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Norway's Internal and External Hydrogen Strategy

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Summary

This paper examines the challenges and prospects for Norway's internal and external hydrogen strategy from around 2019, when Norway's low-carbon hydrogen policies and activities began to gain traction. Norway has taken a technology-neutral approach to 'green' and 'blue' hydrogen technologies linked to reducing emissions. Two end-use sectors have been prioritised: maritime transport and energy-intensive industries. This strategy is based on Norway's energy mix, industry structure/interest and research competence. While climate concerns appear as the predominant motivation underlying the Norwegian government's low-carbon hydrogen strategy, industrial value creation is an additional key goal. Political priorities roughly align with actual funding priorities – there has been a massive increase in direct state aid to low-carbon hydrogen projects. Externally, Norway's hydrogen strategy has potential significance for Europe, particularly for countries with maritime interests and high hydrogen import needs. However, Norway's technology-neutral approach deviates from most other European countries. What Norway's hydrogen strategy will mean for Europe remains to be seen – but its main interests concern the export of 'blue' hydrogen, with 'green' hydrogen primarily suited to meet domestic needs.

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1. Background and Introduction

In 1927, the Norwegian company Norsk Hydro started production of 'green' hydrogen as input to ammonia and fertiliser production from electrolysis, based on Norway's rich hydropower resources. Norsk Hydro's production of hydrogen from electrolysis was gradually replaced by natural gas, as sizable gas resources had been discovered in the North Sea. However, Norsk Hydro continued to develop and manufacture electrolysis technologies for the world market through the company Nel, which has since become a leading global hydrogen technology company based on renewable sources (Hydro, 2021). In 1996, the Norwegian Hydrogen Association (NHA) was established – currently it has some 60 members from industry, universities, and research institutes. These actors and institutions have been involved in international hydrogen research programmes under the International Energy Agency (IEA) and the EU's framework programmes since their inception (SINTEF, 2020).

Since the turn of the 21st century, Norway's hydrogen strategy and activities have undergone at least three phases. In the first phase (2000–2010), several hydrogen initiatives were introduced, with support from the Norwegian Research Council and state-aid programmes (NFR, 2020). In 2004, Norsk Hydro and Enercon established the world's first 'hydrogen society' on the island of Utsira off the southwestern coast, with the aim of demonstrating how isolated communities could become energy self-sufficient. This demonstration project, based on wind power and fuel cells, received worldwide attention before it was terminated in 2010 due technical inefficiency and poor commercial prospects (DN, 2008; SINTEF, 2020). Perhaps the most notable project in this phase was HyNor – a joint Statoil/Equinor and Norsk Hydro undertaking aimed at demonstrating various production technologies in the use of hydrogen cars and fueling stations connecting Oslo and the city of Stavanger. As a result of the financial crisis and the emerging market for electric vehicles in Norway, among other factors, HyNor was terminated in 2009 (SINTEF, 2020).

Although hydrogen technologies continued in niche companies, the second phase (2010–2019) was marked by a low level of political attention and industrial activity; a major 2016 White Paper on Norwegian energy policy towards 2030, for example, paid only negligible attention to hydrogen (Norwegian Government, 2016). The government's strategy focused mainly on maintaining hydrogen research and on following the international development of hydrogen technologies and markets. For most uses, direct electrification based on Norway's large surplus of renewable energy generated mainly by hydropower was seen as preferable to hydrogen, while in the road transport sector, electric vehicles and biofuels were becoming the main climate solution.

By 2019, Norway was producing some 225,000 tons of 'grey' hydrogen from gas reforming in industry, mainly for its own production of ammonia and methanol (DNV-GL, 2019). Two companies (Nippon Gases and Ineos/Rafnes) produced and distributed 'green' hydrogen to the small-transport market – only five hydrogen-fueled buses and 140 registered hydrogen cars, and a mere five filling stations nationwide. In June 2019, a hydrogen filling station near Oslo exploded and injured two people, literally fueling concerns over safety issues (TU, 2019). By this time, low-carbon solutions for ships were underway, but hydrogen-based maritime coastal transport was yet to start operation.

As yet, there is no regular market for low-carbon hydrogen, neither in Norway nor abroad. Norway's major oil and gas industry has potential to supply 'blue' hydrogen based on reforming natural gas with carbon capture and storage (CCS) but such production is not established. Norway's natural gas export through pipelines amounted to around 117 billion m3 (2017) of gas intended for terminals in Germany,

France, Belgium and the UK, enough to cover about a quarter of Europe's needs, and potentially enough to produce approximately 25 million tons of hydrogen (DNV-GL, 2019). Norway has been among the few European countries to advance its CCS development, which focused on extracting CO2 from natural gas and storing it on the continental shelf. The world's largest test center for CCS technologies was established in 2012 at Mongstad, with Equinor and Shell as key partners. After some political back and forth, the government co-funded the establishment of the Northern Lights project on infrastructure for CO2 storage at the Norwegian continental shelf, designed to develop the world's first open-source CO2 transport and infrastructure for delivering carbon storage as a service (Gassnova, 2023). This was further developed to a wider policy initiative called Longship, which in addition to Northern Lights also included carbon capture (Ministry of Petroleum and Energy, 2020).

From around 2019, Norway's low-carbon hydrogen policies and activities began to gain traction. This coincided with the more ambitious climate policy agendas in the EU and Norway. Here we focus on the challenges and prospects for Norway's internal and external hydrogen strategy in this third phase. The key internal issues to be examined are the policies, political priorities of technologies and end-use sectors, and their alignment with actual state aid priorities. Externally, we will examine Norway's international approach, its domestic basis and what this means for Europe.

Data for this study is based mainly on national expert reports, governmental white papers, research papers, media articles and interviews with the Norwegian Ministry of Petroleum and Energy.

2. Norway's hydrogen strategy: Internal dimension

2.1 Strategy and policies

The third phase coincided with the government's preparation and release of the national hydrogen strategy in 2020, immediately prior to the launch of the EU's hydrogen strategy (Norwegian Government, 2020). The strategy is based on several perceived competitive advantages for production and distribution of hydrogen: industrial experience along the entire hydrogen value chain; large gas resources and the potential for increasing the production of renewable energy (in particular hydropower); the Norwegian petroleum industry's expertise in handling large-scale industry projects, and the CO2 storage potential at the Norwegian continental shelf; extensive experience in maritime industries along the value chain.

The government's strategy was criticised for being merely a description of the status quo rather than a full-fledged action plan with specific goals; it was also noted that new policy measures were lacking (TU, 2020a). The government responded by issuing a hydrogen roadmap in 2021, which was backed up by increased state-funding for hydrogen research and industry projects (Norwegian Government, 2021a). This hydrogen strategy and roadmap laid out the development of low-carbon hydrogen (emission-free or close to emission-free) from electrolysis of water from renewable energy ('green'), and natural gas with carbon capture and storage (CCS) ('blue'). In contrast to the EU's 'green' hydrogen approach, Norway has taken a technology-neutral approach to these technologies linked to reducing emissions. Two end-use sectors have been prioritised: maritime transport and energy-intensive process industries. In the maritime sector, hydrogen and ammonia are only two of several possible low-emission technologies. The government and industry have been pursuing various technologies for different types of vessels, including full electrification and biogas. Hydrogen and ammonia are considered most suitable for large, long-distance vessels (Norwegian Government, 2019a).

While climate concerns appear as the predominant motivation underlying the Norwegian government's low-carbon hydrogen strategy and roadmap, industrial value creation is an additional key goal. The hydrogen strategy was initiated by the Conservative Party-led government – more specifically, the Ministry of Climate and the Environment and the Ministry of Petroleum and Energy. The strategy was based on Norway's energy mix, industry structure and research competence, and was placed in the context of the hydrogen strategies of European and other countries, the European Green Deal and the Next Generation EU in response to Covid-19. Industrial interests also shaped Norway's hydrogen initiatives. Equinor has, as noted, a strong interest in natural gas and CCS, and is by far the largest company in Norway, with 67 per cent state ownership. In the first 2019 public consultation on hydrogen strategy, Equinor argued that that the strategy should prioritise the maritime sector and contribute to large-scale 'blue' hydrogen based on natural gas and CCS (Equinor, 2019).[1] The company followed up in its 2020 position paper to the roadmap by stressing that a necessary condition for 'blue' hydrogen

[1] Both the strategy and the roadmap were subject to public consultations – receiving 49 and 53 responses, respectively, from a range of hydrogen stakeholders.

is a value chain for CCS – currently under preparation by the Longship and Northern Lights projects (Equinor, 2020).[2] Moreover, some large stakeholders such as Equinor and Statkraft have ownership interests in both 'blue' and 'green' hydrogen technologies, and represent key drivers alongside technology providers.

When a Labour Party-led government took office in October 2021, replacing the Conservative Party-led government, its main contribution to the hydrogen strategy and roadmap was to link national hydrogen production and consumption more directly to ambitious new national climate targets (Norwegian Government, 2022a).[3] Process industries represent a significant source of national emissions with a major potential for reduction through low-carbon hydrogen; by contrast, the maritime emissions from ferry boats and high-speed water vessels for civilian use are relatively minor, which reflects technology development ambitions particularly in the maritime sector (Norwegian Government 2029b and Norwegian Government, 2022e).[4] In 2022, the government also strengthened its industrial value-creation ambitions by releasing a roadmap and future vision for 'green' industry development. Here, hydrogen figured on the list of seven priority areas, which included offshore wind, batteries, maritime industries, CCS, bioeconomy and process industries (Norwegian Government, 2022 b; c).

In 2021, as noted, the government published the Hydrogen Roadmap, intended to address the shortcomings of the criticised 'thin' strategy. For the short term, by 2025, this roadmap aims to establish: 1) five hydrogen hubs for maritime transport; 2) one or two industrial projects for hydrogen, to demonstrate value chains with global technology diffusion potential; and 3) five to ten pilot projects for demonstration of new, more cost-effective hydrogen solutions and technologies. The Norwegian Parliament also requested that the government focus more on facilitating large-scale 'green' hydrogen production, and explore how ammonia production could be electrified (Norwegian Government, 2022a). We return to Norway's long-term export-oriented strategy in the next section.

The main policy instruments envisaged for attaining the targets and visions consist of a combination of energy, climate, industry and research, and innovation policies (Norwegian Government, 2022a): increase public funding for the whole innovation chain based on existing institutions;[5] increase the CO2 tax from approx. €60/ton to €200/ton by 2030, in line with the national climate plan; develop zero-emissions public procurement standards, particularly for long-range ferries and other ships not suited for electrification; retain current tax benefits for hydrogen cars (as for electric cars) and exemption from consumer tax for electricity used to produce hydrogen through electrolysis; increase funding to research, innovation and market introduction.

The government has also announced that it is giving consideration to establishing a system of Contracts for Difference to stimulate hydrogen value-chain development. Under such a system, the state would guarantee steady income to hydrogen frontrunners. Hydrogen stakeholders have increasingly called for more measures and programmes for scaling up and commercializing technologies – in particular, Contracts for Difference to help to promote a hydrogen market (Energi og Klima, 2020). Contracts for Difference have so far not been used in Norway.

[2] If, according to the company, 10 per cent of Norway's natural gas export were used for production of 'blue' hydrogen, 20 million tons of CO_2 would need storage annually (four times the Northern Lights CO_2 handling capacity).

[3] New climate policy targets included domestic reduction of GHGs by 55 per cent by 2030 – covering both ETS and non-ETS sectors.

[4] In 2020, process industry represented ca. 23 per cent of total CO_2 emissions. Ferry boats and high-speed water vessels for civilian use account for only 3 per cent of total CO_2 emissions from the transport sector (2016).

[5] Norwegian Research Council, Enova (energy transition state fund), Gassnova (gas pipeline operator) and Innovation Norway.

2.2 Funding activities and challenges

Political priorities roughly align with actual funding priorities. All the new political initiatives have propelled state-aided hydrogen activities and projects across the country (E-24, 2021). With regard to research, further upscaling came with the 2022 State Budget, when €31 million in funding was granted for two major new hydrogen R&D centers. Since 2020, there has been a massive increase in direct state aid to hydrogen projects – mostly to industry, followed by maritime transport and, with a declining trend, in funding to road-based transport (see Table 1).

Table 1: State aid to hydrogen projects in Norway 2015–2022 (€ million)

End-Use Sectors	2015	2016	2017	2018	2019	2020	2021	2022*
Industry	0.5	-	0.6	3.9	1.9	18.2	110.1	84.9
Maritime transport	-	64	-	6.4	8.9	41.8	37.9	46.5
Road transport	2.0	20	1.0	3.9	-	-	1.2	-
Other sectors and uses	6.1	75	11.9	13.6	8.2	18.9	8.6	35.5
TOTAL	8.6	159	13.5	27.8	19.0	78.9	157.8	166.9

* Preliminary figures. Source: Enova, 2022b.

In addition to industrial 'green' and 'blue' hydrogen demonstration projects, maritime transport is prioritised. In June 2022 for example, ENOVA – the state fund for the green transition – granted €120 million in support to hydrogen investments in the maritime industries, including five production/infrastructure facilities along the coast to enable further technological development and end-use by seven coastal vessels powered by hydrogen or ammonia (Enova, 2022a). In January 2022, the first contract was signed for two long-range zero-emissions ferry boats, which are required to operate with a minimum of 85 per cent hydrogen.

However, uncertainties about low-carbon hydrogen competitiveness, technologies and costs, infrastructure, markets, transport and safety permeate the hydrogen strategy. Due to Norway's high degree of electrification based on renewable energy, the need for low-carbon hydrogen to reduce emissions is generally limited, compared to the situation in many EU Member States. Furthermore, electrolysis is significantly more energy-demanding than direct electrification (Home and Hole, 2019).[6] Thus, 'green' hydrogen production will increase the demand for renewable power and grids and raise electricity prices. Previous forecasts and expectations of Norway's renewable power surplus have changed rapidly, along with political pressure to develop more renewable electricity. However, there has been strong public opposition to building more renewable energy in Norway, due to trade-offs with land use, such as nature protection. This is clearly illustrated by the massive opposition to land-based wind power (Skjærseth and Rosendal, 2022).

[6] Given 60–65% efficiency, 50–55kWh is needed to produce one kg of hydrogen gas with 33kWh energy content.

3. National hydrogen strategy: External dimension

Norway's international hydrogen strategy mirrors the domestic strategy in that it is directed towards export of 'blue' hydrogen in the long term and development of technology related mainly to the maritime and industrial sectors. Norway's 'blue' hydrogen focus is on European markets, with initiatives linked to the North Sea area. In 2022, there was virtually no production of 'blue' hydrogen in Norway. By 2050, Norway's hydrogen roadmap envisions a well-established market for hydrogen serving the sectors of maritime transport, process industry and heavy vehicles. By that point, Norwegian industry is expected to be a world-leading exporter of hydrogen, technologies and solutions (Norwegian Government, 2021a). Establishing international markets and export are seen as crucial priorities, particularly for the development of 'blue' hydrogen value chains requiring large investments in major facilities and infrastructure for both gas and CCS. As noted above, the state-sponsored CCS projects for capture, transport and storage of CO2 (Longship and Northern Lights) might ultimately facilitate production of 'blue' hydrogen. This initiative has received some €2.5 billion in support, which is likely to increase. The goal here is to establish an operational transport and storage network by 2025, with national CO2 storage customers as well as European users. By contrast, 'green' hydrogen production is regarded as involving quite different economies of scale, with smaller production units serving national demand. A basic premise for this long-term strategy is that future demand will come mostly from international markets outside of Norway (Norwegian Government, 2020). The essential priorities are engagement in the emerging EU regulatory framework, the involvement of industry in projects abroad and international cooperation on research, standard-setting, transport and markets.

3.1 The EU and Norway

The EU's hydrogen strategy and emerging policies both align and conflict with Norway's approach. Although Norway is not an EU member, it is closely tied to EU climate and energy policies through the European Economic Area agreement. Indeed, Norway has a long-standing energy dialogue with the EU. Both the EU and Norway emphasise their mutual interests in achieving climate neutrality and promoting 'green' industrial growth based on the EEA agreement. Still, Norway was not included as a priority partner in the initial EU hydrogen strategy that prioritised 'green' hydrogen, which led to some domestic political reactions (TU, 2020c). Recently, however, the EU and Norway have intensified their energy dialogue by a Green Alliance initiative which includes hydrogen. In February 2022, Norwegian Prime Minister Jonas Gahr Støre met with the President of the European Commission Ursula von der Leyen and EU Executive Vice President Frans Timmermans to discuss enhanced cooperation on climate, energy and industrial transformation to leverage green industry, renewable energy, hydrogen and CCS (EnergyLive, 2022).[7] This initiative was later included in the EU's external strategy for international energy cooperation linked to the REPowerEU plan in response to the war in Ukraine (Norwegian Parliament, 2022; Commission, 2022).

[7] The EU and Norway agreed on the Green Alliance in April 2023.

However, Norway has argued that the European Commission should adopt a more flexible approach to the 'additionality' principle, whereby 'green' hydrogen should be produced through additional renewable electricity. The government holds that this principle may threaten Norway's hydrogen projects as long as Norway remains a net exporter of land-based renewable electricity (Montel, 2022).

Other EU policies apparently align well with Norway's priorities. The FuelEU maritime initiative aims to establish a framework for increased supply and demand of sustainable and low-carbon maritime fuels. The government sees this as a competitive advantage for Norway's engagement in alternative maritime fuels, including hydrogen and ammonia (Norwegian Government, 2021b). The same applies to EU funding programmes, such as Horizon Europe, the Innovation Fund on low-emission technologies linked to the EU ETS, and funds for the build-up of regional hydrogen development initiatives across Europe (Hydrogen Valleys). Also important are state aid guidelines, such as for Important Projects of Common Interest (IPCEI), which provide better opportunities for national state aid to facilitate European technological leadership for hydrogen (2020). State aid to IPCEI projects may cover up to 100 per cent of costs (see below). New EU state aid rules adopted in 2021 include support to both 'green' and 'blue' hydrogen, and the EU taxonomy also includes sustainability criteria for investments in natural gas and the production, distribution and storage of low-emission hydrogen.

Other emerging EU policies that may affect Norway's hydrogen strategy include the ocean energy strategy on offshore wind power production and infrastructure in the North Sea, the revision of the EU gas market, including markets for renewable gases, natural gas and hydrogen, as well as and regulations on energy infrastructure including transborder hydrogen infrastructure and infrastructure for renewable energy at sea.

3.2 Private sector involvement

The private sector is increasingly engaged in the implementation of international hydrogen projects. Several major state-sponsored industrial demonstration projects indicate how the domestic hydrogen strategy includes the positioning of Norway in the emerging international hydrogen value chain, including 'green' and 'blue' hydrogen production, process industries and maritime end users:

- TiZir's hydrogen project at the smelter in Tyssedal has received €26.1 million from Enova and has been granted status as an IPCEI project. The project, which aims to replace coal with 'green' hydrogen for the production of titanium dioxide, may have an international potential (Enova, 2021a).

- The Barents Blue project is led by Horisont Energi in cooperation with Equinor and Vår Energi. The project has received €48.2 million from Enova and has also been granted status as an IPCEI project. Barents Blue aims to develop the world's first ammonia plant with zero CO2 emissions and a daily production of 600 tons of hydrogen to be transformed into 3000 tons ammonia. The CO2 will be stored at the shelf outside Finnmark in northern Norway (Enova, 2021b).

- Yara has received €28.3 million for constructing a 'green' hydrogen demonstration plant to show that ammonia produced using renewable energy can reduce emissions of CO2 in fertiliser production (Yara, 2022).[8]

[8] Two major companies have withdrawn from the project – Aker Clean Carbon and Statkraft.

- The 2019 the Aurora project aimed to develop a complete liquid hydrogen supply chain for commercial shipping, in cooperation with BKK, Air Liquide and Equinor, involving hydrogen produced by electrolysers. However, in March 2022 the parties decided to cancel this project. They announced that they will need to evaluate how the market for liquid hydrogen develops and noted the need for further support schemes for hydrogen production in the form of contracts for difference to make hydrogen available at an affordable price (Eviny, 2022).

Equinor is most active internationally – participating in at least six international hydrogen projects at various points in the innovation chain (Equinor, 2022). In 2019, Equinor partnered with the French energy company Engie to promote the production of 'blue' hydrogen, focusing on consumers and the public authorities in Belgium, the Netherlands and France (Equinor, 2021). In 2020, it launched a 'blue' hydrogen project outside Hull in the UK (H2H Saltend), also to demonstrate the potential of 'blue' hydrogen to the EU and Germany (BT, 2020). In 2021, Equinor started a feasibility study for producing 'blue' hydrogen in Norway for export through new pipelines to Europe (E24, 2021a). The same year, Equinor launched a major 35-billion-euro vison towards 2035 for ocean wind, 'blue' hydrogen and CCS, with the company pledging to cover approximately one-third of the costs (E24, 2021b). Equinor is also looking for property in Norway for large-scale 'blue' hydrogen production for export through pipelines to Europe However, these 'blue' hydrogen plans and projects are surrounded by uncertainty and the company is not yet producing any 'blue' hydrogen.

Several Norwegian companies also export hydrogen technology (e.g. NEL, HydrogenPro, HYON, Zeg Power). Tracing its roots back to Norsk Hydro's production of 'green' hydrogen, NEL has developed into a global hydrogen company with leading technologies in the production, storage and distribution of hydrogen based on renewable sources. In 2017, NEL became one of the world's largest electrolyser companies with the largest manufacturing plant for hydrogen fueling stations and plans for the world's largest electrolyser manufacturing plant (NEL, 2022). In 2022, the company acquired its largest contract ever for electrolyser equipment to a US costumer (DN, 2022).

Many Norwegian companies are active internationally in hydrogen sector, such as Hydro and Yara (roots to Norsk Hydro) and Aker (Horizon/Clean Hydrogen). Yara is engaged in several international projects: Yara Clean Ammonia has teamed up with clean energy companies, including ENGIE, Idemitsu Kosan, Jera, Kyushu Electric Power, Trafigura and Ørsted, to produce clean ammonia (Yara, 2023). In 2020, Yara, Iberdola, Ørsted and others launched the Green H2 Catapult – a global private initiative supported by the UN Climate Change High-Level Champions initiative.

3.3 International policy dimensions

Norway does not have a distinct, unified foreign policy on hydrogen. The Ministry of Petroleum and Energy plays a key role in coordinating Norway's international engagement. However, several sector ministries are involved in various aspects of the hydrogen chain: The Ministry of Climate and Environment 'owns' the state fund for transition (Enova), with main responsibility for the IPCEI projects; the Ministry of Trade, Industry and Fisheries has responsibility for fuels, industrial value creation and 'green' shipping; the Ministry of Transport is in charge of fueling stations and ferry boats; and the Ministry of Education and Research is responsible for research and innovation. This administrative fragmentation may pose coordination challenges.

Europe and European markets are highly important to Norway. Cooperation on research and innovation is seen as vital to cut costs and make low-carbon hydrogen commercially attractive. Norwegian actors participated in several projects under the Horizon 2020 programme for hydrogen called the Fuel Cells and Hydrogen Joint Undertaking (FCH JU). In 2021, the EU launched the Clean Hydrogen Joint Undertaking (usually referred to as the Clean Hydrogen Partnership), a public-private partnership that is the successor of FCH JU and is funded by Horizon Europe. Norwegian research and technology

actors participate in this partnership, which is closely aligned with the goals of the European Hydrogen Strategy and supports R&I activities in the area of the production, distribution and use of hydrogen in transport, industry and buildings. Of these, hydrogen use in transport and industry are especially relevant to Norway.
In addition, the Ministry of Petroleum and Energy, as well as Enova and Innovation Norway are part of the European Clean Hydrogen Alliance for developing hydrogen value chains in the EU. This alliance keeps track of potential hydrogen investment projects. Other EU initiatives of relevance to Norway include the hydrogen initiatives launched by the Austrian and Romanian EU Presidencies.

With some 40 years of energy cooperation, Germany is both a main bilateral partner on hydrogen and the only country that works with Norway on specific hydrogen projects. According to a joint Norwegian-German statement from January 2022 on enhancing the dialogue on energy and industrial transformation, Norway wants to "actively contribute to the rapid development of the hydrogen market in Germany and the EU", and Germany would like to see "Norway become a future partner for the production and supply of hydrogen" (Norwegian Government, 2022f p.1). This includes a joint plan for the use of 'blue' hydrogen for a transition period to "ensure environmental and climate integrity by establishing for example the highest possible standards for Carbon Capture and Storage" – indicating that CCS-skeptical Germany accepts 'blue' hydrogen" (Inderberg and Wettestad, 2015).

In June 2022, Norway signed an agreement with several industrial actors in Northern Germany which ends in 2025. This industrial partnership includes offshore wind, hydrogen and CCS, and aims at developing new projects and funding in these areas (Norwegian Government, 2022d). Germany also represents a potential market for exporting Norwegian maritime hydrogen technology. Through Innovation Norway's High Potential Opportunities programme for major export initiatives, Norway focuses on exporting hydrogen technology to northern Germany for the development of hydrogen value chains in the maritime sector (Innovasjon Norge, 2022). In January 2023, the cooperation between Norway and Germany took a new step forward. During a meeting between German Vice-Chancellor Robert Habeck and Norwegian Prime Minster Jonas Gahr Støre, Equinor and RWE announced joint plans that included the production of hydrogen and infrastructure for export to Germany. Nel also announced agreements with Statkraft and German HH2E on production of electrolysers and hydrogen production facilities.

Other important countries are France, Belgium, the UK and the Nordic countries. Norway has close contact with France on information sharing and innovation: The Global Growth Hydrogen programme with France focuses on private actors and 'green' hydrogen, which is also part of Innovation Norway's new export strategy (Innovasjon Norge, 2023). Norway's Memorandum of Understanding on energy with Belgium includes knowledge sharing on hydrogen. There is also regular bilateral contact with the UK and established cooperation with Sweden and Denmark, particularly on 'green' hydrogen and infrastructure (Hydrogen24, 2022). This is underpinned by the Nordic Council of Ministers' Nordic Energy Research, which has facilitated several hydrogen-related initiatives. Moreover, the Nordic climate and environment ministers have agreed that their countries will work together to establish green corridors for emissions-free shipping between ports in the region (Nordic Co-operation, 2022).
Beyond Europe, Norway participates in several ministerial meeting platforms in North America and Japan, including the Japan-led Energy Ministerial Meetings, where hydrogen frontrunners discuss hydrogen solutions to facilitate a commercial breakthrough, share information and develop standards and regulations. These are followed up in other arenas where Norway is involved, such as Mission Innovation (MI) linked to the Paris Agreement and the International Partnership for the Hydrogen Economy, which is involved in setting standards for hydrogen. Norway also participates in the IEA technology network and has joined the Clean Hydrogen Mission led by Australia, Chile, EU, UK and the USA and the Zero-Emission Shipping Mission led by Norway, Denmark and the USA. The aim of the latter is for 5 per cent of the global deep sea fleet to be emission-free by 2030.

3.4 International markets, financing and capacity development

The European market is central to Norway's 'blue' hydrogen export ambitions. Spurred by the war in Ukraine, the REPowerEU plan aims at rapidly reducing the EU's dependence on Russian fossil fuels (mainly gas) and accelerating the green transition, thereby significantly raising the EU's hydrogen ambitions (European Commission, 2022). The previous goal of 10 million tons of annual hydrogen production within the EU is to be complemented by 10 million tons of annual imports by 2030, in order to meet the EU's climate target. According to European hydrogen industry estimates, there will be a need for ca. 120 GW electrolysis capacity in the EU to meet the 10 million ton domestic hydrogen production target. This is a significantly higher amount than the 40 GW originally envisaged in the 2020 European Hydrogen Strategy (Ansari et al. 2022).

These EU import ambitions generally align with Norway's 'blue' hydrogen export ambitions, but whether Norway will be able to produce and export significant amounts of low-carbon hydrogen to Europe by 2030 remains uncertain. Norway and Germany have initiated a feasibility study on large-scale transportation of hydrogen, mainly via pipelines from Norway to Germany (Norwegian Government, 2022a). Gassco – the Norwegian system operator for the gas pipelines between Norway and Europe – has assessed alternative use of the pipelines and technical barriers to using them for hydrogen transport. However, capacity will probably not be available before 2030 (Government of Norway, 2021; 2022). Mixed transport of natural gas and hydrogen through pipelines is also being considered. Other options include LNG and natural gas export in the form of 'blue' ammonia.

Investments and capacity building beyond Europe have less priority. However, in August 2022, the Norwegian Agency for Development Cooperation (Norad) for the first time allocated some support to hydrogen projects in Africa. Through the company Scatec, €8.5 million was allocated to production of 'green' ammonia in Egypt, Tunisia, Morocco and South Africa. The funding was partly motivated by climate concerns in Africa and the need to support hydrogen production to replace Russian gas export to Europe – in line with the REPowerEU plan (Norad, 2022). Moreover, the state-owned renewable fund 'Nysnø', together with Equinor and Yara, has invested in the hydrogen fund AP venture (DN, 2021).

3.5 Some challenges

The main external challenge to Norway's export ambitions is developing a commercial market for low-carbon hydrogen in Europe. Despite more ambitious EU targets, major challenges that have been identified include demand for electricity and lack of production capacity for electrolysers (Ansari et al., 2022). Regarding competitiveness of 'blue' hydrogen, Norway as a gas producer may not enjoy competitive advantages as gas market prices is expected to develop similarly in Norway and other parts of the European gas market (Norwegian Government, 2021a:116).

Hydrogen may prove controversial also from a sustainability perspective. Ongoing research examines its potential impact on the atmosphere including the ozone layer (Forskning.no, 2021). The sustainability of 'blue' hydrogen specifically is also heavily debated (see NRK, 2021). From a life-cycle perspective, it has been held that 'blue' hydrogen will not be low-carbon unless the release of fugitive methane in the production process is dealt with (Howarth and Jacobsen, 2021). In the EU, carbon capture and storage has a long and politically contentious history, also with regard to the issue of whether captured CO2 can be stored indefinitely. CO2 storage also requires large amounts of electricity (Espegren et al., 2021).

4. Conclusions

Norway’s hydrogen strategy has potential significance for Europe, given its focus on low-carbon hydrogen technologies for industry and maritime end-users, development of electrolysers, and production of ‘blue’ hydrogen for export to the continent. These points concern most EU Member States with low-carbon hydrogen ambitions, particularly those with maritime interests, high hydrogen import needs and gas pipelines to Norway, such as Germany. However, Norway’s technology-neutral approach to ‘green’ and ‘blue’ hydrogen linked to emissions deviates from most other European countries.

Regular domestic or international commercial markets for low-carbon hydrogen have not yet emerged. Uncertainties regarding the competitiveness of low-carbon hydrogen, technologies and costs, infrastructure, markets, transport and safety permeate Norway’s hydrogen strategy. Key internal challenges include growing demands for high-priced, increasingly scarce renewable electricity, and trade-offs with land use, such as nature protection. Other challenges include technical barriers, uncertain commercial prospects, the short-term perspective (2030) for the REPowerEU targets versus Norway’s long-term export strategy and sustainability issues. Exactly what Norway’s hydrogen strategy will mean for Europe remains to be seen – but its main interests concern export of ‘blue’ hydrogen and the maritime and industrial sectors, with ‘green’ hydrogen primarily suited to meet domestic needs.

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