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[51] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

[52] "Die Rolle der maritimen Wirtschaft bei der Etablierung einer deutschen Wasserstoffwirtschaft", Institut für Seeverkehrswirtschaft und Logistik, on behalf of the Deutsches Maritimes Zentrum e.V., 09.11.2021, https://www.dmz-maritim.de/wp-content/uploads/2021/11/Studie-Wasserstoff_2021.pdf.

[53] Expert report "H2-Erzeugung und Märkte Schleswig-Holstein“, compiled by the Umlaut Energy GmbH et al., commissioned by the Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung des Landes Schleswig-Holstein, December 2020.

possible), recovery (use of renewable energies where possible) and onward transport and distribution.

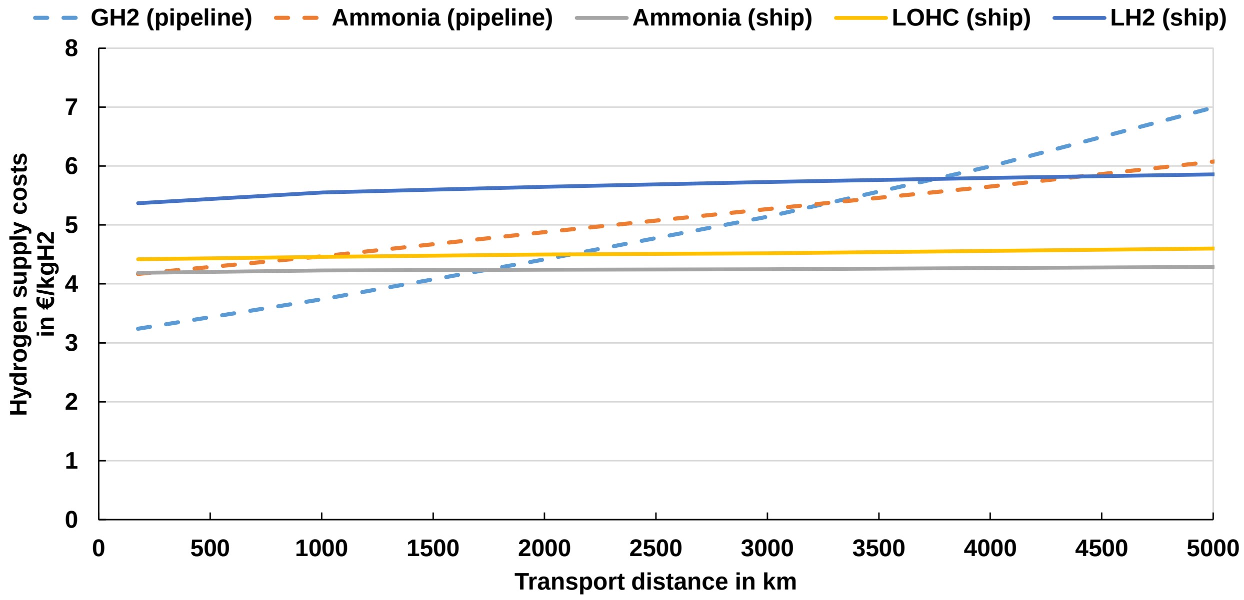

Figure 2: Supply costs of hydrogen (and its derivatives) by pipeline or ship up to a buyer. Hydrogen is transported in gaseous form by pipeline and in liquid form by ship. The costs stated in the figure cover all costs along the entire supply chain.[54]

> **Action point no. 5**
>
> **Import by rail**
>
> Importing hydrogen can in future take place not only by ship or pipeline but also via the existing rail network, for example by tank wagon. The BWI, in partnership with the Hamburg Port Authority (HPA) and the Hamburger Hafen und Logistik AG (HHLA) plus additional interested stakeholders from the sector will therefore report by 2023 as to what this potential type of rail import for hydrogen might look like and whether it is economically sound. This would rely largely

[54] From "The Future of Hydrogen: Seizing today's opportunities", International Energy Agency (IEA), 2019.

on the existing excellent rail infrastructure and inland logistics in the Port of Hamburg and the Hamburg Metropolitan Region.

5.3 Hydrogen transport by pipeline

Due to the advanced discussions with potential export countries geographically close to Hamburg, i.e. less than 1,500 km transport distance – such as Denmark, for example – it can be assumed that hydrogen imports will initially be largely made by pipeline. Transporting gaseous hydrogen by pipeline has the advantage that there is no need for any laborious and expensive reconversion processes, for example if the hydrogen is to be used in metallurgy.[55] In addition, no specific plant is needed for landing, unlike for imports by ship. In fact, after appropriate conversion of individual components, it can be directly connected to the existing natural gas pipeline network or to a dedicated hydrogen grid at the distribution level and via this to the industrial buyer and consumers. Less investment is needed in additional infrastructure in comparison to import by ship. Pipelines also allow the transport of large amounts of hydrogen and the operating costs are relatively low.

These advantages are offset by the fact that constructing a hydrogen transport pipeline requires a major effort in terms of planning and authorisation and takes a lot of time if it is not possible to make use of an existing natural gas infrastructure. Pipeline construction is very expensive, costing about two to three million euros per kilometre, although the investment costs reduce by 60 to 90 per cent if existing natural gas pipelines can be adapted (although in this case the material compatibility must be checked in advance). What is more, constructing a pipeline potentially

[55] Expert report "Hydrogen trade and the Port of Hamburg – Scoping the potential role of the Hamburg Port Authority in an international hydrogen import trade hub", compiled by Deloitte Touche Tohmatsu Limited on behalf of the HPA (December 2020).

involves a longer-term tie to the exporting country, as the high initial investments first have to amortise.[56]

Europe currently has hydrogen pipelines amounting to a total length of around 1,600 kilometres. However, these pipelines normally only transport the hydrogen over short distances between different industrial areas and do not link to any neighbouring countries[57] (for instance, the company Air Liquide operates a hydrogen pipeline in North Rhine-Westphalia that connects 14 production sites in the Ruhr region[58]). An initiative of eleven European transmission system operators would like to change this. In July 2020, under the European Hydrogen Backbone Initiative, they published plans for the gradual expansion of a Europe-wide hydrogen network that can be used both for the import of hydrogen and for onward transport of hydrogen imported by sea. In a first expansion phase of around 6,800 kilometres by 2030, the plan is for this network to connect potential import harbours, cavern storage and large industrial clusters as buyers in the Benelux countries and Northwest Germany. By 2040, all large European consumer centres will be successively connected with regions in North and South Europe that have particularly good conditions for manufacturing green hydrogen. This will require the hydrogen network to grow to a length of 22,900 kilometres and, besides North and South Europe, also link in generating regions in North Africa.[59] [60] Connecting Hamburg as a (potential) import harbour and consumer centre is planned

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56 Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

57 Expert report "H2-Erzeugung und Märkte Schleswig-Holstein", Compiled by Umlaut Energy GmbH et al., on behalf of the Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung des Landes Schleswig-Holstein, December 2020.

58 "Wasserstoffimporte – Bewertung der Realisierbarkeit von Wasserstoffimporten gemäß den Zielvorgaben der Nationalen Wasserstoffstrategie bis zum Jahr 2030", SCI4climate.NRW 2021, Fraunhofer Umsicht, Institut der Deutschen Wirtschaft, Wuppertal Institut, Gelsenkirchen, November 2021.

59 European Hydrogen Backbone – How a dedicated Hydrogen Infrastructure can be created, Enagas et al., July 2020, https://gasforclimate2050.eu/wp-content/uploads/2020/07/2020_European-Hydrogen-Backbone_Report.pdf.

60 Expert report "H2-Erzeugung und Märkte Schleswig-Holstein“, compiled by the Umlaut Energy GmbH et al., commissioned by the Ministerium für Energiewende, Landwirtschaft, Umwelt, Natur und Digitalisierung des Landes Schleswig-Holstein, December 2020.

by 2030 at the latest.[61] However, according to the network development plan Gas 2020-2030 by the German network operator (FNB), this connection could be achieved by 2025, due to the potentially high demand from the local industry.[62] [63]

Connecting Hamburg to a pan-European hydrogen network can be partly achieved through the gas network operator Gasunie's pipeline project HyPerLink. Through this project, Gasunie – in partnership with other national and international hydrogen projects (such as the Clean Hydrogen Coastline project by EWE et al.[64] and the expansion efforts of Energinet in Denmark) – is pursuing the vision of a networked, cross-border, Northwest European (i.e. running between the Netherlands, Germany and Denmark) hydrogen infrastructure.[65] The project will be implemented in three phases: HyPerLink I covers the construction of a hydrogen pipeline from the Netherlands via Bremen to Hamburg; HyPerLink II the construction of a pipeline between Wolfsburg and Bremen; and HyPerLink III the establishment of a pipeline from the German-Danish border via Schleswig-Holstein to Hamburg. At the Danish border there will be an interface to the planned network by Energinet which will run all the way to Esbjerg and Holsebro. Expansion phases I and II were chosen for the national pre-selection for the IPCEI Hydrogen for funding, but not HyPerLink III.

In addition to supporting the HyPerLink project I under the IPCEI Hydrogen, Hamburg will in future concentrate more on implementing the construction of HyPerLink III. The reason for this is that it is not clear whether enough green hydrogen to meet demand will reach Hamburg via the

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[61] European Hydrogen Backbone – How a dedicated Hydrogen Infrastructure can be created, Enagas et al., July 2020, https://gasforclimate2050.eu/wp-content/uploads/2020/07/2020_European-Hydrogen-Backbone_Report.pdf.

[62] Gas – Die Fernleitungsnetzbetreiber, Netzentwicklungsplan 2020, https://www.fnb-gas.de/netzentwicklungsplan/netzentwicklungsplaene/netzentwicklungsplan-2020/, last accessed on 21.01.2022.

[63] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

[64] "Clean Hydrogen Coastline als Grundstein für eine europäische Wasserstoffwirtschaft", ew-Magazin für die Energiewirtschaft, 24.03.2021, https://www.energie.de/ew/news-detailansicht/nsctrl/detail/News/clean-hydrogen-coastline-als-grundstein-fuer-eine-europaeische-wasserstoffwirtschaft, last accessed on 07.09.2021.

[65] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

HyPerLink I pipeline as the other regions in this network (such as the Netherlands and the federal states of North Rhine-Westphalia and Bremen) will potentially also have large requirements. Implementing HyPerLink III could reduce this competition. Furthermore, without this third expansion phase, there will be no connection from Denmark to the German and European hydrogen network, even though Denmark has a high export potential for green hydrogen and is determined to develop export markets. Denmark is therefore rapidly expanding offshore and onshore wind energy, hydrogen production and the necessary export infrastructure. HyPerLink III would enable Schleswig-Holstein and Hamburg to access this market. Based on a jointly commissioned prefeasibility study, the gas network operators Gasunie and Energinet have calculated that 10 to 25 per cent of the future German hydrogen demand can be met via this pipeline as early as 2025.[66] Another argument in favour of building HyPerLink III is that this pipeline will open up the enormous green hydrogen supply potential in Schleswig-Holstein (particularly the refinery in Heide[67]) for Hamburg and will increase the security of supply for Hamburg and Schleswig-Holstein.

In Hamburg itself the aim is to connect the national or European hydrogen networks to the hydrogen industry network south of the River Elbe planned by Gasnetz Hamburg GmbH under the project name HH-WIN. The aim of this project is to develop a hydrogen pipeline network that can meet a large proportion of the green hydrogen demand of the industrial enterprises south of the Elbe, both from piped and in future also marine imports as well as from production on site (such as from the large electrolyser planned on the site of the former Moorburg coal-fired power plant). The network is due to be developed in two phases: the first phase will initially create a hydrogen core network of around 60 kilometres, ideally by 2030. In the subsequent second phase, the

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[66] "Energinet and Gasunie publish pre-feasibility study on hydrogen infrastructure", Energinet, 27.04.2021, https://en.energinet.dk/Gas/Gas-news/2021/04/27/GUD-rapport, last accessed on 21.01.2022.

[67] The plan is to construct a scalable large electrolyser for producing green hydrogen at the Heide refinery in Schleswig-Holstein ("Umweltminister Albrecht erfährt Hintergründe über Großprojekt HySCALE100 in der Raffinerie Heide", 15.07.2021, https://www.heiderefinery.com/umweltminister-albrecht-erfaehrt-hintergruende-ueber-grossprojekt-hyscale100-in-der-raffinerie-heide, last accessed on 21.01.2022).

hydrogen network will then we expanded, largely through a gradual conversion of existing natural gas pipelines. The planned pipelines are currently designed for a capacity of around 3.3 GW hydrogen, which in future will enable the transport of around 100 tonnes of hydrogen per hour.[68]

Action point no. 6

HyPerLink III

The implementation of HyPerLink III and therefore a connection between Schleswig-Holstein and Hamburg to the Danish hydrogen network as well as connecting Hamburg to the huge green hydrogen supply potential in Schleswig-Holstein (Heide / Brunsbüttel) can only be progressed in close cooperation with Schleswig-Holstein. As part of a joint inter-state approach, Gasunie, the Schleswig-Holstein Netz AG, Gasnetz Hamburg and potential investors need to be involved at an early stage in order to secure the later operation of the pipeline as well as the connection to local pipeline projects, such as the Hamburg Hydrogen Industrial Network (HH-WIN). An inter-agency working group will be set up with Schleswig-Holstein at the start of 2022. The BWI and BUKEA will develop a sectoral policy standpoint jointly with Schleswig-Holstein. Following this, Hamburg and Schleswig-Holstein will undertake the political consultations with Denmark on implementing the pipeline project HyPerLink III. The aim of these consultations is to pave the way for concluding a joint Memorandum of Understanding by mid-2022, so initiating the necessary steps for implementing the project. The relevant German Federal ministries need to be included in this process.

[68] "HH-WIN: Hamburger Wasserstoff-Industrie-Netz", Gasnetz Hamburg, https://www.gasnetz-hamburg.de/fuer-die-zukunft/wasserstoff/hh-win?utm_campaign=B2Bbrand&utm_content=RSA&utm_medium=cpc&utm_source=bing&utm_term=phrase, last accessed on 21.01.2022.

5.4 Hydrogen transport by ship

Besides the export countries who can supply Germany with hydrogen by pipeline via Hamburg, there are other export countries with very good conditions for the cost-effective production of green hydrogen that are considerably further away than 1,500 kilometres. In these cases importing hydrogen by pipeline is not cost-effective with the current technology, but can only be done by ship.[69] So hydrogen transport by ship is also an important mode of transport and needs to be included in this strategy.[70]

5.4.1 Hydrogen carrier media[71]

When considering hydrogen transport by ship, one of the key questions is what form or which derivatives could be used for the marine import via the Port of Hamburg. The ministerial strategy on this issue is based on the strategic objectives and economic considerations of the Hamburg port industries.

According to the TÜV Nord, both methanol and gaseous compressed hydrogen are less suitable as carrier media for marine imports of hydrogen due to technical and climate policy reasons. This section therefore focusses on describing and evaluating the transport chains of liquid hydrogen, LOHC and ammonia. Importing green methanol or synthetic methane for direct use e.g. as a fuel for shipping or raw material for the chemicals industry can nevertheless still make sense, but is not part of this strategy. Which if any of the media will finally become established for import by ship will emerge from the discussions with the exporting countries and the consumers in Germany

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[69] See Figure 2.

[70] "Die Rolle der maritimen Wirtschaft bei der Etablierung einer deutschen Wasserstoffwirtschaft", Institut für Seeverkehrswirtschaft und Logistik, on behalf of the Deutsches Maritimes Zentrum e.V., 09.11.2021, https://www.dmz-maritim.de/wp-content/uploads/2021/11/Studie-Wasserstoff_2021.pdf.

[71] The statements in this section are largely based on the expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by the TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH on behalf of the FHH (2021).

and Europe over the next few years – no decision can be made by the ministry in advance under these circumstances.

Hydrogen transport using **liquid hydrogen** first requires the manufacturing country to have a plant where the gaseous hydrogen is liquefied, in other words cooled down to -253 °Celsius, as well as what are known as cryotanks[72] for temporary storage. The components are available and already tested. However, the amount of (electrical) energy required for liquefying the hydrogen is relatively high.[73]

The marine transport is carried out using vacuum insulated tanks in liquid gas carriers. At the moment there are no ships specifically designed for transporting liquid hydrogen; however, a prototype is already being trialled in Japan.[74] For the landing and onward transport of the liquid hydrogen, the Port of Hamburg needs a suitable terminal plus, if the hydrogen is to be transported onwards in liquid form, cryotanks and filling facilities. If the onward transport is to take place in gaseous form, an evaporation facility is also required.[75]

If hydrogen transport is carried out using **LOHC** then hydrogen is bound to a liquid organic carrier after production using what is known as a hydrogenation facility.[76] The loaded LOHC (known as LOHC+) can then be stored and transported using conventional petroleum infrastructure. Once the hydrogen arrives in the target port, what is known as a dehydrogenation facility[77] utilising

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[72] A cryotank is a tank where cryogenic gases or liquids can be stored. The tanks therefore require expensive insulation in order to minimise evaporation losses.

[73] "The Future of Hydrogen: Seizing today's opportunities", International Energy Agency (IEA), 2019.

[74] "Wasserstoffimporte – Bewertung der Realisierbarkeit von Wasserstoffimporten gemäß den Zielvorgaben der Nationalen Wasserstoffstrategie bis zum Jahr 2030", SCI4climate.NRW 2021, Fraunhofer Umsicht, Institut der Deutschen Wirtschaft, Wuppertal Institut, Gelsenkirchen, November 2021.

[75] For a detailed description of the transport chain when using liquid hydrogen as the carrier, see the expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH on behalf of FHH (2021), page 13 f. in the annex.

[76] A hydrogenation facility is one where the hydrogen is added to other chemical elements or compounds.

[77] In a dehydrogenation plant, the hydrogen is split from the carrier medium.

thermal energy is required for recovering the hydrogen. The hydrogen also has to be cleaned in accordance with the current state-of-the-art to remove impurities from the LOHC. An additional logistics chain is also required for returning the unloaded LOHC (known as LOHC-) to enable this to be recirculated. This technology is still new and is currently being tested. However, thanks to the high energy density and low cost of the storage technology, LOHC is already looking very suitable for marine transport.

No energy is required to hydrogenate the LOHC-: on the contrary, thermal energy is released, which can potentially be used in the exporting port for other purposes.[78] On the other hand, dehydrogenating the LOHC+ requires a relatively high input of thermal energy.[79] A range of organic liquids can be used as the carrier, with dibenzyltoluene, benzyltoluene and toluene currently being the most promising media. While they are virtually identical in terms of their storage capacity and handling, there are differences in terms of their potential dangers. Unlike pure hydrogen, all three liquids are toxic and harmful to water organisms if they escape into the biosphere.

If the hydrogen is transported as **ammonia**, the manufacturing country needs a plant for extracting nitrogen from air for the ammonia synthesis as well as an electrolyser for hydrogen production. Storage and marine transport then take place in liquid form at -33 degrees Celsius in LNG carriers. To recover the hydrogen, the Port of Hamburg then needs what is known as an ammonia cracker.[80] The technologies required for transporting ammonia are basically available and tested, as ammonia is already produced and transported in large quantities especially for the production of fertilisers. However, the technology for the large-scale application of the ammonia cracker

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[78] "Techno-ökonomische Analyse alternativer Wasserstoffinfrastruktur", Markus Eduard Reuß, Energie & Umwelt, Volume 467, 2019.
[79] "Techno-ökonomische Analyse alternativer Wasserstoffinfrastruktur", Markus Eduard Reuß, Energie & Umwelt, Volume 467, 2019.
[80] An ammonia cracker is a plant where ammonia is separated into its two components of nitrogen and gaseous hydrogen at temperatures above 600 degrees Celsius.

requires further development and testing. Liquefied ammonia exhibits a considerably higher hydrogen storage capacity than pure liquid hydrogen or LOHC. Moreover, the energy requirement for synthesising ammonia in the manufacturing country is relatively low. However, recovering the hydrogen by cracker again requires a high input of (thermal) energy.[81] It should also be noted that ammonia is highly toxic, corrosive and very hazardous to water, entailing strict requirements for handling along the entire transport chain.[82]

5.4.2 Landing and transshipment of the hydrogen carriers in the port

Both liquid hydrogen as well as LOHC and ammonia should in future be able to be landed, transshipped and put into interim storage quickly in the Port of Hamburg. This will require establishing one or several hydrogen import terminals. The next section examines the potential for this in the Port of Hamburg followed by a theoretical presentation of the legal framework for the landing, transshipment and intermediate storage of hydrogen carriers.

5.4.2.1 Hydrogen import terminal: construction potential

Specialised infrastructure is required for the landing, transshipment and temporary storage of liquid hydrogen, LOHC and ammonia as well as for the reconversion of the last two named substances into gaseous compressed hydrogen. As already described in Section 5.4.1, there is a need for plant such as cryotanks, crackers and dehydrogenation and purification facilities, depending on the specific substance. This specialised infrastructure is not currently present in Hamburg. In terms of the handling and onward transport of LOHC, there is already infrastructure available through the local oil industry.[83] However, when it comes to handling liquid hydrogen and

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[81] "The Future of Hydrogen: Seizing today's opportunities", International Energy Agency (IEA), 2019.

[82] For a detailed description of the transport chain for using ammonia as the carrier medium, see the expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH on behalf of FHH (2021), page 18 f. in the annex.

[83] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

ammonia, it should be borne in mind that the Port of Hamburg is not at present a transshipment location for gas tankers.

In order to enable large-scale imports, hydrogen import terminals would need to be constructed or existing plant adapted. In the Port of Hamburg there are various possible locations – subject to tests required for legal authorisation – including the port development site Steinwerder Süd, the Hohe Schaar with its existing tank farm and the area in the course of restructuring of the former Shell tank farm which is due to be developed into a Sustainable Energy Hub by the HPA, the site of the former Moorburg coal power plant and areas in Altenwerder. According to initial assessments, it is unlikely that there will be one central hydrogen import terminal. It is more likely that several import terminals will be used in parallel, as the market will in future require a range of hydrogen derivatives and these will require technically diverse import infrastructures.

Potential sites must be checked to determine whether they are capable of being approval. This requires clarification of the legal framework and responsibilities, an assessment of the risks and potential accidents for each site and substance, and the development of measures to minimise risk.[84] Besides the terminal layout and licensing issues, it is essential to incorporate factors such as landing options and distance rules (particularly w.r.t. sensitive uses such as residential areas). These studies are in part already being planned by companies who intend to carry out changes on their premises. The HPA will undertake this for the areas for which it is responsible.

5.4.2.2 Legal framework

A series of legal provisions, particularly the licensing laws, must be observed for landing, transshipment and temporary storage of liquid hydrogen, LOHC and ammonia in the Port of Hamburg. As at present there is no definite information either about the sites for establishing hydrogen import terminals or which hydrogen derivatives will be involved and what quantities will

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[84] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

require transshipment, the following description is abstract and can only serve as a starting point for the detailed examination of individual cases.

Licensing law

In the context of approving a hydrogen import terminal, in other words a plant where liquid hydrogen, LOHC or ammonia can be landed, transshipped and stored, the principal legislation to take into account is the Federal Immission Control Act (Bundes-Immissionsschutzgesetz) in combination with the Ordinance on Installations Requiring a Permit (Verordnung über genehmigungsbedürftige Anlagen, 4. BImSchV), the Hazardous Incident Ordinance (Störfallverordnung, 12. BImSchV) and the Federal Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung). Whether this regulatory system will actually be applicable and which obligations will affect the operators of these types of terminals will depend primarily on the size of the plants and the thresholds of the specific substance groups. The description that follows is therefore based on the assumption that the hydrogen import terminals in the Port of Hamburg will in future tranship over 30 or over 50 tonnes of liquid hydrogen, LOHC or ammonia, values corresponding to the current limit values in the applicable standards, above which special measures require to be taken.[85] It must be borne in mind that, besides the material transshipped, the quantities of materials in store and any other amounts arising elsewhere have to be included in the calculation of any limit values, so that the limit values could be exceeded even with lower transshipment quantities.

Potential hydrogen terminals in the Port of Hamburg are installations that would be covered by the Federal Immission Control Act (BImSchG). The installations covered by the BImSchG are premises, other fixed facilities, storage areas and also machines, devices and other mobile technical facilities. Plants that, due to their characteristics or operation, present an increased risk

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[85] See 4. BImSchV Annex 2, 12. BImSchV I.

are therefore subject to approval.[86] The Ordinance on Installations Requiring a Permit (4. BISchV) includes a comprehensive list of which types of installations are subject to approval.

Installations with the estimated transshipment quantities require a formal approval procedure in accordance with Section 10 BImSchG.[87] In particular, this procedure requires a public notification of the project, a public display of the application documentation and a public consultation.

Additional obligations from the BImSchG arise if the threshold of 30 tonnes for hydrogen is exceeded in accordance with Annex 2 of the 4. BImSchV. This refers to general operator obligations which ensue from Section 5 BImSchG, which serve to ensure a high level of protection for the environment. The main emphasis is on the precautions against and prevention of damaging environmental impacts, waste prevention and energy efficiency. These operator obligations apply for the construction and operation of the plant and may also apply to its shutdown.

The Major Accident Ordinance (Störfall-Verordnung, 12. BImSchV) must also be complied with if relevant. This applies to all facilities where specific quantities of hazardous substances are present or may occur.[88] The threshold for hydrogen according to Annex 1 of 12. BImSchV is 50 tonnes. The Major Accident Ordinance confers specific operator obligations on all operators of these facilities.

Under the assumed transshipment quantities[89] the terminal operators are subject both to basic obligations and also extended obligations.[90] The basic obligations, laid down in Sections 3 to 8 of

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[86] See Section 4, Clause 1.1 BImSchG.

[87] The approval procedure under Section 10 BImSchG applies to hydrogen and ammonia above a quantity threshold of 30 t.

[88] The relevant quantities are specified in Section 2.1 and 2.2 of 12. BImSchV in combination with Annex I.

[89] With reference to ammonia, extended operator obligations only apply above 200 tonnes.

[90] The operator obligations apply from 5 t (hydrogen) and 50 t (ammonia) and the extended operator obligations from 50 t (hydrogen) and 200 t (ammonia).

12. BImSchV, include measures to prevent accidents[91] or to limit their impact, including the obligation to establish an accident prevention plan and to inform the public about any possible hazards. The extended obligations, laid down in Sections 9 to 12 of 12. BImSchV, additionally require safety reports and emergency plans to be drawn up as well as an additional reporting duty to the public.

If the limit values are exceeded as specified in 12. BImSchV, then a separation rule must be maintained in accordance with Section 50 BImSchG. This specifies that a suitable safety distance must be kept between areas where accidents could occur and uses or objects that have been identified as requiring protection under Section 3 BImSchG. This safety distance must be determined by expert report and must be established and safeguarded in the plans. The minimum distance for, e.g. ammonia, is around 500 metres according to the Commission on Process Safety (Kommission für Anlagensicherheit).[92]

Moreover, under certain circumstances, setting up the hydrogen import terminal in the Port of Hamburg may require an Environmental Impact Assessment (EIA) to be carried out in accordance with the Federal Environmental Impact Assessment Act (UVPG). Whether an EIA is necessary is dependent on the specific substances being handled in the installation and the corresponding storage capacities.[93]

For the transshipment quantities that are forecast for the Port of Hamburg, the EIA obligation can be determined through a general preliminary examination of individual cases in accordance with

[91] According to Section 2.7 of the 12. BImSchV, an "accident" is an event that immediately or at some later time, within or outside the premises, leads to a serious hazard or to material damage in accordance with Annex VI Part 1 Item 1.4 of the 12. BImSchV.

[92] "Leitfaden – Empfehlungen zwischen Betriebsbereichen nach der Störfall-Verordnung und schutzbedürftigen Gebieten im Rahmen der Bauleitplanung – Umsetzung § 50 BImSchG" Kommission für Anlagensicherheit, https://www.kas-bmu.de/kas-leitfaeden-arbeits-und-vollzugshilfen.html?file=files/publikationen/KAS-Publikationen/Leitfaeden%2C%20Arbeits-%20und%20Vollzugshilfen/KAS_18.pdf&cid=1535, last accessed on 21.01.2022.

[93] Details are given in Section 1 UVPG in combination with Annexes 1 and 5.

Section 7, Clause 1.1 UVPG. A project with an assumed quantity of over 200,000 tonnes of hydrogen (or its derivatives) always requires an EIA in accordance with Annex 1 UVPG.

Other legal provisions

When handling hazardous substances in the Port of Hamburg there are additional regulations to observe, particularly the Hazardous Substances Ordinance (Gefahrstoffverordnung, GefStoffV), the Technical Rules for Hazardous Substances (Technischen Regeln für Gefahrstoffe, TRGS)[94] and the Industrial Safety Ordinance (Betriebssicherheitsverordnung (BetrSichV).[95] These provisions are aimed at protecting human beings and the environment from substance-related damage and injury. The main aims of the BetrSichV are to protect the health and safety of employees when using materials and tools, while the TRGS sets out the current state-of-the-art, industrial medicine and occupational hygiene, and established scientific evidence for activities with hazardous substances, drawn up by the committee for hazardous substances (Ausschuss für Gefahrstoffe, AGS).

In addition, regulations of particular importance for the Port of Hamburg are, for instance, provisions for handling hazardous goods within the Port of Hamburg, as specified in the Hazardous Goods and Fire Prevention Ordinance of the Port of Hamburg (Gefahrgut- und Brandschutzverordnung Hafen Hamburg, GGBVOHH). Regulations of particular relevance are those relating to registration and safety during transshipment.

If the infrastructure is financed in whole or in part by public funds, then an approval under state aid law is required in the form of a notification to the European Commission.

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[94] Technische Regeln für Gefahrstoffe (TRGS), https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/TRGS.html, last accessed on 21.01.2022.

[95] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

Action point no. 7

Import infrastructure in the Port of Hamburg

The BWI coordinates the development of the Port of Hamburg and therefore the import infrastructure for green hydrogen in the harbour area. On behalf of the BWI, the HPA will carry out an expert assessment of the relevant sites in their area of responsibility in terms of their technical suitability and whether they are likely to gain approval, and advance the development of import terminals in the Port of Hamburg. They will also provide support for the assessments carried out by potential private terminal operators.

Action point no. 8

Linking maritime stakeholders

The maritime economy is an important branch of industry in Hamburg and provides opportunities for large decarbonisation potentials. The BWI, along with the EEHH Cluster and the Maritime Cluster Northern Germany (MCN), therefore plans to organise and run a maritime workshop focussed on hydrogen in 2022. This event will discuss important issues relating to the implementation of the hydrogen import strategy for Hamburg. It is also hoped to stimulate networking amongst the participants and the ensuing formation of consortiums. The aim is to initiate practical projects and identify investors, for example for constructing tankers or for establishing import terminals. Project consortiums then have the opportunity to network within the two clusters, to get organised and to obtain support from the cluster management for putting their plans into action.

5.5 Onward transport of hydrogen

Different logistics chains can be considered for the onward transport of the green hydrogen arriving in Hamburg via pipeline or ship. After reconversion of the liquid hydrogen, LOHCs and ammonia to gaseous compressed hydrogen, onward transport can be carried out via pipeline network or, in small quantities and over short distances, in containers by road. Without being reconverted, the substances can be forwarded via waterway, road or rail. The quantity of each of the transportable types of hydrogen is largely dependent on the storage capacity per unit volume of the carrier medium. Transporting liquid hydrogen by truck and rail has already been tested: transporting LOHC can make use of the existing oil infrastructure.[96]

The different logistics chains incur different distribution costs, depending on the substance in question and the quantities and transport distance to the consumer (see Figure 4). For large quantities (over 500 t/day), the onward transport of gaseous compressed hydrogen via pipeline (400 mm diameter) is the most cost efficient method.[97] Onward transport by road as liquid hydrogen or ammonia also incurs relatively low costs. Onward transport of LOHC by road is only economically viable over short distances due to the low storage density and, like the onward transport of ammonia, incurs conversion costs at the consumer's location in addition to the transport costs.[98]

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[96] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).
[97] "The Future of Hydrogen: Seizing today's opportunities”, International Energy Agency (IEA), 2019.
[98] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).

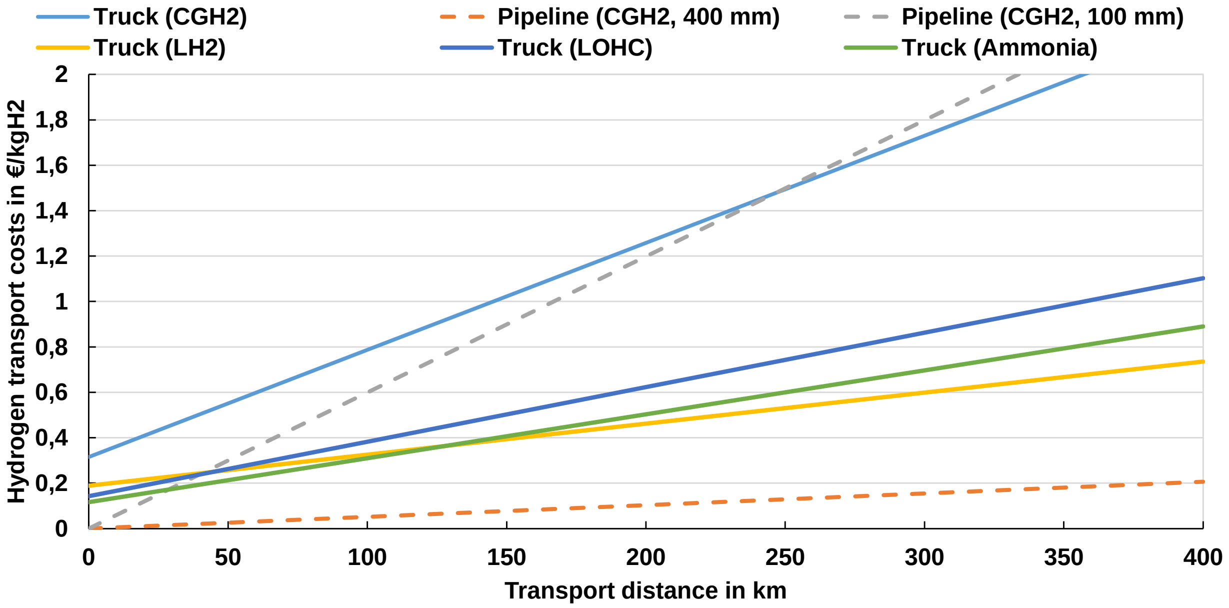

Figure 3: Comparison of distribution costs for hydrogen and its derivatives.[99]

In the long term, the onward transport of hydrogen in a compressed gaseous state via pipeline appears to be the most sensible, not merely due to the comparatively low distribution costs. Ultimately, all three of the substances looked at in greater detail in this strategy are suitable for this logistics chain (if the hydrogen is imported in liquid form then only vaporisation and compression are required; if it is imported using LOHC or ammonia, it requires to be reconverted, cleaned and compressed). It also enables transport to a large number of consumers over long distances up to an economically justifiable distance of around 1,500 kilometres.[100] However, during the market ramp-up phase of hydrogen applications and therefore low hydrogen demands, it can make sense for the onward transport to take place in liquid form or as ammonia via other,

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[99] Based on "Conditioned Hydrogen for a Green Hydrogen Supply for Heavy-Duty Vehicles in 2030 and 2050 – A Techno-economic Well-to-Tank Assessment of Various Supply Chains. Sens, L. et al. In: International Journal of Hydrogen Energy (2022), submitted”

[100] See Chapter 5.2.

non-pipeline-dependent methods. The only solution that seems impracticable is onward transport using LOHC. Ultimately, the conversion costs for using decentralised smaller plants are considerably higher and a logistics infrastructure has to be created for the return transport of the discharged LOHC (known as LOHC-) which is associated with further costs.[101]

5.6 Sustainability and certification

The imported hydrogen can in principal be produced using a range of energy sources. However, using hydrogen only provides a contribution to climate protection and to achieving the Paris Climate Goals if the CO_2 emissions or the entire greenhouse gas emissions connected to its production and use are less than those of the energy carriers that it replaces.[102] Added to this, the production and use must be environmentally, economically and socially sustainable.

In order to trace whether hydrogen has actually been produced sustainably, there is a need to formulate criteria for a sustainable production and use. These sustainability criteria have to be internationally compatible as imports will in future come both from EU countries and non-European ones. There is also a need for a system that certifies compliance with these sustainability criteria, so that (local) consumers can determine whether the hydrogen is actually green.

5.6.1 Sustainability criteria[103]

At a European level the goal is to privilege the production of hydrogen using so-called green energy in the EU single market. In this connection, a delegated act to the Renewable Energy Directive in the 2018 version (known as RED II) is currently being developed. This will define

[101] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).
[102] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).
[103] The comments in this section are based on the following documents: "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", position paper, Nationaler Wasserstoffrat, 29.10.2021 and expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)" compiled by the TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH on behalf of the FHH (2021).

criteria for the European Union that must be satisfied by electricity procurement in the EU so that the hydrogen produced with this electricity can qualify as "green". This will probably also apply to hydrogen manufactured outside the EU but to be sold in the EU single market as "green" hydrogen in accordance with the RED II classification.

In addition to these criteria related to use in the EU internal market, further sustainability criteria need to be developed for hydrogen manufactured in non-European countries, to be used as a standard component of international trade agreements on the import of green hydrogen to the EU. The aim should be to have internationally unified and binding definitions. Basically, the criteria should be designed so that the market ramp-up is not blocked from the start, which makes the selection and definition very difficult.

At present there are no uniformly defined sustainability criteria for hydrogen, either in Europe or elsewhere in the world. A range of widely differing sustainability criteria are under discussion, such as those produced by the National Hydrogen Council in its position paper "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten"[104] (sustainability criteria for import projects for renewable hydrogen and PtX products). These criteria can in general be divided into environmental, economic and social criteria.

In relation to environmental sustainability, the discussion centres on the criterion of "additionality" which states that electrolysis may only make use – in whole or in part – of electricity from renewable energy plants that have been newly constructed and are therefore additional to existing installations. One of the key arguments for this is that the production of green hydrogen should not extend the operation of environmentally damaging fossil energy sources in the future export countries, nor prevent these countries from achieving their own energy and environmental policy goals.[105] However, it must be ensured that the relevant regulatory provisions do not negatively

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[104] "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", Position paper, National Hydrogen Council, 29.10.2021.

[105] "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", Position paper, National Hydrogen Council, 29.10.2021.

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impact the profitability and therefore the feasibility of the electrolysis projects currently being planned. Another environmental sustainability criterion under discussion is the intensity of greenhouse gas emissions that arise along the entire value chain, from the raw materials to delivery to the end consumer. Experts also believe that avoiding local water shortages should be taken into consideration as an environmental sustainability criterion.[106] [107] Electrolysis involves splitting water into its components. In dry regions in particular, it is therefore important to ensure that the regional water supply is not impaired to an unreasonable degree, either for nature or for human beings.

In terms of social sustainability, discussions centre round the criterion of complying with labour standards, as many regions with plentiful sun and wind for the production of hydrogen lie in developing and emerging countries. In addition, other criteria being considered are the prohibition of child and forced labour, a guarantee of a healthy working environment and adequate pay as well as equal opportunities when creating new jobs. Discussions also cover the compliance with human rights, preserving the rights of indigenous peoples, observance of standards to combat corruption and the introduction of transparency mechanisms.

In terms of economic sustainability, the main focus is on creating jobs and the production or expansion of local value creation potential in the manufacturing countries. Contracts and profits that arise as part of hydrogen production should not merely go to foreign states or companies but must also benefit the local economy and local population.

In contrast to other sites, Hamburg has focussed solely on green hydrogen from early on. This applies both to hydrogen produced on site as well as to imported hydrogen. In order to achieve

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[106] Expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)", compiled by TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH commissioned by the FHH (2021).
[107] "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", Position paper, National Hydrogen Council, 29.10.2021.

the reduction targets in the Hamburg Climate Plan as well as the goals of the Paris Agreement, Hamburg is committed to the preferred treatment of green and sustainably produced hydrogen.

5.6.2 Certification[108]

In order to trace whether a tranche of green hydrogen has been produced and transported sustainably, there is a need for a comprehensive certification and compliance system along the whole hydrogen value chain. The first national certification systems are currently in place or under development. Examples are the certification system "Low Carbon Fuel Standard" from the American state of California[109] and the "Zero Carbon Certification Scheme" for renewable hydrogen, renewable ammonia, renewable metals and other hydrogen derivatives developed by the Australian Smart Energy Council with support from the German Energy Agency (Deutsche-Energie-Agentur).[110] At the European level there is also the CertifHy system. This covers Europe's first register for proof of origin of zero or low carbon dioxide hydrogen as well as a comparatively well-developed system for tracing the origin and production standards of hydrogen.[111] However, none of these certification systems provides a recognised standard for the whole of Europe or the world.

The success of the market ramp-up of green hydrogen and the development of a global market for it urgently requires an internationally applicable certification system coordinated in the EU.

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108 The statements in this section are based on the following documents: "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten" (Sustainability criteria for import projects of renewable hydrogen and PtX products - available in German only), Position paper, National Hydrogen Council, 29.10.2021 and the expert report "Technische Rahmenbedingungen für den Import von Wasserstoff (-derivaten)" (Technical conditions for the import of hydrogen and its derivatives - available in German only), compiled by the TÜV Nord EnSys GmbH & Co. KG, EE ENERGY ENGINEERS GmbH on behalf of the FHH (2021).

109 Low Carbon Fuel Standard, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard, last accessed on 21.01.2022.

110 Zero Carbon Certification Scheme, https://smartenergy.org.au/zero-carbon-certification-scheme/, last accessed on 21.01.2022.

111 CertifHy, https://www.certifhy.eu/, last accessed on 21.01.2022.

Without this and without a clearly accepted definition of green hydrogen, both future hydrogen producers and potential buyers and consumers lack the necessary planning and investment security. Accordingly, both the European Hydrogen Strategy[112] and the German Hydrogen Action Plan 2021-2025 produced by the National Hydrogen Council[113] as well as the above-mentioned position paper[114] demand an international certification system agreed by the EU. This should, where possible, be developed in dialogue with selected non-European exporting countries so that it can be implemented internationally.

Action point no. 9

Green hydrogen certification

Germany and the EU need to take a leading role in developing a suitable certification system agreed by the EU that functions across borders and is internationally compatible.[115] Hamburg is willing to take an active part in this process. The BWI, along with the BUKEA, the Hamburg Chamber of Commerce and the EEHH Cluster will strengthen the dialogue with representatives of companies involved in importing green hydrogen as well as the German Federal Government and the EU, and in 2022 will promote the sharing of ideas and development of a certification system through appropriate formats.

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[112] "A hydrogen strategy for a climate-neutral Europe", 08.07.2020, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

[113] "Wasserstoff Aktionsplan Deutschland 2021-2025", Nationaler Wasserstoffrat, July 2021, https://www.now-gmbh.de/wp-content/uploads/2021/06/NWR_Aktionsplan_Wasserstoff_2021-2025.pdf.

[114] "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", Position paper, National Hydrogen Council, 29.10.2021.

[115] "Nachhaltigkeitskriterien für Importprojekte von erneuerbarem Wasserstoff und PtX-Produkten", Position paper, National Hydrogen Council, 29.10.2021

6 Conclusion

Hamburg is ready to begin the transformation process towards a more climate-friendly future. Going beyond traditional transshipment and transport activities in the Port will enable environmental sustainability and the decarbonisation of industry nationally and internationally and add value by establishing a hydrogen-based value chain, thus securing jobs.

With the increasing use of green hydrogen, the hydrogen demand will rise to such a degree that both Hamburg as an industrial location and Germany as a business location will soon come to rely on imports of green hydrogen. Over the next few years, Hamburg will develop into a Green Hydrogen Hub Europe, partly due to its port, but also thanks to its excellent geographical situation and infrastructure, plus the fact that large consumers of hydrogen are concentrated directly in the port.

Hydrogen imports to Germany via Hamburg will take place in future via both pipeline and ship, and it is to be assumed that pipeline imports will be the focus in the short to medium term. In this context the activities of the European Hydrogen Backbone Initiative for setting up a Europe-wide hydrogen network are most welcome and Hamburg, in addition to supporting the HyPerLink I project within the IPCEI Hydrogen, will in future concentrate on implementing HyPerLink III. For the important long-term imports of hydrogen by ship through the Port of Hamburg, current assessments conclude that liquid hydrogen, LOHC and ammonia are the most suitable media. The Port of Hamburg will therefore require the creation of a flexible terminal infrastructure for imports. In terms of the onward transport of hydrogen from the Port of Hamburg to the local buyers as well as to Germany and Europe, the most practicable solution would appear to be via pipeline. It is fortunate that Hamburg already has its first project for establishing a local hydrogen distribution network – the HH-WIN project – which will enable buyers to be supplied with both imported and locally produced hydrogen. In the next few years this project needs to be completed by connecting Hamburg to the planned European hydrogen pipeline network.

During the market ramp-up phase in particular, companies who are involved in the hydrogen value chain are reliant on state funding to implement their activities. The companies therefore need to be directed to suitable funding options and given support to make use of these. The activities under the scope of H2Global will be particularly important in setting up a global hydrogen market. In relation to certifying green hydrogen, it is crucial to develop a suitable certification system agreed in the EU that functions across borders and is internationally compatible.

Hamburg has already taken the first steps in all the action areas for the import of hydrogen covered in this strategy paper. However, there is still considerable need for action to enable the necessary quantities of hydrogen imports from the rest of Europe and non-European countries via Hamburg to Germany and Europe, so as to guarantee the market ramp-up of the hydrogen economy. Only if the action points listed in this strategy and summarised again below are systematically implemented by the various stakeholders by the end of the current legislative period can Hamburg become established as the Green Hydrogen Hub for Germany and Europe.