Abstract

# Masterplan Hydrogen City of Cuxhaven

Agentur für Wirtschaftsförderung

Landkreis Cuxhaven

Stadt Cuxhaven

*Aktiv für die Wirtschaft!*

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## Summary
## of the Masterplan Hydrogen City of Cuxhaven

One of the most important goals and challenges for the coming years is to transform the economy from one based on fossil fuels and energy sources to one that is green and sustainable. This can only be achieved if ambitious targets are set to bring about the necessary change. It is precisely this change and transformation that the City of Cuxhaven is addressing and underlining with the claim „Climate and Energy Transition - City of Cuxhaven".

In order to define these goals and to identify the opportunities and possibilities, a plan, a vision and, last but not least, a guideline is needed to set an agenda that determines the daily course of action. This booklet is the „Masterplan Hydrogen City of Cuxhaven", which describes these tasks and at the same time identifies the opportunities. Not everything is immediately feasible and achievable, but it is identical with the daily thought of adapting the economy, and in particular the economy of Cuxhaven, to a „green economy" and the claim of sustainable economic activity.

We can and will succeed. Hydrogen will certainly make a decisive contribution. That is why it was important for us to draw up this „Masterplan Hydrogen City of Cuxhaven" and to hand it over to the economy as a guideline and working document.

The concrete recommendations for action contained in this document enable the economic partners to draw the necessary conclusions immediately and implement them in their daily activities. With this report I am pleased to be able to bring the city of Cuxhaven and its economy closer to the topic of hydrogen and to see hydrogen as an opportunity for change. This brochure is an abridged version of the „Masterplan Hydrogen City of Cuxhaven".

M. It

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# Hydrogen and its derivatives significance for the energy transition

### Why hydrogen?

Hydrogen ($H_2$) is the most abundant, smallest and lightest element in the universe. On Earth, the colourless and odourless gas is found almost exclusively in the combined state and is present in many compounds, such as water ($H_2O$). Using energy, hydrogen can be extracted from hydrogen-containing compounds and used in a wide range of applications.

- Burning hydrogen produces only water vapour and a small amount of nitrogen oxide.
- Hydrogen has the highest volumetric energy density per kilogram.
- Hydrogen can be stored and transported in a variety of ways.

Hydrogen will therefore play a key role in our future energy system based on renewable energies. By converting and storing intermittent green electricity in the form of hydrogen, it can be used downstream as needed.

In the future, green hydrogen can also be used to decarbonise sectors that are currently still dependent on fossil fuels and cannot be directly electrified. These include the steel and chemical industries, as well as parts of the transport and heating sectors. It is important to note that the aim is not to use hydrogen everywhere as a substitute for fossil fuels, but where fossil fuels cannot be replaced by direct use of electricity or where the hydrogen molecule is used as a raw material.

### How is hydrogen produced?

Hydrogen requires energy to produce. Today, hydrogen is mainly produced from natural gas by steam reforming. This releases carbon dioxide, which is harmful to the climate. The climate-neutral alternative is to produce hydrogen by electrolysis, i.e. splitting water into hydrogen and oxygen using electric current.
Various electrolysis processes have been established, which differ mainly in the electrolyte used, the operating temperature and the structure of the electrolysis cell, and are used depending on the application.

### What are the colours of hydrogen?

Hydrogen is a colourless gas, but it is classified according to its colour. The colour of the hydrogen tells you how it was produced: What energy source was used? Are greenhouse gases produced in the production process and, if so, how are they dealt with?

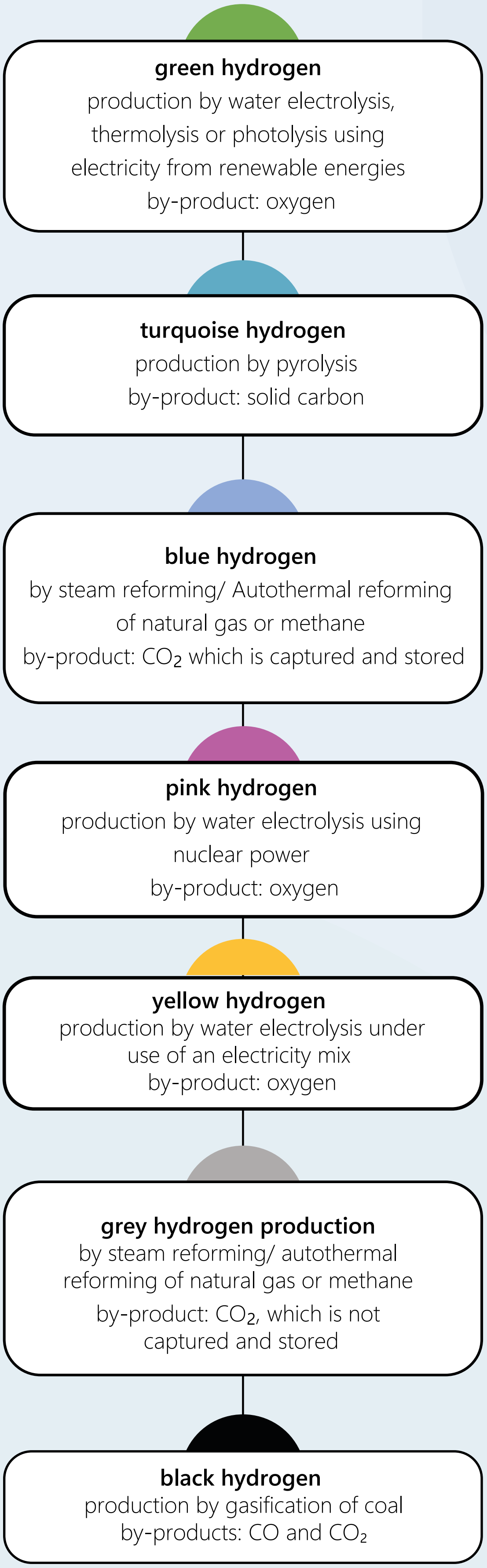



Figure 1: Production of hydrogen and colour coding; CO = carbon monoxide, $CO_2$ = carbon dioxide

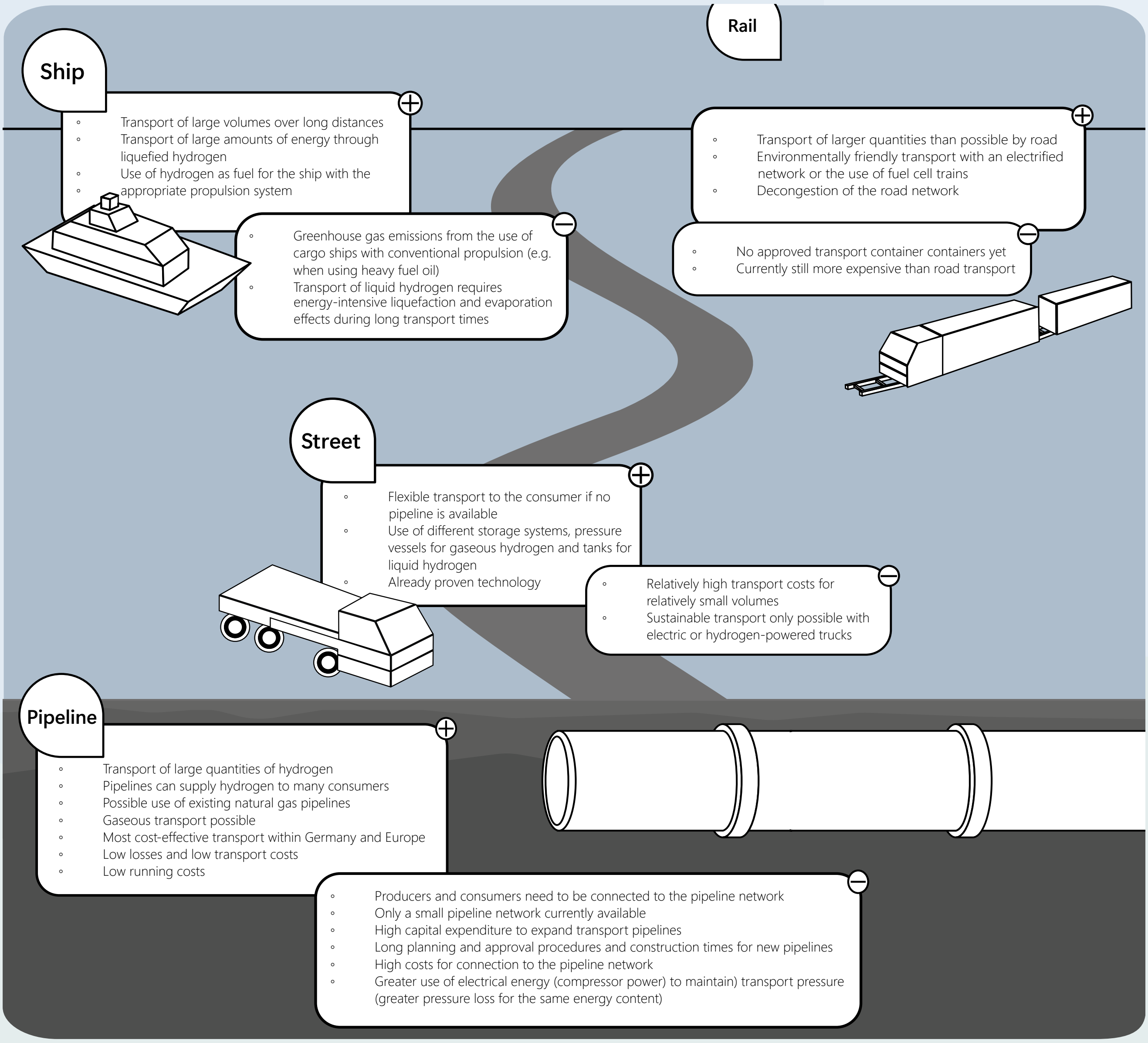



Figure 2: Advantages and disadvantages of the means of transport

## How is hydrogen stored and transported?

Since hydrogen is not always used at the point of production or immediately after production, storage and transport technologies are required. A distinction is made between physical and material storage. Physically, hydrogen can be stored in pressurised, liquid or cryogenic form by changing pressure and/or temperature. Pressure tanks, gas cylinders and cryogenic tanks are used for this purpose. For large quantities of hydrogen, underground storage facilities such as salt caverns can be used to store hydrogen under pressure. Currently, the most important commercial storage method, especially for end users, is the storage of hydrogen as a pressurised gas. Material-based forms of storage use a physical or chemical bond with another substance. Chemical bonding is the most important method. In this case, the hydrogen is transferred to another substance through a chemical reaction, which, for example, can be stored and transported at room temperature without pressure. These can be, for example, ammonia or methanol - very common chemicals used as feedstocks for various products. Liquid Organic Hydrogen Carriers (LOHC), which can absorb and release hydrogen through a chemical reaction, can also be used. The different methods of storing hydrogen offer different options for transporting it to the end user. Options include road, rail, ship or pipeline. At present, hydrogen is almost exclusively transported by road in pressurised containers. A look at the costs shows that there is no universal solution for hydrogen transport. The choice of transport solution depends on the final use of the hydrogen and the distance between producer and consumer. Figure 2 illustrates the advantages and disadvantages of the transport options.

## Where is hydrogen used?

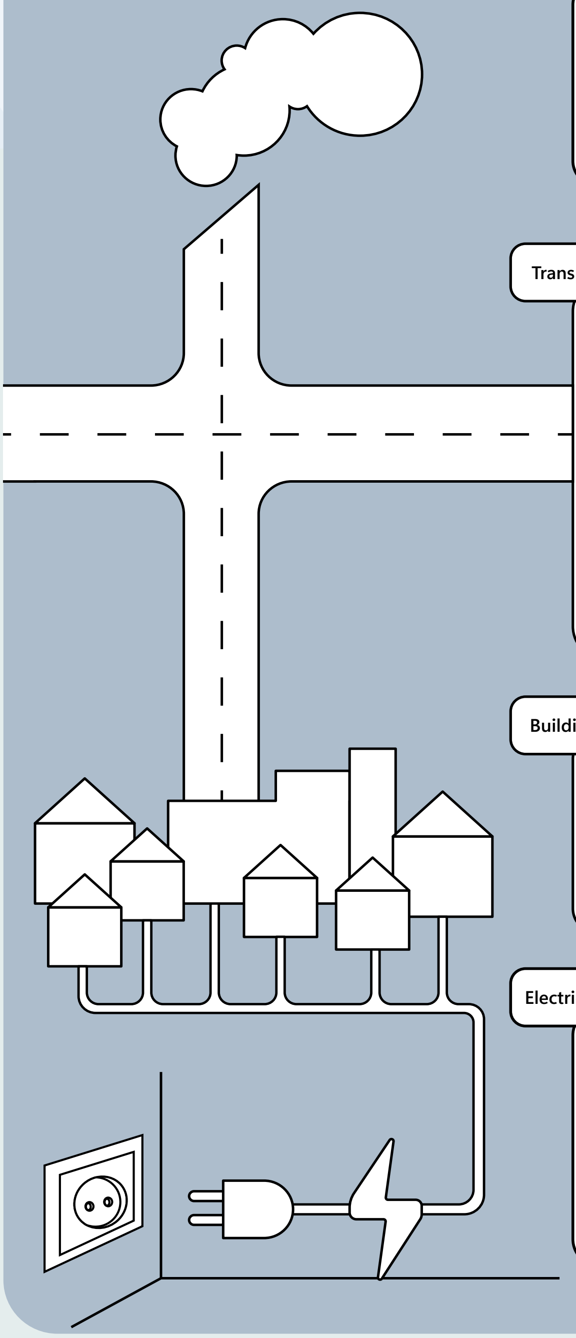
Hydrogen can be used in industry, transport, buildings and electricity. Today, hydrogen is already used in large quantities in refineries and the chemical industry - but mostly as grey hydrogen. This will increasingly change in the future. Green hydrogen can play an important role in all sectors for defossilisation and reduction of greenhouse gas emissions.

## What does hydrogen cost?

The three main factors influencing the production cost of green hydrogen are

- the cost of renewable electricity (electricity procurement costs)
- the capacity costs of the electrolysers, which include investment and financing costs
- and the capacity utilisation achieved.

The largest cost factor is the cost of purchasing electricity. In some cases, however, green hydrogen can already be cost-competitive with fossil hydrogen in ideal locations with the lowest costs for electricity from renewable energy sources. For the purchase of electricity for the production of green hydrogen, the criteria in the draft Delegated Act Red II are currently under discussion. As a guide to possible purchase prices for grey, blue and green hydrogen and green hydrogen, the Hydex price index from EBridge Consulting GmbH is available. Hydex is a cost-based price index. It reflects the average price of hydrogen ex steam reformer (with and without $CO_2$ storage) or electrolyser in Germany. The Hydex takes into account the short-term production costs of hydrogen. Capital costs are not included.



**Industrial sector**

- Currently, the most important single uses of hydrogen are oil refining (33%), ammonia production (27%), methanol production (11%) and steel production (3%).
- In the longer term, the steel industry and high-temperature heat generation offer enormous potential for the use of green hydrogen for decarbonisation.

**Transport sector**

- The most important use of hydrogen in the transport sector is seen in the fuel cell. Fuel cell vehicles are of particular interest for road transport.
- In rail transport, the world's first fleet of hydrogen-powered passenger trains will run between Buxtehude, Bremerhaven and Cuxhaven from the end of 2022
- At European level, the first regulatory approaches are in place to promote green electricity-based fuels and the use of clean and energy-efficient road vehicles (e.g. Clean Vehicle Directive).
- In shipping and aviation, where the use of alternative propulsion systems is limited, hydrogen-based fuels are the only decarbonisation option available at present.

**Building sector**

- The use of hydrogen as an energy source in the global building sector is currently very limited. Possible options include use in fuel cell heating systems or direct combustion instead of natural gas.
- However, for efficiency reasons, heating buildings with heat pumps or using waste heat from industrial processes is preferable.

**Electricity sector**

- In the electricity sector, hydrogen can help to bridge so-called dark slack periods.
- Power generation in gas turbines, for example, can bridge long periods without wind or solar power.
- In pperiods when more wind and solar power is produced than the grids can absorb, this power can be converted into hydrogen and fed into the natural gas grid or stored..

Figure 3: Cross-sector use of hydrogen

## Hydrogen demand in Germany and worldwide

In Germany, the National Hydrogen Strategy estimates the future demand for hydrogen at 90-110 TWh in 2030, compared to 55-60 TWh in 2020. Various studies predict a hydrogen demand of about 270 TWh in 2050. Of this, 31 % will be produced in Germany. The rest will be imported. To meet the growing demand, the coalition agreement calls for the construction of water electrolysis plants with a capacity of 10 GW by 2030, with a focus on domestic production. In the long term, the current consumption of grey hydrogen is to be replaced by $CO_2$-neutral hydrogen. European expansion targets include a total installed capacity of 40 GW by 2030. Some countries around the world have also announced ambitious expansion targets for water electrolysis. Chile plans to build a total capacity of 25 GW by 2030 (see Table 1). Australia has already announced several projects involving water electrolysis, and in some cases further processing into ammonia, to meet global demand. According to the IRENA study, in order to limit global warming to below 2 °C, 270 GW of total water electrolysis capacity would need to be installed worldwide by 2035. According to the McKinsey study „The Global Hydrogen Flows Perspective", a global demand of 660 million tonnes of hydrogen is expected by 2050 to achieve carbon neutrality.

## Overall importance of importing hydrogen

This showed that there is a high demand for hydrogenbased energy carriers in Germany, but also in Europe as a whole, as well as in Japan and South Korea as other important demand regions, cannot be met by domestic production alone. According to the McKinsey study, they will not be able to meet all their needs at competitive costs. In addition to building up a strong domestic production landscapae, imports, both from Europe and non-European countries, will play an important role. There could be different trade flows for hydrogen. On the one hand, pure hydrogen is a „neighbourhood" business. This means that the hydrogen can be sourced mainly domestically or via pipelines from neighbouring regions and then be shipped out. On the other hand, if these options are not available, hydrogen derivatives could be shipped globally; transport costs are low and production costs depend primarily on the availability of resources such as $CO_2$ and iron ore. Global trade in hydrogen and derivatives, including hydrogen carriers, ammonia, methanol, synthetic paraffin and green steel (using green hydrogen in its production), can significantly reduce the overall investment and system costs required. Investment in long-distance transport and trade accounts for less than 20 % of total investment, but is key to achieving significant savings.

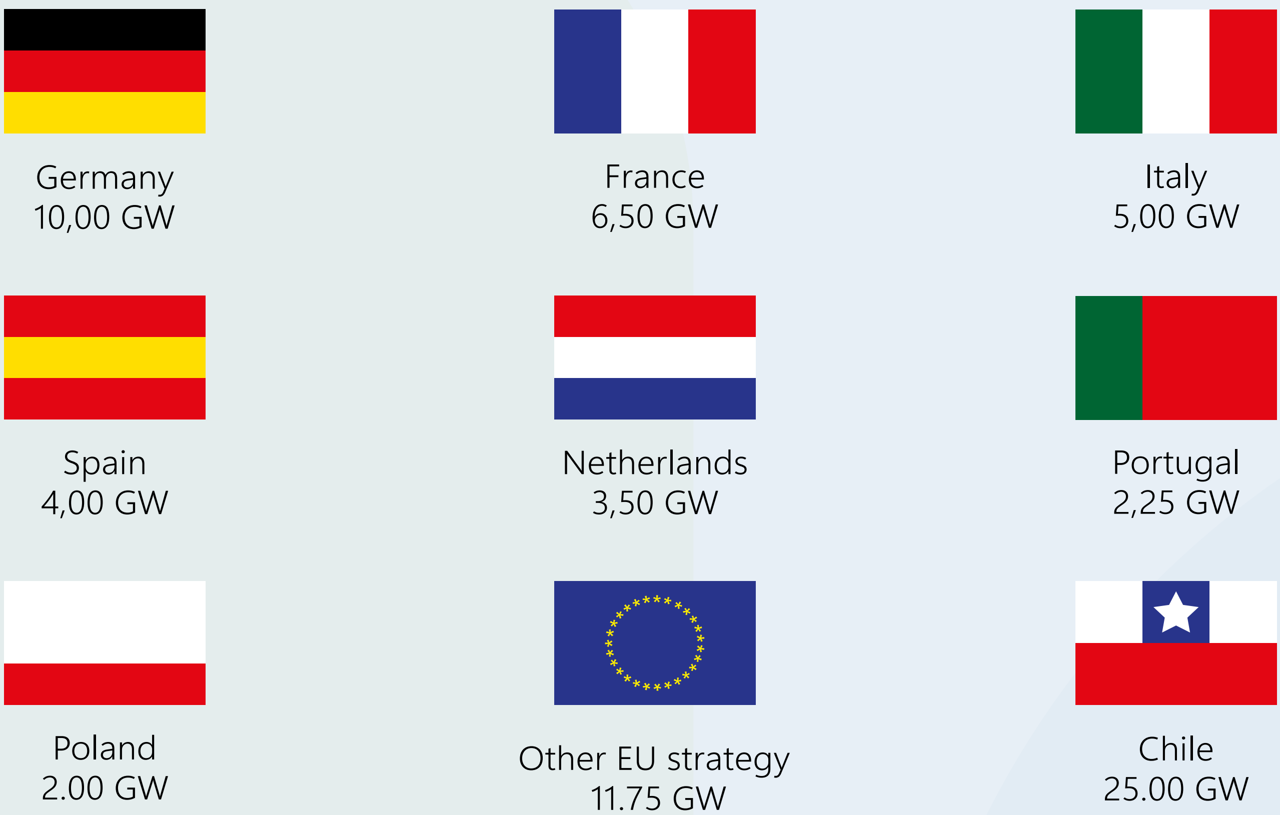



Figure 4: Explicit expansion targets in gigawatts (GW) for water electrolysis by 2030

# Cuxhaven: What are the prerequisites for a hydrogen economy?

In order to assess the hydrogen potential of Cuxhaven and the surrounding region, a site analysis is essential. Of particular interest are connections to the gas and electricity grids, as well as transport connections - both on land and by water.

| Energy source | Installed capacit | Attachments | In planning/ under construction |
|---|---|---|---|
| **Biomass** | 695 kW | 3 | 17 MW (wood-fired power |
| **Other gases** | 1,058 kW | 3 | 20 kW (1 plant) |
| **Natural gas** | 895 kW | 49 | - |
| **Solar radiation energy** | 11,773 kW | 766 | 151 kW (23 plants) |
| **Wind** | 67,160 kW | 25 | - |
| **Total** | **81,581 kW** | | **17,171 kW** |

Table 1: Installed plants (without storage) according to the market master data register rounded to kW (as of 01.12.2022)

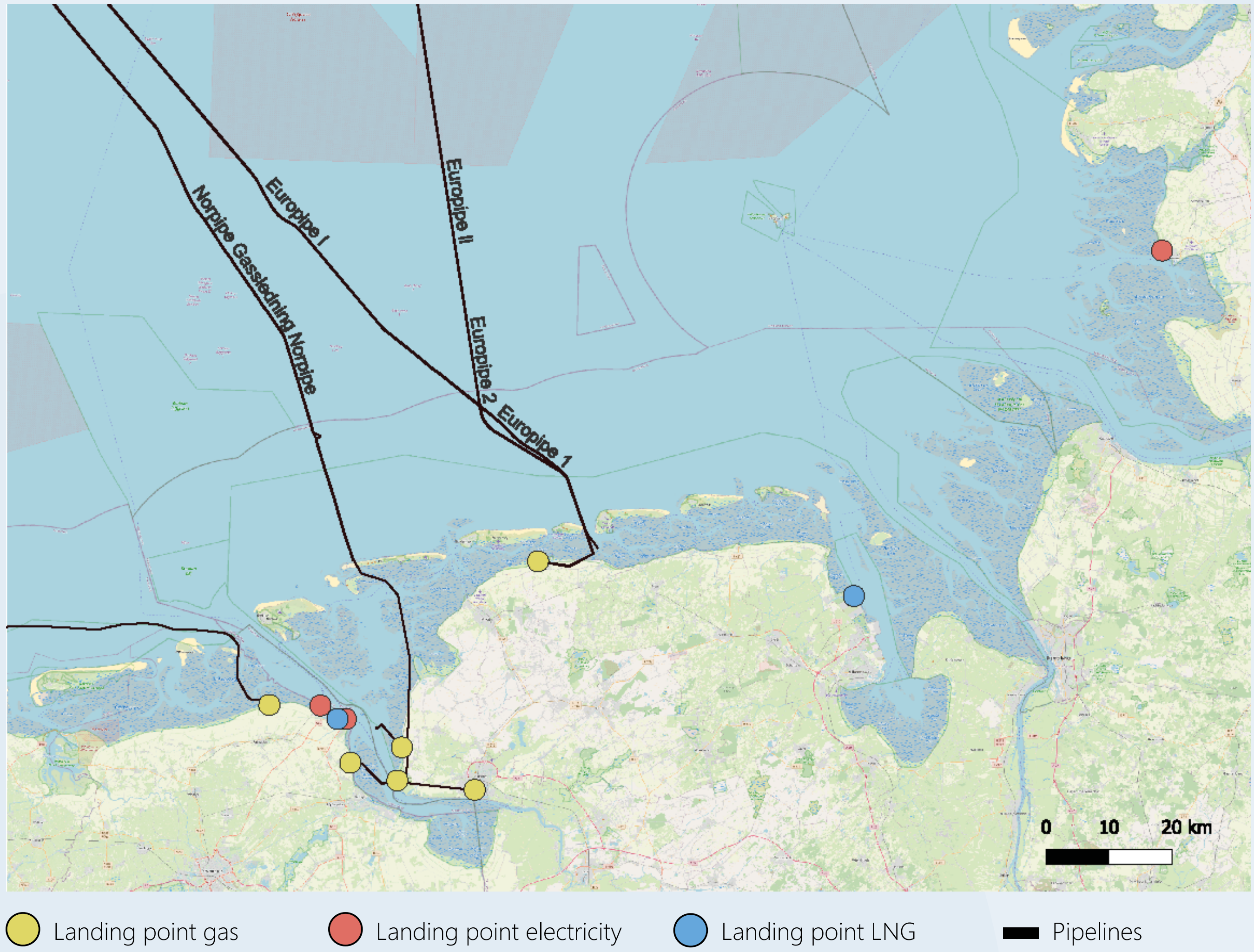



Figure 5: Pipelines in the North Sea

## Electricity infrastructure

The local electricity supply in Cuxhaven has a very high share of renewable energy - 97.6 % (approx. 80 MW) of the local electricity supply is generated from renewable sources. Only 2.4 % (approx. 2 MW) comes from fossil fuels. Within the German electricity grid, Cuxhaven is connected to a high-voltage line (110 kV), which offers opportunities for sector coupling. At present, if the grid cannot absorb any more energy when there is a high level of input from wind or photovoltaic plants, the operators shut down their plants. In the future, this „surplus" electricity could be increasingly used to produce hydrogen. This would help to increase the use of green electricity in the energy system and significantly reduce the number of renewable energy plant shutdowns.

## Gas infrastructure and gas storage

EWE Netz GmbH is currently the operator of the local gas supply network. The network is fed by a gas pipeline (ETL-69) operated by Gasunie Deutschland Transport Services GmbH. Apart from this status quo, it is interesting to ask to what extent Cuxhaven and the region will be taken into account in future network planning: Looking at the future onshore connection, it quickly becomes clear that no connection to the „European Hydrogen Backbone" network is currently planned. According to the vision of the European Hydrogen Backbone, five hydrogen supply and import corridors could be created by 2030, connecting industrial clusters, ports and hydrogen valleys with hydrogen supply regions across Europe. The hydrogen infrastructure could then be developed into a pan-European network of almost 53,000 km by 2040, largely based on the re-use of existing natural gas infrastructure.

As can be seen in Figure 5, there are no offshore natural gas pipelines in and around Cuxhaven. The nearest pipelines are at Dornum (Europipe I/II) and Emden (Nordpipe). The construction of a dedicated hydrogen sea pipeline called AquaDuctus is planned for 2035. This is part of the AquaVentus project family and is designed to transport one million tonnes of hydrogen per year. According to the plans, the hydrogen green produced by the offshore wind farms in the so called ducks bill will pass the island of Heligoland and then land on the northern shore of the Elbe estuary.

If hydrogen is landed or imported in Cuxhaven in the future, cavern storage facilities offer an option for storing gaseous hydrogen. A total of six underground salt and clay rock formations have been identified in the region, which have been considered and analysed in the past, for example for the disposal of nuclear waste. A specific assessment of their suitability for hydrogen storage would be required.

## Transport infrastructure

Transport infrastructure is an essential component for the development of the city of Cuxhaven and the surrounding region. The use of hydrogen in fuel cell vehicles can increasingly decarbonise mobility. In addition, the players in the transport infrastructure are relevant customers for hydrogen. In particular, heavy goods vehicles, public transport, ferry connections and the diesel locomotives still in use, as well as the port infrastructure, could be converted to fuel cell technology.

Cuxhaven is linked to Bremerhaven and Bremen via the A27 motorway and to Stade and Hamburg via the B73. Many towns from Hamburg to Stade and Bremerhaven are served by urban and suburban services. For a number of years, the latest models from bus manufacturers with various alternative propulsion systems (hybrid, hydrogen, fuel cell, rechargeable battery) have been tested at the various local public transport sites. In the next few years, KVG Stade GmbH & Co KG plans to gradually purchase vehicles with alternative drive systems. On the existing rail network between Buxtehude, Bremerhaven and Cuxhaven, 14 hydrogen-powered passenger trains have already been in operation since the end of 2022. Other non-electrified lines could offer further potential for use. As part of the Hyways for Future funding project, the Cuxhaven Economic Development Agency has signed letters of intent with around 18 partners for the purchase of 60 fuel cell vehicles to activate the hydrogen value chain in the mobility sector. For example, Cuxhaven's technical services will replace a conventional refuse collection vehicle with a fuel cell vehicle in the future. The fire brigade is also planning to switch to fuel cell vehicles. No port logistics projects are currently planned in Cuxhaven. However, Cuxport GmbH, a subsidiary of Hamburger Hafen und Logistik AG, is part of the Clean Ports & Logistics network, in which the technical analysis of the conversion of port forklift trucks is being driven forward.

## Port infrastructure

Ports are important building blocks of a hydrogen economy - both for potential imports and for the transport and transfer of the molecule from offshore production facilities to land. The port of Cuxhaven is one of the largest multipurpose ports in Germany and is located on the southern bank of the Elbe estuary.

An important part of the port and the logistics chain for wind turbines is the German Offshore Industry Centre Cuxhaven (DOIZ). This is where all the necessary components for offshore wind turbines are built and shipped. As a strategically located deepwater port, it is equipped for the loading of offshore wind turbines. In a future offshore hydrogen economy, Cuxhaven could therefore act as a hub for the development of a possible offshore hydrogen value chain. There is currently no oil or gas terminal available or planned that could be converted in the future, so importing hydrogen is currently only possible by container.

The port is currently being expanded and, when completed, will have a continuous quay length of almost four kilometres and nine berths. Recently, the state of Lower Saxony pledged an initial €100 million subsidy for the port expansion. This will increase Cuxhaven's potential as a possible offshore wind energy location. Strengthening the location and expanding the local infrastructure is a basic building block for attracting further companies, for example in the field of component production for offshore wind energy as well as in the field of operation and maintenance. To the east of the port, there are still vacant industrial sites available for new companies.

## Hydrogen projects

Cuxhaven and its stakeholders have been involved in various hydrogen projects for several years. These projects include the offshore production of hydrogen, the use of hydrogen-powered trains and buses, and qualification and training issues. The most important projects are briefly described in Figure 6.

2016 2035

| | | |
|---|---|---|
| **Hydrogen trains in local passenger transport (Coradia iLint)** | Use of hydrogen-powered trains on the Cuxhaven, Bremerhaven, Bremervörde and Buxtehude line and construction of a hydrogen refuelling station to supply the trains in Bremervörde. | **2016 – 2022** |
| **OffsH2ore** | Concept study for offshore hydrogen production using offshore wind energy as an isolated solution | **2020 – 2022** |
| **Hydrogen mobility through biowaste (WaMoBa)** | Collection of bio-waste by fuel cell vehicles and production of biogas, reforming the biogas into hydrogen and supplying the collection and logistics vehicles from a hydrogen filling station | **2020 – 2023** |
| **Hyways for Future** | Activation of the hydrogen value chain in the mobility sector in Northwest Germany | **2020 – 2024** |
| **AquaVentus** | 10 gigawatts of green hydrogen generation capacity from offshore wind energy and production of 1 million tonnes of green hydrogen using electrolysis technology plus transport on land by 2035 | **2020 – 2035** |
| **H2Skills** | Identification of training needs in the hydrogen economy | **2021 – 2023** |
| **H2Move** | Development of a hydrogen infrastructure in Cuxhaven:<br>Construction of a 2 MW electrolyser (expansion to 20 MW)<br>Conversion of the Mittelplate supply fleet to hydrogen hybrid propulsion<br>Construction of a petrol station for landside use | **2022 – 2024** |
| **Energy Island** | Feasibility study for the construction of an energy island in the Elbe estuary | **not specified** |

Figure 6: Hydrogen projects in and around Cuxhaven

# Cuxhaven: First steps towards a hydrogen economy

Following the detailed site and hydrogen market analysis of the city of Cuxhaven and the region, the results are summarised in a SWOT (strengths, weaknesses, opportunities and threats) analysis (see Figure 7). In this study, the strengths and weaknesses of the city of Cuxhaven in relation to a regional hydrogen economy were highlighted and the opportunities and threats were compared in the context of an external analysis. Taking into account the results of the SWOT analysis, five recommendations for action were made for the city of Cuxhaven and the region, and initial measures for dealing with hydrogen were formulated.1. Ensure political support in the region

The amended Renewable Energy Sources Act came into force on 1 January 2023. In particular, offshore wind energy is to be expanded to 30 GW by 2030 and to at least 70 GW by 2045. In addition, the German government is promoting innovative concepts for combining renewable energy generation with local hydrogen-based electricity storage. Against this background, the expansion of offshore wind energy and local hydrogen production is a great opportunity for Cuxhaven, as the region's strengths lie in its high share of renewable energy and its deep-water port, which can handle the cargo of offshore wind projects. The state government of Lower Saxony is also committed to the North German Hydrogen Strategy and, together with the federal government, is currently making €2.3 billion available for hydrogen projects. The course has thus been set for a future green hydrogen economy. For further steps, political support „on the ground" is an important success factor. This is because projects and programmes in which all the players involved are pulling in the same direction and pursuing the same goals are much easier and more resource-efficient to implement.

**First measures:**

- Establish a shared vision with local stakeholders and policy makers
- Provide human resources, e.g. a hydrogen site manager
- Explore the possibility of policy incentives for companies in the region

**2. Further consolidation and expansion of the German Offshore Industrial Centre and the port as a basic building block**

The port of Cuxhaven and the associated DOIZ, with its existing infrastructure and business community, offer an optimal starting point for the offshore industry: as one of Germany's largest multi-purpose ports on the southern bank of the Elbe estuary, it is strategically well placed for the import and export of the required components. The deep-water port has the infrastructural advantages of a trimodal multipurpose terminal, including container and RoRo handling with rail and road connections. Other terminals are available for bulk and breakbulk, as well as for the handling and storage of offshore wind project cargo and heavy lift. Cuxhaven thus has a well-developed port infrastructure with berths for deep-draft vessels he announcement by the Lower Saxony state government that it will provide €100 million for the expansion of the port underlines the importance of the location. The expansion of the area will provide planning security for future projects for the resident companies and is a positive signal for new (industrial) settlements. By attracting more companies to the area, synergies (e.g. short production routes) and shared resources (e.g. common logistics infrastructure) can be exploited. It is conceivable, for example, that the range of companies could be expanded to include manufacturers of electrolysers for coupling with offshore wind turbines for the production of green hydrogen at sea. The locations must therefore be further strengthened and the expansion of the infrastructure must be promoted as a basic building block for the establishment of further companies.

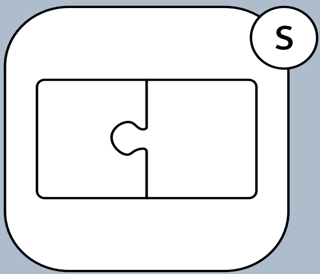
**First measures:**

- Expansion of the local infrastructure - development and connection of the plots of land
- Establishment of contacts with local companies in order to identify further needs
- Establishment of a round table between electricity producers, grid operators and large-scale consumers or prospective hydrogen producers
- Continuation of the active approach incl. advertising measures of further supplier companies in the offshore sector
- Examination of political incentives for settlement
- Strengthening the training of skilled workers on site and establishing a knowledge centre together with the Cuxhaven Vocational School, the Elsfleth University of Applied Sciences, the Fraunhofer IFAM and the Chamber of Industry and Commerce

**3. Mobility as a driver for regional hydrogen economy in Cuxhaven**

In addition to the local supply of hydrogen, the purchase of hydrogen is crucial to the development of the hydrogen economy in Cuxhaven. The public transport and mobility sector in particular can provide initial planning certainty and at the same time make a significant contribution to reducing greenhouse gas emissions. This includes the conversion of public transport to hydrogen-powered vehicles, the use of more hydrogen trains on non-electrified sections of line, and the supply of the first ferries with compressed hydrogen to drive decarbonisation on the water side as well. To supply the DOIZ with materials, parts and modules for production, an initial conversion of logistics to hydrogen-powered vehicles and carbon-neutral logistics could take place.

The construction of a 2 MW electrolyser with an attached refuelling station for heavy-duty vehicles will ensure the initial market ramp-up. The construction of the necessary hydrogen infrastructure provides an incentive to convert other parts of the mobility sector. In the medium term, if the market situation is good, a scale-up to 20 MW hydrogen production capacity is envisaged. At the same time, the conversion of the Mittelplate supply fleet to hydrogen hybrid propulsion creates another pilot project in the maritime sector that could serve as a model to motivate other market participants to convert their shipping flee.

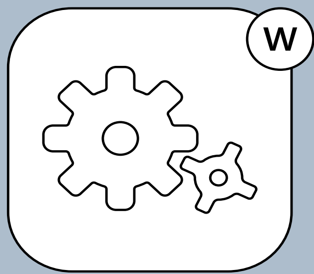


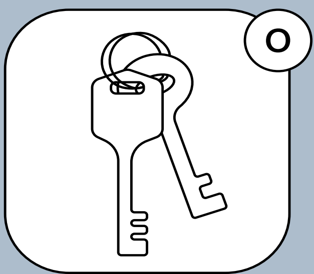

## Strengths

- At around 97 %, a high proportion of locally installed capacity for electricity generation from renewable energies
- Good transport links to Cuxhaven as well as well-developed public transport and rail connections
- Natural deposits of salt and clay rock in the region
- Deep-water port with developed port infrastructure and a developed industrial area near the port with additional open space
- German Offshore Industry Centre (DOIZ)
- Strengthening of hydrogen mobility and the entire value chain in the north-west through Hyways for Future (BMDV funding programme)
- Construction of a land-based hydrogen refuelling station for heavy goods vehicles (H2Move project)
- Many interested and in some cases already active local hydrogen stakeholders

## Weaknesses

- No connection to the extra-high voltage grid and no offshore submarine cable to convert electricity into hydrogen and downstream products on land.
- No connection of Cuxhaven to the hydrogen network ("European Backbone") planned by 2050 in the current network development plan.
- No plans for terminals to receive ship-borne natural gas that could later be converted to hydrogen.
- There is only a small heat network in Cuxhaven which could use the waste heat from hydrogen production




## Opportunities

- Use of natural rock formations for the construction of large volume hydrogen storage caverns
- Conversion of buses and trains to hydrogen power
- Attracting companies in the value chain of the offshore hydrogen economy
- Encouraging other market players to convert their logistics or production to hydrogen through imitation effects to hydrogen through imitation effects
- Medium term: Hydrogen production at sea and onshore in Cuxhaven and green hydrogen imports by ship
- Establishment of a bunkering station for green marine fuels and thus green shipping
- Further processing of hydrogen into other energy carriers such as ammonia or methanol

## Threats

- No landfall of hydrogen via pipelines or imports
- Ocean shipping prefers a port other than Cuxhaven for bunkering alternative energy sources

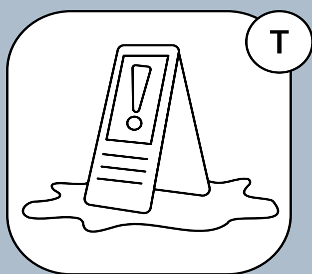



Figure 7: SWOT analysis

**First measures**

- Carrying out a hydrogen demand analysis or forecast in the field of mobility, both on land and on water
  - Status quo analysis: Analysis of current fleet size and distances travelled to calculate consumption and mileage as a function of fleet composition (vehicle/vessel types) and distance travelled.
  - Vehicle/vessel life and replacement cycles: Determine with stakeholders when and what proportion of new vehicles/vessels to be procured should be hydrogen-powered vehicles/vessels, examine conversion options in shipping
  - Hydrogen demand/volume structure: Calculate the volume structure depending on the introduction of hydrogen-powered vehicles/ships
- Expansion of hydrogen production capacity
- Expansion of refuelling infrastructure and conversion fleets to hydrogen-powered ferries

## 4. Establishment of hydrogen processing industry and provision of hydrogen-based synthesis products - in particular as marine fuel

The synthesis of ammonia and methanol offers the possibility of further processing hydrogen and expanding its applications. In particular, fuels in the form of ammonia and methanol could be made available for alternative ship propulsion systems instead of the heavy oil often used in current propulsion systems. Further processing into the synthesis products mentioned above and further maritime transport are also conceivable. The location of Cuxhaven has the advantage of being close to the German Bight, the Kiel Canal (NOK) and the Elbe waterway. This means that all ships manoeuvring to or from the NOK or Hamburg pass through Cuxhaven. The port's favourable location also means that ships are only a short distance away from a bunkering station to take on hydrogen, methanol or ammonia.

The deep draught of the port allows it to be used for refuelling any class of ship. The free land in the immediate vicinity of the port and the high proportion of renewable energy could be used for the early construction of on-site hydrogen production, with the possibility of synthesis, storage and refuelling.The existing synthesis capacity could be further expanded if hydrogen were to be brought onshore by ship or pipeline at a later date. In addition, the waste heat from hydrogen production could be used for local district heating. The extent to which waste heat from the downstream exothermic ammonia synthesis can be used should be investigated. Currently there is only a small local heating network in Cuxhaven. The wood-fired combined heat and power plant currently under construction could be the first step towards the development of a local heating network.

**First measures:**

- Identification and analysis of stakeholders in the methanol and ammonia sector (both producers and consumers)
- Establishment of contact with these stakeholders and discussion of the vision of a hydrogen and hydrogen processing industry in Cuxhaven
- Identifcation of the initial needs of the stakeholders
- Investigation of available sites for the construction of an ammonia or methanol production plant

## 5. Construction of large storage facilities for hydrogen or a bunker station for hydrogen and its synthesis products

The gas network development plan does not envisage a land-based pipeline connection from Cuxhaven to the German or European hydrogen network (European Hydrogen Backbone) by 2050. However, Cuxhaven has a favourable location close to the planned AquaDuctus offshore hydrogen pipeline in the German Bight and has the potential for a possible connection to it, e.g. via a spur line. A connection to the planned „energy island" would also be conceivable. In order to be able to make the hydrogen available on a large scale in line with demand or, if necessary, to process it and make it available afterwards, storage facilities will be needed. The use of caverns is particularly suitable for large storage volumes. In Cuxhaven and the surrounding area, there are several underground layers of salt and clay rock which, once explored, could provide large volume storage facilities. As already described, there is great potential in the maritime use of hydrogen and in land-based mobility applications. In particular, the refuelling of ships, e.g. for offshore operations and smaller vessels such as crew transfer vessels (CTVs), can become a significant growth market.

**First measures**

- Geological assessment of salt and mudstone formations as potential cavern storage for hydrogen
- Outreach to offshore hydrogen pipeline stakeholders to consider a stub line
- Planning of a refuelling station, with the refuelling method depending on the energy carrier to be used as fuel in future ship propulsion systems (e.g. GH2, LH2, ammonia, LOHC or methanol). There are several options for the conversion of hydrogen or derivative refuelling on ships:
  - Ship-to-ship: A common option for refuelling is the water-side transfer of fuel from a bunker barge to the recipient vessel. In this case, the bunker barge is moored alongside the recipient vessel to carry out the hydrogen transfer.
  - Truck-to-ship: A land-based refuelling option is trailer-based refuelling. Fuel-laden trailers are positioned at the quayside and connected to the ship by bunker hoses.
  - The transfer of hydrogen in exchangeable tank containers is also flexible in terms of location. Here, empty mobile tank containers are unloaded from the ships and replaced by full ones.
  - Port-to-ship: At a fixed hydrogen bunkering station, ships are bunkered at a special berth.

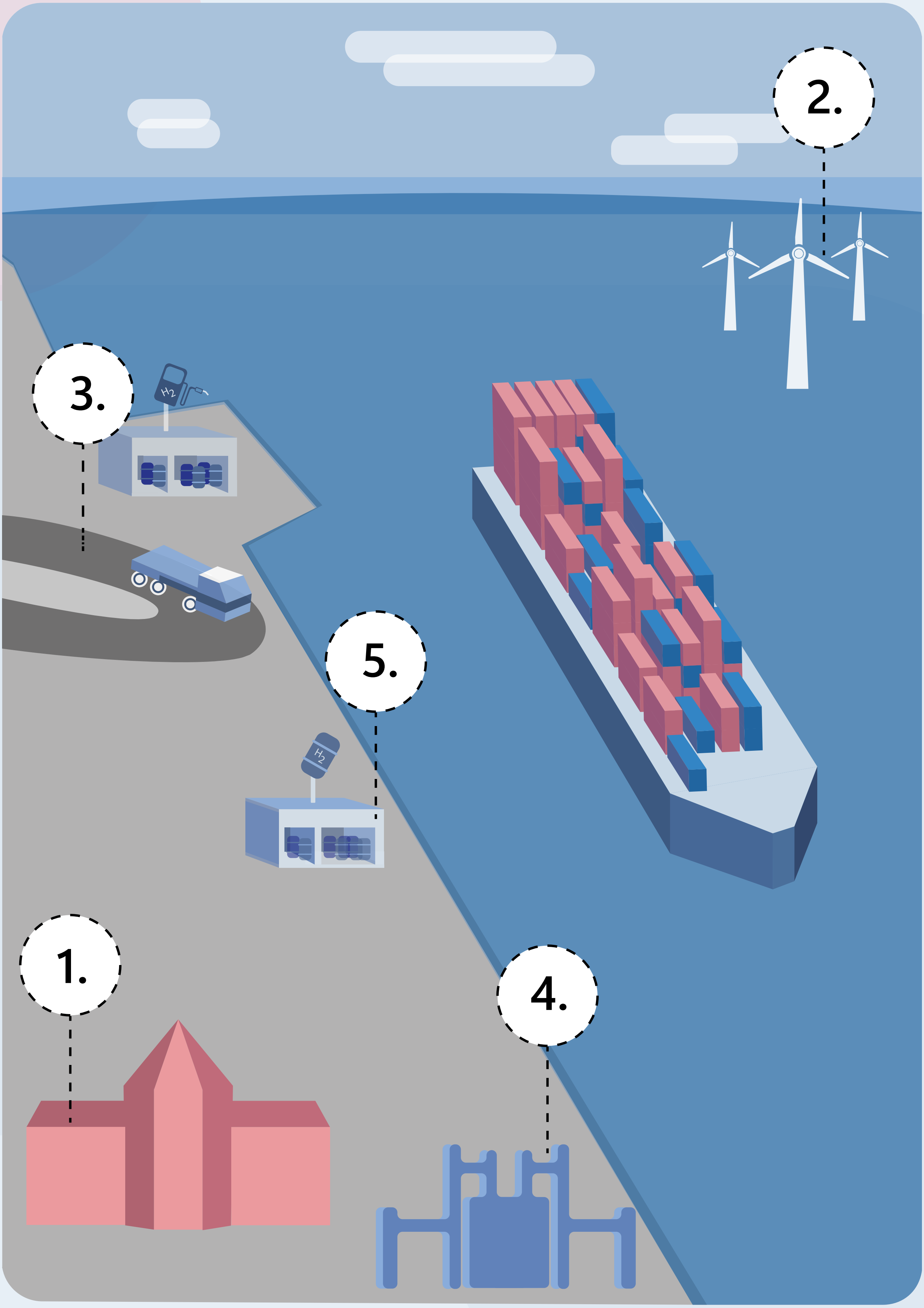


Figure 8: Visualisation of measures 1-5

**Imprint**

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