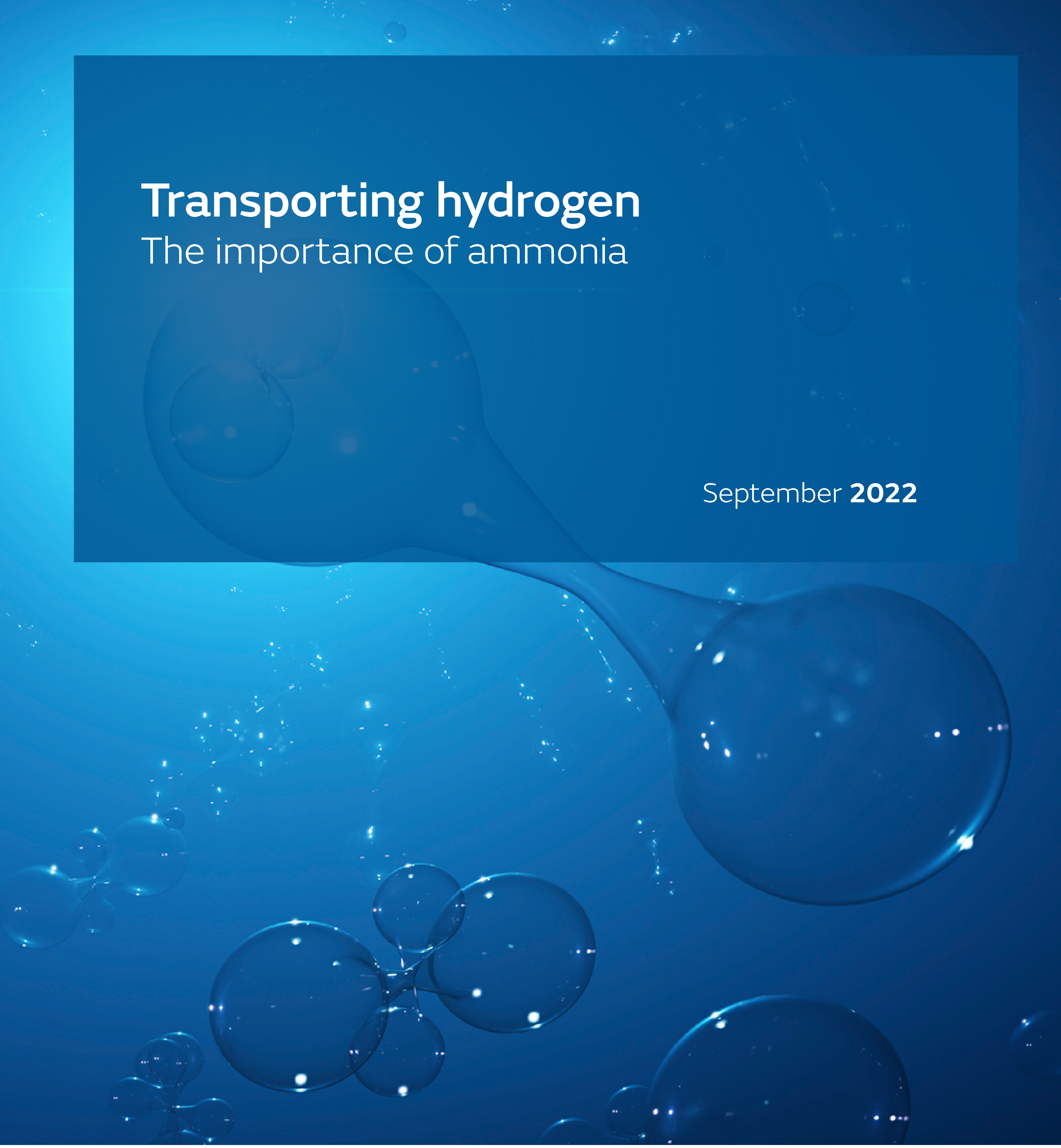

Transporting hydrogen

The importance of ammonia

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frontier economics

Naturgy Foundation

Executive summary

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Clean hydrogen is going to play a key role in decarbonisation, replacing fossil fuels in various uses. Although there is still uncertainty as to the precise sectors in which it will be used, at the very least clean hydrogen is expected to be used in industry, cargo transport and for seasonal storage of electricity. **It is estimated that by 2050 hydrogen will satisfy between 13% and a quarter of the world's energy demand.**

This clean hydrogen **will have to be transported internationally, from countries with a high production capacity (for example, those with abundant renewable resources) to densely populated and highly industrialised countries.** This international transport of hydrogen can be carried out through pipelines (compressed) or by ship (liquefied, transformed into ammonia or other compounds, or via liquid organic hydrogen carriers: LOHCs). For local transport, road transport may continue to be employed.[1]

With regards to the **maritime options, transporting hydrogen in the form of ammonia is currently the most viable option.** This is because transport costs for liquefied hydrogen are high[2] and LOHCs represent a technology that is still in an early stage of development. In contrast, ammonia has lower costs and existing transport and storage infraestructure.

Compared to pipelines, **shipping becomes more economical the greater the distance and the smaller the volume transported.** The relative advantage of shipping over long distances is due to the fact that the most relevant costs (transforming hydrogen into ammonia and building the ship) remain constant. In contrast, the main costs associated with pipelines increase with distance: the land and materials required to build the pipeline and the gas compression costs.

The advantage of pipelines when transporting greater volumes is due to their better economies of scale. In the case of maritime transport, increasing the volume implies an almost proportional increase in the costs of ships, conversion and reconversion. In the case of pipelines, the costs of land and the metal and labour required to build pipelines increase far less than the increase in the volume of gas transported.

In **the case of Europe, importing hydrogen from North Africa via pipeline represents the most economical option.** When looking to diversify the origin of the supply, the Middle East and South America are the most promising exporting regions. The construction of pipelines to transport hydrogen from South America is not viable; and, at least as things stand today, it is difficult to do so from the Middle East due to the technical and commercial complexities involved. In the latter case, a simplified cost analysis suggests that the competitiveness of pipelines, compared to transport by ship in the form of ammonia, depends on the volumes of hydrogen transported and on whether the ammonia is to be used directly or needs to be reconverted to hydrogen.

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[1] It is also possible to transport hydrogen mixed with natural gas, though only in limited quantities.

[2] This is due primarily to the high cost of liquefying hydrogen (which involves cooling it to -263ºC), the reduced mass of hydrogen that can be transported per vessel due to its lower density, the difficulties and costs involved in keeping the hydrogen cold during the trip, and the boil off loses due to the inevitable increase in temperature.

In terms of **security of supply, transportation by sea has additional advantages:**

- Trade depends only on the producing country and the importing country. Unlike pipelines, it does not depend on the countries that are geographically located between the two.
- A country with an ammonia receiving terminal can buy hydrogen from any producing country that has, or has access to, an ammonia loading terminal, regardless of its geographic location. Likewise, a producing country with a loading terminal can sell hydrogen to any country with a receiving terminal.
- Infrastructure (loading and receiving terminals) for international trade of ammonia already exists. This allows for the direct use of clean ammonia. It will be necessary to build reconversion terminals to obtain hydrogen at the destination, but their construction is faster than that of international hydrogen pipelines.
- The problems with gas supply caused by the war in Ukraine have led the European Commission to seek diversification of the sources of European gas and to propose a high volume of hydrogen imports by 2030: 10 million tons of hydrogen/ammonia (REPowerEU). It will be difficult for pipelines to supply this quantity from a variety of countries by 2030. This is due to the fact that the available infrastructure coming into Europe from North Africa will be necessary to supply natural gas beyond the year 2030, and also to the long lead-time for planning and developing new pipelines. This latter consideration is particularly true for longer pipelines that cross several countries.

All these factors suggest that the optimal path to follow is to develop **a combination of transportation of hydrogen via pipeline and ship,** similar to the current situation with the transportation of gas. Europe imports gas from Russia by pipeline, from North Africa by both pipeline and ship, and from Asia and the Americas by ship.

In addition to its use for transporting hydrogen, clean ammonia will be necessary to decarbonise current ammonia production. This **demand for clean ammonia will be high, mainly for the production of fertilisers: it is estimated that in 2020 ammonia production was 183Mt worldwide (IRENA, 2022). Given this level of guaranteed demand, ammonia can be a way of fostering investments in clean hydrogen,** helping to reduce costs.

Decarbonisation is also expected to lead to the use of ammonia in sectors where it is not currently used but in which it can replace polluting fuels. One example is as fuel for maritime transport of heavy duty. Aviation is another option. In fact, the Australian company AviationH_2 has built a prototype which is expected to star flying in 2023.

Other potential uses include the electricity sector. One possible use is to generate electricity by co-combusting ammonia with coal in places where the capacity to produce or import renewable electricity is insufficient to meet demand. This would allow the operating life of existing thermal power stations to be extended while they are prepared for their subsequent evolution to the exclusive combustion of ammonia. Also, in regions with considerable renewable resources, ammonia can play an important role in the seasonal storage of power, to balance the intermittent supply of renewable electricity and the demand for power.

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