Hydrogen in the Nordics: Collaboration Opportunities for Dutch Companies

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Including the market characteristics and industrial policy processes in Denmark, Finland, Iceland, Norway, and Sweden

SPINVERSE

NL Netherlands

This report has been completed by Spinverse in collaboration with the Embassies of the Netherlands in the Nordics and the Netherlands Enterprise Agency (RVO).

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1 Executive summary

- The Nordics offer a unique opportunity for Dutch companies to collaborate in the development of a sustainable hydrogen economy, thanks to their abundant renewable energy resources and the Nordic countries' ambitious carbon neutrality goals.
- The Netherlands and the Nordics can collaborate on technological innovation and knowledge exchange building hydrogen value chains together.
- The Nordics are expected to have excess green hydrogen production in the coming years. This presents an opportunity for Dutch companies to import green hydrogen and its derivatives from the Nordics, potentially creating a valuable new market for both regions.
- The Nordics have a stable and long-lasting political environment, which translates into a business-friendly environment that is open, transparent, and conducive to collaboration. This stability makes it an attractive destination for Dutch companies looking to expand their business in Northern Europe.
- Collaboration between Dutch and Nordic companies presents a valuable opportunity to address global challenges, including reducing greenhouse gas emissions and transitioning to sustainable energy sources. This collaboration offers Dutch companies the chance to play a leading role in driving the global shift towards sustainability.
- Despite the vast potential for green hydrogen production in the Nordics, there are challenges to be overcome such as the need for extensive infrastructure development, high production costs and uncertainty of regulation. However, with the right partnerships and strategies in place, these risks can be mitigated and overcome to create a sustainable future for all.

Introduction

The role of green hydrogen in renewables and circular economy has been increasing globally over the past decade. Ambitions are currently translated into policy plans and legislation. The EU, especially, is highly committed to reaching climate-neutrality by 2050. To achieve this, the European Commission has reserved hundreds of billions to support the green hydrogen transition in EU countries. This study assesses both import and export opportunities for the Netherlands in the Nordic countries by elucidating the current market situation in the Nordics. It aims to both identify potential opportunities for Dutch companies in the Nordics and find areas where the Nordic countries can contribute to the hydrogen ecosystem in the Netherlands. The Nordic region presents a promising opportunity for Dutch companies to collaborate and develop a green hydrogen economy due to the Nordics' renewable energy resources and ambitious carbon neutrality goals. The stable political environment in the Nordics creates a business-friendly environment that is transparent and conducive to collaboration, making it an attractive destination for Dutch companies looking to expand in Northern Europe. Collaboration between Dutch and Nordic companies could address global challenges such as reducing greenhouse gas emissions and transitioning to sustainable energy sources and offer Dutch companies a leading role in driving the shift towards sustainability. While challenges such as infrastructure development and high production costs exist, these risks can be mitigated through partnerships and strategies, creating a sustainable future for all. The countries have a long-lasting history of commercial partnerships, and the advanced technology and infrastructure provides a great opportunity for cooperation where the Netherlands can capitalise on its innovation, import, and human capital advantages.

The Netherlands is currently the second-largest fossil-based hydrogen producer in Europe and targets to become a key green hydrogen hub with its already existing natural gas infrastructure, and strategic location as a gateway to

North-Western Europe. To reach these ambitious goals, the Netherlands must take a step toward in its international cooperation with the Nordic countries.

Methodology

The present study was carried out by combining comprehensive literature reviews, and interviews with sector professionals, both from the Nordic countries and the Netherlands. The scope was framed by the five main research questions from the Terms of Reference of the assignment and contains subsections for the respective Nordic countries. The process included multiple reviews and feedback phases with the commissioning party to ensure the quality of the report. While the study aims to include the most relevant and recent information, the sources are primarily limited to those published before Q2/2023. Given the rapidly evolving nature of the green hydrogen industry, new information is constantly emerging, which may limit comprehensiveness of the full scope of the market. However, this does not limit the ability of this report to provide detailed and insightful analysis of the relevant actions and opportunities in the Nordic hydrogen market. This study provides an in-depth overview of the hydrogen landscape in the different Nordic countries, assessing the current state, policies, main projects, and networks.

Denmark has great electricity production possibilities and plenty of offshore wind parks under development. The country has ambitious goals for green hydrogen and specifically for Power-to-X. However, due to the limited number of off takers for PtX products, Denmark is expected to focus on exporting its hydrogen products. Consequently, the country has already signed agreements with Germany on trading hydrogen for CO_2. Currently there's only one company operating hydrogen refuelling stations. The country is particularly strong on inventions, having most patents per million inhabitants for green transition.

Finland has published ambitious targets to reach for climate neutrality in 2035. With a stable electricity grid and significant geographical area for wind power capacity, Finland has the potential to play a key role in meeting the EU's green hydrogen targets. Finland´s hydrogen strategy was published in 2022 as part of the country´s climate and energy strategy, and a government resolution was adapted in February 2023, stating that Finland could produce 10% of the EU's green hydrogen goals. Industry believes capability is even more. While Finland has a well-established R&D sector and thriving industry, Finland's hydrogen production capabilities are hindered by the lack of adequate infrastructure and large-scale electrolysers.

Iceland's national target to reach carbon neutrality is 2040, but achieving this will be difficult without the widespread use of hydrogen. The transport industry is the most crucial sector to focus for the reduction of fossil fuel consumption, and here hydrogen can play a key role. Presently there is no clear roadmap in place for hydrogen implementation in Iceland.

Norway has the highest share of renewable energy in total final energy consumption (TFEC) among International Energy Agency (IEA) member countries. In 2020, 61% of TFEC came from renewables. With good geographical location and access to renewable energy, Norway promises huge potential to produce green and blue hydrogen and believes it can become an exporter of hydrogen to countries in the EU. Norway has a solid hydrogen strategy in place already, with active participation by the government in supporting companies investing in the field through various funding opportunities.

Sweden has a proposed strategy which sets concrete goals for both 2030 and 2045, the strategy identifies key actions, and initiatives to be implemented for the Swedish hydrogen development. Announced in 2021 by the Swedish Energy Agency, backed up and revised in 2022, has been developed together with companies and other actors in the hydrogen value chain. In March 2023 the government assigned the Swedish Energy Agency to coordinate the Swedish hydrogen work. The purpose is to identify and contribute to the removal of barriers and integrate hydrogen into the energy system those fulfilling EU directives. There is a well-established R&D sector, the industry also is involved and in collaboration in several projects and initiatives with research institutes and universities.

Entry opportunities

Jointly for the Nordics, the Netherlands can provide technological knowhow, especially about hydrogen storage and infrastructure. The Dutch knowledge on building hydrogen valleys can support the Nordic countries in strengthening their hydrogen ecosystems. Collaboration between hydrogen ecosystems in the Netherlands and the Nordics can create valuable partnerships and knowledge exchange.

The Netherlands can leverage its offshore wind expertise to help the Nordics expand their offshore wind capacity for hydrogen production, for instance in Denmark and Finland. Danish, Finnish and Swedish companies are in need of parts for electrolysers. Sweden and Finland can benefit from the Netherlands' leading, long-lasting hydrogen infrastructure knowledge to create value chains and infrastructure. In Finland, several big SME projects announced still actively need funding and could benefit from collaboration with innovative Dutch companies. Norway has established itself as a leader in the development and implementation of hydrogen-based solutions, and Dutch companies can bring their expertise and know-how in heavy-duty transportation and refuelling systems to support Norway's efforts. Norwegian companies' expertise in electrolyser manufacturing presents an opportunity for Dutch industry to catch up and position itself as a developer and supplier of electrolysis components. With the hydrogen market not yet fully developed in Iceland, there are several potential opportunities for Dutch companies in the hydrogen value chain of Iceland, particularly in the areas of infrastructure development, maritime sector, aviation sector and the use of sustainable aviation fuels, research and development, and consultancy and advisory services.

Risks and Challenges

Even though all the Nordic countries besides Iceland have a concrete hydrogen strategy, the regulation and law-landscape regarding hydrogen in all of the countries is still in its infancy. Clear regulations and laws are necessary to guide the development of infrastructure, such as production facilities, storage, and transport networks. As the global supply chain for green hydrogen is still developing, companies may struggle to bring hydrogen-related products to the market. The lack of a hydrogen strategy also relates to inconsistent industry standards which can create barriers to entry and limit market growth. The competitiveness of green hydrogen production will depend on the relative pricing of fossil fuel-based alternatives, which may need to be driven up through measures such as taxation. Additionally, given the current state of the industry, the level of subsidies required to support green hydrogen production may need to be significant. It is worth noting that the **potential for future investments in the green hydrogen sector may not fully materialize if fossil fuel-based alternatives remain considerably cheaper.** As such, a strategic approach to subsidies and pricing mechanisms will be necessary to support the long-term viability of the green hydrogen industry in the Nordics. Furthermore, the Nordic hydrogen industry faces competition from other low-carbon technologies such as battery storage and electric vehicles.

Contents

1.1 Abbreviations

CCS	Carbon capture and Storage
CO_2	Carbon dioxide
DSO	Distribution System Operator
FF55	Fit for 55
GHG	Greenhouse gas
H_2	Hydrogen
IEA	International Energy Agency
ILUC	Indirect Land Use Change
IPCEI	Important Projects of Common European Interest
PES	Project Establishment Support
PtX	Power-to-X (also P2X)
RED	Renewable Energy Directive
RFNBO	Renewable Fuel of Non-Biological Origin
R&D	Research and Development
R&D&I	Research and Development and Innovation
TFEC	Total Final Energy Consumption
TSO	Transmission System Operator

1.2 List of figures

1.3 List of tables

1.4 Structure of the report

The report is structured in the following way. Chapter 2 provides the background and objectives for the study, while Chapter 3 extends these objectives to describe the methodology used in the research, including limitations of the study. Chapter 4 introduces the main topic, renewable hydrogen on a global level, in the Netherlands, and in the Nordics. Chapter 5 explores the most important EU policies that impact the Nordic countries' hydrogen production. Chapters 6 to 10 focus individually on each country, providing detailed discussions on policy landscapes, market characteristics, and opportunities for Dutch companies. Finally, Chapter 11 presents the study's results and conclusions. A summary of Nordic events and report interviewees can be found in the appendices in Chapter 12. Each section begins with a short bullet point summary of the key takeaways of the corresponding chapter. Throughout the text, the most important key facts are bolded, making it easy to skim through the report.

2 Background and objectives

This report was commissioned to Spinverse by the Embassies of the Kingdom of Netherlands in the Nordics together with the Netherlands Enterprise Agency (RVO) in December 2022, with the objective of clarifying the current market situation in different Nordic countries in the hydrogen industry, identifying potential opportunities for Dutch companies, and finding areas where Nordic countries can contribute to the hydrogen ecosystem in the Netherlands.

First, this study aims to provide insight into the characteristics of the regional Nordics market and more specifically, the Danish, Finnish, Icelandic, Norwegian, and Swedish sustainable hydrogen economies. Moreover, the goal is to identify opportunities for Dutch companies (and organisations) delivering products and/or services that contribute to the transition towards a fossil free energy market. The purpose of this is to seek possibilities to set up or intensify cooperation between the region and the Netherlands in (parts of) specific value chains and support the export to these countries.

Second, the objective is to examine possible export capacity of hydrogen to the Netherlands as well as map current and planned activities of important stakeholders from the Nordics in the Netherlands. The present report is a qualitative study which aims at understanding and identifying the factors that can help the hydrogen market, for the two objectives above. The contents of the study do not represent the official position of the Government of the Netherlands.

3 Methodology

A comprehensive search was performed during Q1, 2023, including government documents, scientific papers, articles, books, journals, and case studies. The data and study materials were limited to English, Dutch, Danish, Finnish, Norwegian and Swedish languages based on the relevant keywords related to the concept for the study. The research focused mostly on content from years 2021-2023. Previous knowledge was updated as new information was released.

The following five questions, within the framework of the scope, centred around the hydrogen market and served as a guideline for literature research and interviews. Relevant previous studies were identified and selected.

1. What parts of the hydrogen value chain in the Nordics as a region and in Denmark, Finland, Iceland, Norway, and Sweden provide opportunities for Dutch companies and organisations?
2. How can Dutch technology and innovative solutions contribute to the transition towards hydrogen solutions in the Nordics?
3. What are the hydrogen export opportunities from the Nordics to the Netherlands?
4. Who are the main partners for global cooperation in the Nordics?
5. Which challenges/risks are to be foreseen within the joint Nordics hydrogen market and the different countries?

Moreover, the analysis was supported by interviews with industry professionals from each Nordic country and the Netherlands (See 12.1). The final selection of interviews included national hydrogen hub members and selected professionals (See Appendix). These contact points were formed either directly or indirectly through the Dutch Embassies in the Nordic countries. The initial kick-off workshop helped in identifying and grouping the study. The process also included multiple review and feedback phases with the commissioning party to ensure the quality of the report.

To understand the study a comprehensive review of the collected literature was undertaken. The content for the interviews was then based on the research questions and the relevant literature. Finally, the data was structured and divided into subsections under the different countries, concluding with the recommendations for the Dutch companies.

Limitations of study

The applied methodology has some limitations that must be considered when interpretating the results of this report.

The green hydrogen industry is evolving rapidly with new information being released at a fast pace. The report aims at including as many recent reports and announcements as possible that have been released prior to May 2023. However, the report might have outdated information as some material is from 2021 and 2022. Moreover, general time constraints limit covering the full scope of the industry, with the report emphasising the most relevant parts of hydrogen value chain. Additionally, some content is based on interviews with company representatives in the hydrogen industry and might portray subjective and biased views of the current state of the industry. Nevertheless, these points do not limit the usefulness of this report as it fully covers the required actions and opportunities for approaching the sustainable hydrogen industry in the Nordic countries.

4 Introduction

Renewable hydrogen globally

The developments surrounding (green) hydrogen are characterized worldwide by high expectations and great ambitions. These aspirations are currently being translated into policy plans and legislation. For example, in its Hydrogen Strategy, the European Commission presents a target of 6 GW electrolyser capacity (1 million tons of green hydrogen) for 2024 and 40 GW (10 million tons of green hydrogen) in 2030[1]. By comparison, currently around 170 MW of electrolyser capacity is installed across the EU and the increase is below 1 GW per year. To help realize the ambitions, the European Commission has promised tens of billions to stimulate the development of water electrolysers and hundreds of billions for the development of solar and wind farms.

The Netherlands

The Dutch Government is currently facing a challenge to reach the EU's 2030 ambitions for green hydrogen production. As the second largest (grey) hydrogen producer in Europe (after Germany) the Netherlands has well established market for industrial hydrogen use with an annual fossil-based production of around nine million m^3. Strategically located as a gateway to North-Western Europe, the country is already considered as a key hub in global oil and gas trade. In addition, there is existing infrastructure of 136 000 km of natural gas grid pipeline that can be retrofitted to transport hydrogen at low cost. The country also has a favourable location for land and marine transit and a large-scale rollout of offshore wind energy. Furthermore, there are around 1 000 Dutch companies active in the new hydrogen markets, collaborating in a rich ecosystem of research institutes and industrial partners.

The country aims to position itself as a European hydrogen hub with the goal to produce 30% of demand, the remaining 70% coming from imports. The industry is driven by the European legislation, strong government support and necessity toward renewables. Industrial hydrogen applications are seen as the largest market segment, followed by transportation. Industrial applications are easily accessible due to the existing infrastructure in the Netherlands whereas the transportation market is still limited by the lack of infrastructure and competition from alternative options.

However, to reach its ambitious goals, the Netherlands needs to bring down the price of green hydrogen to be competitive as an industrial region. Moreover, solutions for storing large amounts of energy and space for electrolysers are needed. The Nordic countries provide a great opportunity for international cooperation as the Netherlands can benefit from its advantages in innovation and human capital while further strengthening its positioning in the industry with imports from the Nordics. The Netherlands is planning on hosting an auction to import green hydrogen or its derivatives at the end of 2023 or early 2024 backed by EUR 300m of subsidies.[2] The tender would be held through Germany's state-owned H_2Global auction platform, which acts as a middleman between producers and buyers. The German Government has so far launched three auctions worth of a total of EUR 900 million. The launch will depend on the final decision of Parliament in The Hague and state aid approval from the European Commission.

[1] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_2829

[2] https://www.hydrogeninsight.com/policy/netherlands-plans-green-hydrogen-import-auction-by-early-2024-backed-by-300m-of-subsidies/2-1-1435546

The Nordic countries

Nordic countries have an abundance of renewable energy resources at a competitive low cost with ambitious energy and climate policy goals, allowing for significant potential for producing, consuming, and exporting hydrogen and electro fuels to the Netherlands.[3] Moreover, the Nordics have a well-established R&D environment with high-level technology know-how and potential for large-scale underground storage of hydrogen and carbon. All countries have implemented CO_2 taxation. The countries have existing collaboration in the areas of hydrogen with a high level of public and private investments. Additionally, each country has national funds to support research and innovation as well as the EU's funding possibilities (See Chapter 5.5 for more details).

Preparing funding applications can be a complex and time-consuming process that requires significant knowledge and expertise. To help companies in the Nordic countries, there are several innovation consultancies offering support for preparing funding applications for EU funding opportunities, helping companies to achieve applications of highest quality. Finland, Denmark, Norway and Sweden all have programs granting financial support for preparing EU funding applications. In **Finland**, **Business Finland** provides financial assistance, while in **Denmark**, **the EUopSTART program**[4] aims to simplify the process of submitting funding applications. Meanwhile, **Norway's PES Scheme**[5] focuses on improving the quality of funding applications involving Norwegian participants in Horizon Europe. In Sweden, such program is called **EUSME Support**[6]**.** These financing programs provide companies with the opportunity to engage external consultant firms to help them produce high-quality funding applications, thus enhancing their chances of securing funding.

Besides renewable power, the Nordics have great resources of biomass for energy production, primarily because of the pulp and paper industries in Sweden and Finland, and the agricultural industry in Denmark and Southern Sweden. The countries are relying on cross-Nordic collaboration as imports of biogenic material are expected to drop. Moreover, Sweden and Finland aim to become part of the European backbone hydrogen network (Figure 1). The pipeline infrastructure along the Baltic and North Seas provides a direct link to major European hydrogen users, Sweden among other countries are getting prepared for the hydrogen routes (See Ch 10.1.2 and 10.1.5). There are also plans to build a H_2 pipeline between Norway and Germany (See Ch 6.1.5 for details). In Denmark, hydrogen is expected to be used to produce Power-to-X products or exported through the potential European backbone hydrogen network. Iceland will focus more specifically on the production of e-fuels to export energy from the country. These e-fuels are expected to impact aviation in the shape of sustainable jet-fuel and as ammonia or methanol for international maritime transport.

[3] Source: European Hydrogen Backbone (ehb) https://pub.norden.org/nordicenergyresearch2022-02/#87985

[4] https://ufm.dk/en/research-and-innovation/funding-programmes-for-research-and-innovation/find-danish-funding-programmes/euopstart

[5] https://www.forskningsradet.no/en/call-for-proposals/2021/project-establishment-positioning-horizon-europe/#sub73016

[6] http://www.eusme.se/

Figure 1 Snapshot from the European Hydrogen Backbone Maps dated 31st of March 2023.[7]

In terms of gaps, Norway, Sweden, Iceland, and Finland lack a national natural gas network which could be converted for hydrogen transmission. This implies that green hydrogen will most likely be in heavy industries use and produced close to the off takers. Each of the countries are also in vast need of solutions for storage, and as production is scaling up, research, skilled labour and equipment are needed.

The present study divides the industry in segments based on the typical renewable hydrogen value chain (See Figure 2) to identify gaps in specific parts of the value chain. The study will assess the Nordic hydrogen industry from production to end use and thus provide concrete market entry opportunities for Dutch small and medium-sized enterprises (SMEs) and provide specific actions on where and how to enter.

[7] European Hydrogen Backbone Maps | EHB European Hydrogen Backbone

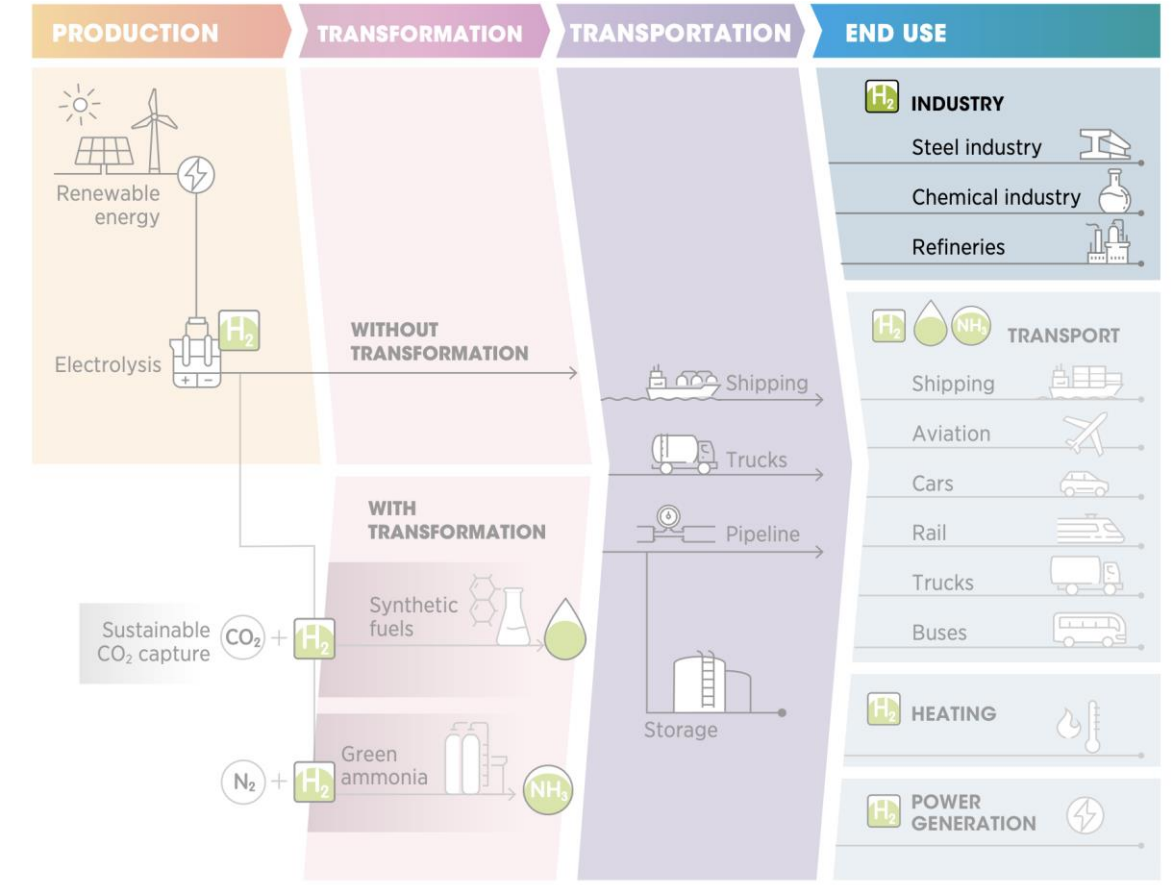


Figure 2 Hydrogen value chain from production to end use[8]

Industry challenges

An overarching challenge for the development of the green hydrogen value chain is the so-called 'chicken and egg' challenge. In simple terms, this means that green hydrogen demand is needed to scale up production, scaling up production is needed to decrease costs and lower costs are needed to stimulate demand. The various parts of the hydrogen value chain are interdependent and need to simultaneously scale up, also including the supply chain of equipment, materials, and technology providers. This obstacle was frequently mentioned in the interviews with parties in the sector. The dependencies on other parts of the value chain are an inherent challenge, which can increase risks (e.g., financial, security of supply, delays) and the cost of hydrogen.[9]

The following table illustrates the export potential for Dutch businesses in the five Nordic countries, Norway, Sweden, Finland, Denmark, and Iceland. The table is structured with Dutch strengths listed in the left-hand column, and the export potential of each segment for each country denoted by a score of either "++", "+", "+/-", "-", or "--." A score of "++" indicates that there are plenty of opportunities for Dutch companies in that country, "+" indicates there are opportunities, but they are limited or there might be some expertise on the segment already. A score of "-" indicates that opportunities are limited or that there is a lot of competition on the segment already. "--" indicates highly limited opportunities or no opportunities. It is important to note that these scores are based on the authors knowledge based on the information gathered and are not absolute facts. The purpose of this table is to provide a high-level overview of the export potential for Dutch businesses in the Nordics, and to combine information that are further explained in

[8] Source: IRENA (2022), Green hydrogen for industry: A guide to policy making, International Renewable Energy Agency, Abu Dhabi. ISBN: 978-92-9260-422-6. IRENA (2020a).

[9] Groenvermogen: Quickscan development green hydrogen value chain

the "Segments providing opportunities" -sections for each respective country. Overall, the table provides a useful snapshot of the export potential for Dutch companies in the Nordic countries. However, it is important to note that these scores are based on author's knowledge based on currently available information, and companies should always conduct their own research and due diligence before entering any of the market.

Table 1 Strengths of the Dutch hydrogen ecosystem and a tentative indication of their potential commercial interest in the Nordics: Export opportunities for Dutch companies. Read '++' as: on this topic the Netherlands clearly have something to offer to this Nordic country.

	Export potential for Dutch companies				
Dutch strengths	Denmark	Finland	Iceland	Norway	Sweden
Knowledge of hydrogen valleys	+	++	+	+	+
Logistics	+	++	++	++	++
Gas pipeline tech & knowledge	+	+	-	-	+
Electrolyser components	+	++	+	++	+
Repurposing existing gas infrastructure	++	-	--	+	++
Rich research landscape (RTO/industry)	+	+	++	+	++

The following table illustrates the import potential for Nordic companies to the Netherlands. The table is structured with Dutch needs listed in the left-hand column, and the export potential of each segment for each country denoted by a score of either "++", "+", "+/-", "-", or "--." A score of "++" indicates that there the country can provide significantly to that sector. "+" indicates there are opportunities, but they are limited. A score of "-" indicates that opportunities are limited. "--" indicates highly limited opportunities or no opportunities. It is important to note that these scores are based on the authors knowledge based on the information gathered and are not absolute facts. The purpose of this table is to provide a high-level overview of the import potential for Nordic businesses in the Netherlands, and to combine information on the strengths of the Nordic countries. Overall, the table provides a useful snapshot of the import potential for Nordic companies in the Netherlands. However, it is important to note that these scores are based on author's knowledge based on currently available information, and companies should always conduct their own research and due diligence before entering any of the market.

Table 2 Sectors where existing strengths in the Nordic countries have potential to fill gaps in the Dutch landscape. Import opportunities for the Netherlands from the Nordic countries. Read '++' as: here a Nordic country has something the Netherlands could benefit from.

	Import potential for Dutch companies				
Dutch needs	Denmark	Finland	Iceland	Norway	Sweden
Competitively priced hydrogen imports	++	++	-	++	++
Logistics	-	-	-	+	++
Skilled workforce	+	+	-	+	+
Electrolyser OEM	+	+	--	++	-
Renewable electricity	++	++	++	++	++
Targeted fuel cell/electrolyser research	++	+	--	++	+

Note: The +/- have been given based on the available information gathered via research and interviews. It is based on a country's strength in a particular sector based on the authors' understanding. The tables are not to be used to compare between the countries.

5 EU Policies

In December 2020, a total of 22 EU Member States, as well as Norway, signed a hydrogen manifesto to participate in the hydrogen Important Projects of Common European Interest (IPCEI) process. Notably, Finland, Denmark, the Netherlands, and Norway, which are the focus of this study, were among the countries that signed the manifesto, while Iceland and Sweden did not. While the manifesto itself is a non-binding agreement, it is a clear indication of the participating countries' commitment to collaborate on promoting the deployment of hydrogen and advancing the development of a hydrogen-based economy in the EU. This can serve as a foundation for future cooperation and tangible action.

Regarding IPCEI, it is an EU State aid framework that aims to promote cross-border cooperation on large-scale research and innovation projects in the EU, including those related to hydrogen technology. The program provides funding for joint projects between different EU Member States and is designed to address market and systemic failures that inhibit investment in innovative technologies. The IPCEI process provides a framework for Member States to collaborate on ambitious, large-scale, and strategically significant projects that require significant resources, financial and otherwise, beyond what one country can provide.

This chapter will go through the major EU policies affecting the growth of green hydrogen industry or green transition as a whole.

5.1 The Renewable Energy Directive III (RED III)

- The EU's revised Renewable Energy Directive III sets binding targets for renewable energy in member states, including a 14% target for renewable energy in the transport sector by 2030.
- The RED III directive is expected to increase demand for renewable energy and hydrogen in the Nordic countries, which have ambitious targets and abundant renewable resources.
- The directive only considers green hydrogen, not blue hydrogen.
- The EU has proposed rules for supplying renewable electricity to hydrogen production, which includes requirements for direct connection to renewable energy resources, high shares of renewable energy in electricity grids, and low CO_2 intensities in bidding zones.
- Only a few bidding regions in Europe meet the emissions limitations for supplying renewable electricity to hydrogen production.

Originally adopted in 2021, the EU's latest revision of Renewable Energy Directive (RED) III sets binding targets for the EU and for each Member State for the share of renewable energy in the final energy consumption, and for the share of renewable energy used in the transport sector. The directive requires member states to increase the share of renewable energy in the final energy consumption to at least 45% by 2030. It also sets a target for the share of renewable energy used in the transport sector, which is 14% by 2030.

The RED III -directive is expected to have a positive impact on the hydrogen markets in the Nordic countries, as it will increase the demand for renewable energy and, by extension, for hydrogen. The directive’s specific target for the transport sector will also increase the demand for hydrogen as a fuel for vehicles. As all the Nordic countries have ambitious targets for the use of renewable energy, they have a good potential to reach the target set by the directive. Additionally, the Nordic countries have a high potential for renewable energy resources such as wind, solar and hydropower which are the main sources of hydrogen production via electrolysis. This gives the Nordic countries an advantage in terms of producing hydrogen using renewable energy sources. Overall, the RED III is expected to create

new opportunities for hydrogen as a clean and renewable energy source and will support the development of the hydrogen infrastructure and technologies. It is noteworthy to mention that RED III amendment proposal only covers green hydrogen but does not take blue hydrogen into consideration.

The EU Commission has proposed detailed rules for renewable hydrogen with the adoption of two Delegated Acts required under the Renewable Energy Directive. The first Delegated Act[10] contains three main rules for supplying renewable electricity consumed by hydrogen production; the third of which allows the use of nuclear power:

1. The hydrogen plant has direct connection to a renewable energy resource.
2. The hydrogen plant is connected to an electricity grid where the share of renewable energy in the bidding zone is more than 90%, based on the previous calendar year.
3. The hydrogen plant is connected to the grid in a bidding zone where the CO_2 intensity are below 19gCO_{2eq} / MJ, stipulating that the electricity consumption is compensated by PPAs for renewable energy.

It is worth noting that only few bidding regions in Europe fall below these emission limitations.
The European Parliament and the Council have 2 months to scrutinise this Act and to either accept or reject the proposal. There is no possibility for the Parliament or Council to amend the proposals.

5.2 Fit for 55

- The Fit for 55 package is part of the EU's efforts to decarbonize its economy and meet its climate target of reducing greenhouse gas emissions by at least 55% by 2030.
- Hydrogen is seen as a key player in decarbonization efforts and can help to reduce the EU's dependence on fossil fuels.
- The package sets ambitious targets for the deployment of hydrogen refueling stations (HRS) along the Trans-European Transport Network (TEN-T) to facilitate the deployment of zero-emission hydrogen fuel cell vehicles.

The fit for 55 package is part of the European Union's efforts to decarbonize its economy, which includes increasing the use of renewable energy sources to reduce greenhouse gas emissions. The European climate law makes reaching the EU's climate target of reducing greenhouse gas emissions by at least 55% by 2030 a legal obligation. (Council of the European Union) According to council of the European Union[11], "*The Fit for 55 package is a set of proposals to revise and update EU legislation and to put in place new initiatives with the aim of ensuring that EU policies are in line with the climate goals agreed by the Council and the European Parliament*."

Hydrogen can play a key role in this effort as it is considered a clean and renewable energy source that can help to decarbonize a variety of sectors, such as transportation, heating, and industry. As mentioned in the previous chapter, the EU has set a target of increasing the share of renewable energy in its final energy consumption to at least 32% by 2030. Green hydrogen can be used to meet this target and help to reduce the EU's dependence on fossil fuels. **As stated by the Hydrogen Cluster Finland (HCF), most, if not all, relevant regulation relating to hydrogen is either missing or under re-view, and the Fit for 55 package gives an excellent opportunity to create long-term regulatory certainty for investments.**

The recently adopted Fit for 55 -package sets ambitious targets for the deployment of hydrogen refuelling stations (HRS) in the coming decade. **Under this package, at least one HRS must be available every 200 km along the**

[10] https://energy.ec.europa.eu/delegated-regulation-union-methodology-rnfbos_en
[11] https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

Trans-European Transport Network (TEN-T) and in every urban node by the end of 2031. This requirement is aimed at facilitating the deployment of zero-emission hydrogen fuel cell vehicles, reducing the carbon footprint of the transport sector, and contributing to the EU's goal of becoming carbon-neutral by 2050.[12]

The TEN-T network is a strategic transport infrastructure network that connects all member states of the European Union, including roads, railways, airports, and waterways. The network is critical to ensuring the free movement of goods, services, and people across the EU, and its decarbonization is a key priority for the European Commission. The deployment of HRS along the TEN-T network will require significant investment in infrastructure, technology, and regulatory frameworks. However, the benefits of this transition are immense, with the potential to drastically reduce the carbon footprint of the transport sector and contribute to the creation of a sustainable hydrogen economy in Europe. An interactive map can also be reached and followed for the TENtech network[13].

5.3 RepowerEU

- The RePowerEU initiative aims at accelerating the transition to clean energy and reaching EU's climate and energy targets.
- In the hydrogen industry, it aims to support the development and deployment of green hydrogen technologies, including hydrogen production, storage, transportation and end-use.
- The plan includes a goal of 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes of imported renewable hydrogen in the EU.

RePowerEU is an ambitious initiative launched by the European Union to accelerate the transition to clean energy and help the EU reach its climate and energy targets for 2030 and 2050. The initiative is designed to support the deployment of renewable energy sources, such as wind, solar and hydropower, and to promote the use of clean hydrogen as a key enabler of the energy transition.

In the context of hydrogen, **RePowerEU aims to support the development and deployment of green hydrogen technologies, including hydrogen production, storage, transportation and end-use.** This includes support for the development of hydrogen production technologies such as electrolysis, as well as the development of infrastructure for hydrogen transportation and storage. The initiative also aims to support the deployment of hydrogen fuel cell vehicles and other hydrogen-powered equipment, such as forklifts, buses, and trains. **The EU aims to reach 10 million tonnes of domestic renewable hydrogen production and 10 million tonnes of imported renewable hydrogen in line with the plan.**

The RePowerEU initiative also aims to promote the use of hydrogen in the industry sector, for example in the production of chemicals and fertilizers. This includes support for the development of technologies for the production of hydrogen from renewable energy sources, such as wind and solar power, and for the development of technologies for the use of hydrogen as a feedstock in the chemical and fertilizer industries.

The initiative also includes measures to support the development of hydrogen clusters and networks across Europe, in order to facilitate the sharing of knowledge and expertise among stakeholders in the hydrogen sector and to promote cooperation between different actors in the field. This includes support for the development of hydrogen

[12] https://www.europarl.europa.eu/news/en/press-room/20230327IPR78504/fit-for-55-deal-on-charging-and-fuelling-stations-for-alternative-fuels

[13] TENtec Interactive Map Viewer (europa.eu)

demonstration projects, which will help to demonstrate the technical and economic viability of hydrogen technologies and applications.

To achieve these objectives, **the European Commission has proposed to allocate a significant amount of funding from the RePowerEU program to the hydrogen sector**. This includes funding for research and innovation, as well as funding for the deployment of hydrogen technologies and infrastructure. The commission also propose to set up a hydrogen alliance to bring together key stakeholders in the hydrogen sector, including industry, academia, and governments, to coordinate efforts and to develop a common strategy for hydrogen development in Europe.

5.3.1 REFuelEU Aviation & FuelEU Maritime

- The EU launched REFuelEU and FuelEU Maritime initiatives to accelerate the GHG emission reductions in aviation and shipping by 2050.
- The two initiatives align with the Nordic countries' long-term visions of transitioning their energy systems to renewable energy and offer opportunities for foreign collaboration.

The European Union has launched two major initiatives, namely the ReFuelEU Aviation and FuelEU Maritime strategies, to drive the adoption of sustainable aviation and maritime fuels in Europe. The initiatives aim to achieve a significant reduction in greenhouse gas emissions from aviation and shipping by 2050, with a specific focus on green hydrogen as a promising alternative to traditional fossil fuels.

The initiatives are expected to create significant market opportunities for businesses and organisations involved in the production and distribution of green hydrogen, particularly in the Nordic countries. The Nordic countries are well-positioned to capitalize on this growing market given their abundant renewable energy resources and strong track record in renewable energy deployment. This will enable the development and deployment of green hydrogen technologies and infrastructure to support the growing market for sustainable aviation and maritime fuels in Europe.

The ReFuelEU Aviation and FuelEU Maritime initiatives align with every Nordic country's long-term vision of transitioning their energy systems to renewable energy and offer significant opportunities for Nordic businesses and organisations to invest in and develop green hydrogen technologies and infrastructure to support the growing market for sustainable aviation and maritime fuels in Europe. Of course, Nordic companies by themselves are not able to fulfil all the needs, thus **international collaboration is needed for the Nordic countries to achieve their goals of generating significant amount of the needed fuels for these initiatives.**

5.4 EU strategy on energy system integration

To optimise and modernise energy systems as a whole system sector integrations will make it easier (EU strategy on energy system integration). The strategy towards sector integrations is to link the various energy carriers (gas, heat, cold, electricity, solid and liquid fuels) and collaborating with the end-use sectors (industry, transport, buildings among others as also illustrated in Figure 2 Hydrogen value chain from production to end use). ICT, digitalization, smart grids, meters, and flexibility markets). The path can look different in EU countries, some are presented in national energy and climate plans (NECPs) 2021-2030.[14]

[14] https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en

5.5 EU financing and fundings

The Innovation Fund´s 3rd Large Scale Call was launched in November 2022 and ran until March 2023 with a budget of EUR 3 billion. In addition, **Important Projects of Common European Interest (IPCEI)** were approved focusing on technology and production. In 2022 the commission approved, the Hydrogen value chain, **IPCEI Hy2Use** EUR 5,2 billion project. The project will cover a wide range of hydrogen value chain through different projects, such as large-scale electrolytic hydrogen production. The overall completion of the project is planned for 2036. A total of 76 technology and production projects received public funding amounting to over EUR 10 billion, some of these are in Figure 3 below.

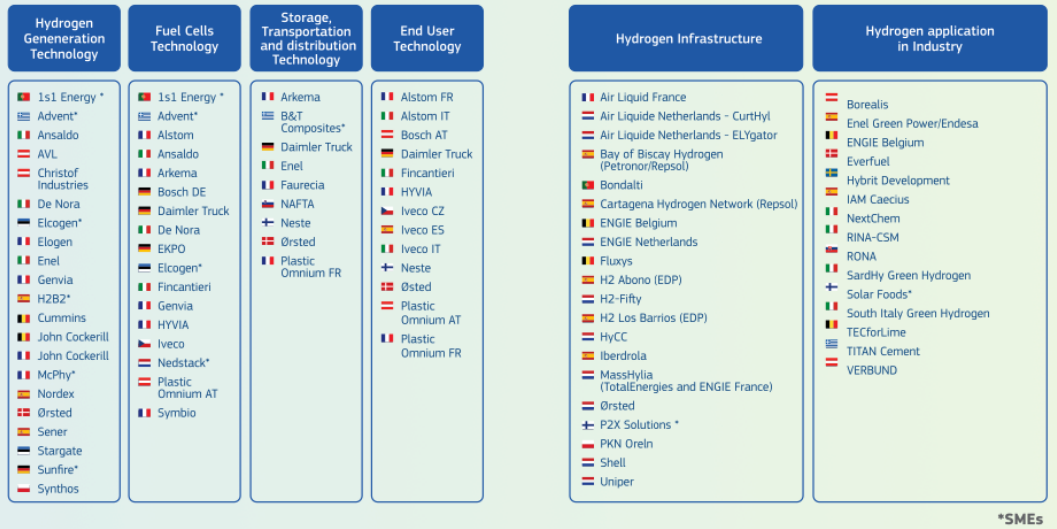


Figure 3 Financing and funding from 76 technology and production projects[15]

Set up in 2005, the EU ETS is the world's first international emissions trading system. It is now in its fourth phase (2021-2030). The cap on allowances was set at national level through national allocation plans (NAPs)[16].

In September 2022 European Commission President von der Leyen announced the establishment of **the European Hydrogen Bank** to connect future supply of renewable hydrogen with the demand objective of 20 million tonnes of renewable hydrogen. The Bank will facilitate renewable hydrogen production within the EU and imports, contributing to RepowerEU objectives and to the transition to climate-neutrality. The European Hydrogen Bank complements the EU's regulatory and supportive framework for establishing a full hydrogen value chain in Europe and supports the Net-Zero Industry Act. The Commission intends to operationalize all four pillars of the Bank by the end of the year, in continued dialogue with Member States and stakeholders. The European Hydrogen Bank aims to increase transparency on hydrogen demand, supply, flows, and prices while coordinating and blending with existing financial instruments to support hydrogen projects**. It will consist of two new financing mechanisms to support renewable hydrogen production within the EU and internationally**[17]**.**

[15] Source: European Clean Hydrogen Alliance, ISBN 978-92-76-60056-5, doi:10.2873/934256
[16] Development of EU ETS (2005-2020) (europa.eu)
[17] https://energy.ec.europa.eu/system/files/2023-03/COM_2023_156_1_EN_ACT_part1_v6.pdf

5.6 European Associations and alliances

1. **The European Clean Hydrogen Alliance**[18]

The European Clean Hydrogen Alliance was set up in July 2020 by the European Commission. With more than 1 650 members from different stakeholders the members are committed to the green transition of the EU economy. They represent the entire hydrogen value chain, covering renewable and low-carbon hydrogen, from production to transmission to its end-uses in mobility, industry, energy, and heating applications. The European Clean Hydrogen Alliance identified 840 hydrogen projects across all parts of the value chain.[19]

2. **Hydrogen Europe**

Hydrogen Europe is the European association representing the interest of the hydrogen industry and its stakeholders and promoting hydrogen as the enabler of a zero-emission society. With more than 400+ members, including 25+ EU regions and 30+ national associations, Hydrogen Europe encompasses the entire value chain of the European hydrogen and fuel cell ecosystem. Their vision is to propel global carbon neutrality by accelerating European hydrogen industry.

3. **The European Hydrogen Association (EHA)**

The European Hydrogen Association is an association located in Brussels, Belgium. The association has an objective to promote hydrogen as a clean energy carrier in transport. Currently, they represent Europe's 15 main organisations operating in the field of hydrogen and fuel cell technologies. EHA is network partner of the UNFCC Climate Technology Centre and Network.

[18] https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance_en
[19] https://single-market-economy.ec.europa.eu/industry/strategy/industrial-alliances/european-clean-hydrogen-alliance/project-pipeline_en

6 Denmark

6.1 Policy landscape

6.1.1 Energy mix

- Denmark's commitment to renewable energy, mainly offshore wind, presents a significant opportunity for the development and production of green hydrogen.
- The overall capacity of renewable energy production is expected to increase from 10GW to 30GW by 2040.
- The transition offers opportunities for businesses to invest in and develop necessary infrastructure and technologies for green hydrogen production.
- The government is expected to announce an allowance of a straight connection from windmills to electrolysers, opening more possibilities for green hydrogen.

Denmark's long-term vision of transitioning to renewable energy presents a significant opportunity for the development and production of green hydrogen. The country's commitment to renewable energy in the electricity and heating sector, along with its goal of achieving a complete transition to renewable energy by 2050, creates a favourable environment for the development of green hydrogen production. The transition to renewable energy offers opportunities for businesses to invest in and develop the necessary infrastructure and technologies for green hydrogen production. This includes investments in electrolysers, energy storage, and transportation infrastructure, which can enable the widespread adoption of green hydrogen as a fuel source.[20]

Currently, the Danish energy mix is still highly dependent on oil, with wind-power having had a significant increase throughout the current decade, as can be seen in Figure 4**. In 2021, Renewables amounted to a total of 48% of Danish energy production**, with wind-power totalling around 14%. In 2021, the country produced 110,73 TWh of energy, from which renewables amounted 52,93 TWh. The Danish energy production mix is illustrated more detailed in Figure 4.[21]

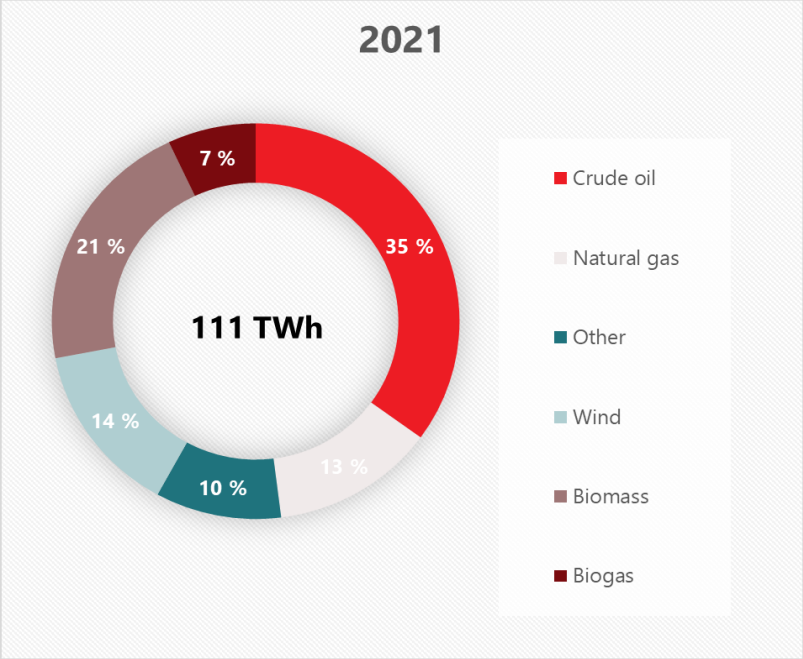


Figure 4 Danish Energy mix 2021

Underlined by the reform paper "Denmark can do More II", the green transition must happen at a much quicker pace than originally planned, driven by the European supply crisis and stronger climate change initiatives. The paper suggests that the transition must be more ambitious, with former goals for 2040 or 2050 now applying to 2030. For example, Denmark must quadruple its electricity generated from solar power and onshore wind turbines in just eight years.[22] In Figure 5, the current production capacity and the future forecasts can be seen.

[20] Energy Concept 2030 – Summary. 2015. Energinet. Available: https://energinet.dk/media/azacsx3d/notat-energy-concept-2030-english-summary.pdf
[21] Data based on Danish Energy Agency database. Available: https://ens.dk/en/our-services/statistics-data-key-figures-and-energy-maps/annual-and-monthly-statistics
[22] https://en.energinet.dk/about-our-news/news/2022/12/08/strategy-energy-in-time/

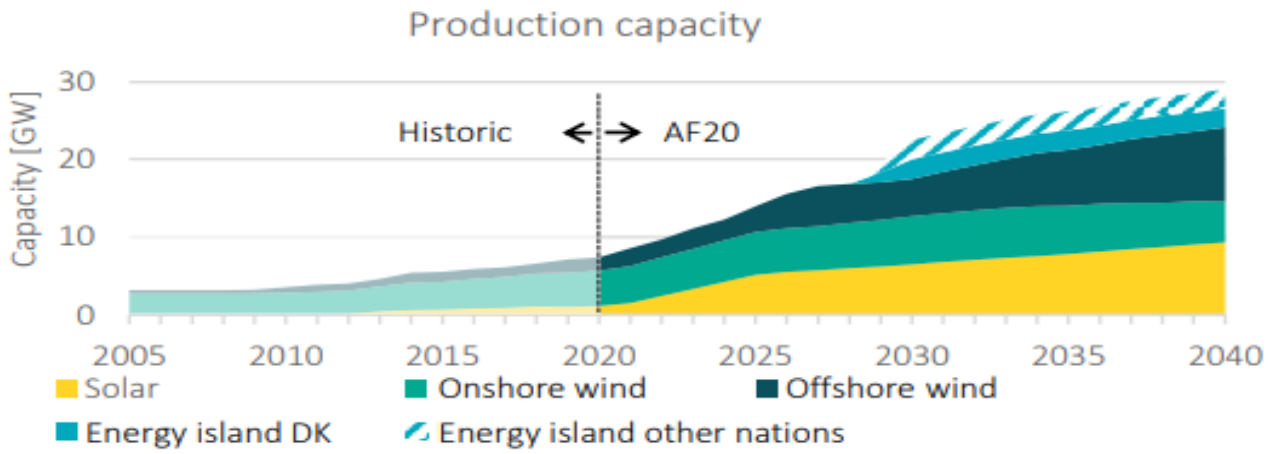


Figure 5 Danish production capacity

As can be seen from Figure 5**, the overall capacity of renewable energy production is expected to increase from approximately 10GW to 30GW (263 TWh) by 2040**, with the onshore and offshore wind having a significant share. Solar power is expected to increase rapidly towards 2040.

A positive look towards using renewable energy for hydrogen production was established, when the Danish Government announced it will allow a straight connection from windmills to electrolysers, without connecting windmills to the open grid. This could open more possibilities for green hydrogen, as the plants won't have to pay the costs that the grid connection requires. The direct connection option also opens possibilities for companies to ensure their energy used to be 100% renewable, which could be necessary in order to certify that the produced hydrogen is green hydrogen. The European Commission is currently working defining the conditions under which hydrogen and other energy carriers can be considered Renewable Fuel of Non Biological Origin (**RFNBO**) and will introduce criteria to ensure that renewable hydrogen is produced only where sufficient renewable energy is available. On February 2023, the EU Commission defined clear set of rules on what constitutes green, or RFNBO hydrogen. These Delegated Acts identifies 5 production routes for green hydrogen production, **with one being direct connection between renewable energy and RNFBO production and for others related to the grid connection, making the Danish decision to allow direct connections very timely.** These delegated acts are subject for revision in 2028, when their impacts will be further assessed by the EU Commission.

The Danish Open Door scheme, which allows companies to present their own proposals for wind power projects, was suspended recently, creating uncertainty for the future of the scheme in the Danish wind power build-up. The Danish Energy Agency stated that the scheme was potentially in breach of EU law. According to WindEurope's CEO "*Pausing their established and effective "open door" approach to offshore wind development now will seriously undermine these targets. It will create uncertainty for more than 20 GW of wind farms currently under development.*"[23] However, already in 2023 there has been several offshore projects that have been allowed to go forward with the Open Door scheme, even if it was paused for the moment.

[23] https://www.offshorewind.biz/2023/02/08/offshore-wind-industry-says-danish-open-door-scheme-suspension-absurd-and-bad-news-for-european-energy-transition/

6.1.2 Outlook of the hydrogen industry

- There are several companies operating in the PtX and CCU/S area in Denmark, covering the entire value chain of hydrogen.
- Big well-established companies paving the way in the development of green hydrogen. Several big consortiums announcing large-scale projects up to 3GW capacity.
- Danish companies among the most innovative companies in the field of hydrogen.
- Power-to-X strategy announced in 2022, including a EUR 170 million tender available for hydrogen projects in Denmark.[24]
- 43 projects worth of around 22,5GW by 2030 announced.

Currently, there are around 70 companies operating in the Power-to-X (PtX) and Carbon Capture, Utilization and Storage (CCUS) area in Denmark. These companies cover the entire value chain of hydrogen production, from the production of hydrogen from renewable energy sources to the distribution and storage of hydrogen.[25] **The value chain is particularly strong on the R&D sector**, as can be seen from the number of patents Danish companies have received for (green) hydrogen in the 21st century. Some of the strongest parts of the value chain in Denmark include renewable energy production and electrolysis. Denmark has been investing heavily in offshore wind power and has become a leading global player in this field. The country also has a strong base of companies involved in electrolysis technology and who have proposed their ambitions for several large-scale electrolysis projects[26].

Denmark has a strong base of companies and research institutions that are focused on developing and deploying renewable energy and hydrogen technologies, and electrolysis is a key are of focus. For example, companies like **Topsoe, Green Hydrogen Systems, Danfoss** and **Orsted** are all working with electrolysis technology. However, there are still **areas where the value chain in Denmark could be strengthened,** such as **hydrogen storage, transportation, and utilization.** It is also uncertain whether current companies working with electrolysers will have enough capacity to provide all the electrolysers needed to fulfil Denmark's ambitious green hydrogen production goals. **While Denmark has made progress in hydrogen storage, more work needs to be done to develop efficient and cost-effective methods for storing and transporting hydrogen.** Additionally, there is a need for further development and deployment of fuel cell technology to enable the utilization of hydrogen as a fuel for transportation and other applications.

Some significant actors on Danish hydrogen economy are listed in Table 3. While there is a strong appetite for collaboration among Danish companies, there are also competitive dynamics that Dutch firms should be aware of when seeking to enter specific segments of the value chain. It is important for Dutch companies to carefully assess their value proposition and competitive positioning in order to effectively navigate the Danish market and identify optimal partnership opportunities.

[24] https://www.ethics.dk/ethics/eo#/2b3ea81c-1ca9-4d3d-b563-b87f629fb79c/homepage
[25] Green Hydrogen is Danish Hydrogen. 2022. State of Green. Available: https://stateofgreen.com/en/publications/green-hydrogen-is-danish-hydrogen/
[26] See Table 4 for more detailed context.

Table 3 Some players of Danish hydrogen value chain.

Energy & Storage	**Production**	**Infrastructure & supply**	**End-use**	**Technology, services & support**
RWE Renewables Denmark	Everfuel	Evida	Everfuel	GreenLab
Copenhagen Infrastructure Partners	Topsoe	Energinet	A. P. Moller-Maersk	COWI
Siemens Gamesa	Green Hydrogen Systems	DFDS	DSV Panalpina	Arkitema Architects
Poul Schmith	Ballard Power Systens	BlueKolding	DFDS	New Power Partnership
GreenLab	Danfoss	Molslinjen	SAS	AFRY
GreenGo Energy	Orsted	Everfuel	Molslinjen	Sweco
New Power Partners	Umwelt Energy	Vireon (Norwegian Hydrogen AS)	GreenLab	Ballard Power Systems Europe
corre.energy	GreenLab		Air Liquide	Blue World
Eurowind	Skovgaard Energy		Hyundai	DNV
Gas Storage Denmark	Nel Hydrogen			ITM Power
	Advent Technologies			
	Ballard Power Systems Europe			
	ITM Power			
	H2 Energy Europe			

In December 2022, **the Danish Energy Agency granted the first-ever permit for a CO_2 storage project in Denmark**, including the injection and storage of up to 15 000 tons of CO_2. The permit is valid for a period of four months, expiring on 1 April 2023. The pilot project is an important part of Denmark's future on CO_2 storage. The project is part of the EUDP-supported "Project Greensand Phase 2 – Enabling environmentally safe and long-term storage of CO_2 by 2025" aiming to generate the necessary knowledge to subsequently deliver a storage capacity of 0,5 to 1,5 million tonnes of CO_2 yearly from 2025 in the Nini field.[27]

Shortly afterwards, in February 2023, Denmark awarded exclusive licenses for exploration of full-scale CO_2 storage in the Danish North Sea, which marks the beginning of a new era for the country's ambitions of achieving climate neutrality. This is the first time such licenses have been awarded in Denmark, and they grant the exploring company exclusive rights to the area for up to six years, during which they can explore and evaluate the potential for CO_2

[27] https://stateofgreen.com/en/news/denmark-awards-its-first-co2-storage-permit-in-the-north-sea/

storage. If a suitable location is found, the permit can be extended for up to 30 years for storage operations. The successful conclusion of the tender marks the end of the first annual tender round for licenses for exploration of full-scale CO_2 storage on the Danish continental shelf. Denmark is looking to leverage the full-scale storage of CO_2 offshore, which is a known technology that has been in operation in Norway since 1996. In Denmark, the technology will be tested in connection with Project Greensand, which is a pilot and demonstration project by INEOS E&P funded by the EUDP. The Geological Survey of Denmark and Greenland (GEUS) has estimated that the Danish subsurface theoretically can store up to 22 billion tons (GT) of CO2, which is equivalent to between 500 and 1000 years of total Danish emissions at current levels. **This presents a significant opportunity for Dutch companies to explore potential partnerships and collaborations with Danish firms in this area,** leveraging their expertise and experience in carbon capture and storage. Additionally, the Netherlands has set ambitious climate goals, and this could be an opportunity for Dutch firms to learn from Denmark's experience and potentially replicate similar projects in the future.[28]

Denmark's first underground hydrogen storage facility project is planned to start in 2025 with **Gas Storage Denmark, Corre Energy, and Eurowind Energy** as operators and developers. The storage will be a salt cavern and has finished its feasibility study.[29]

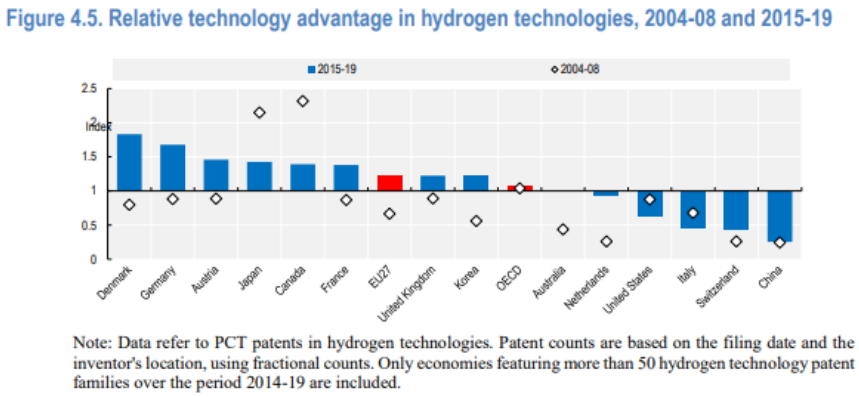


Figure 6 Danish patents in hydrogen

Denmark's hydrogen companies are well positioned to gain a strong market position in the industrial expansion of global market for green fuels. The country has a strong tradition of innovation in the energy sector, and Danish companies have developed key technologies that are needed for producing large PtX production plants that are also efficient. This is reflected in the fact that, according to the OECD, **Denmark is one of the countries with the highest specialization in hydrogen patents** in the world between 2015 – 2019[30], as illustrated in Figure 6.

Current patents also indicate Danish stronghold in green transition solutions as a whole. In 2021, Danish companies obtained **551 green patents** at the European Patent Office, most per million inhabitants in Europe. This equals to 93 green patents per million inhabitants[31], showcasing a solid first place when compared to 24 other western countries. From Figure 7, it can be seen that Denmark, Switzerland, Sweden, and Finland are all leading in the number of green patents published per million inhabitants. Whereas Denmark had 93 green patents per million inhabitants, two other Nordic countries – Sweden and Finland had 37 and 33, respectively.

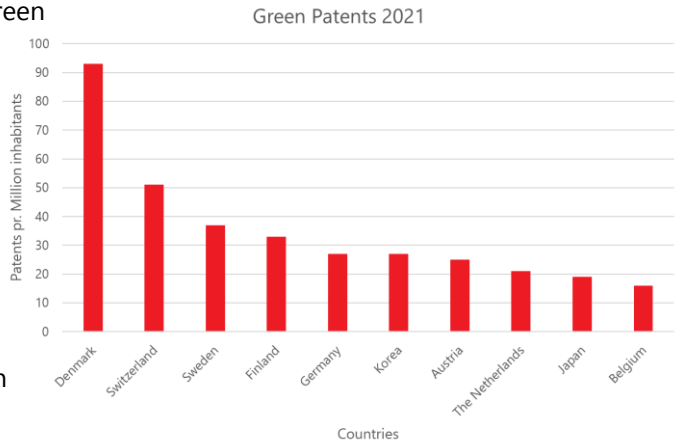


Figure 7 Green patents 2021 at the European Patent Office

[28] https://ens.dk/en/press/ministry-climate-energy-and-utilities-grants-denmarks-first-full-scale-co2-storage-permits
[29] Northwest European Hydrogen Monitor. International Energy Agency. 2022. Available: https://iea.blob.core.windows.net/assets/38ceb32d-9d49-4473-84c7-6ba803f8de08/NorthwestEuropeanHydrogenMonitor.pdf
30 https://www.oecd.org/sti/intellectual-property-statistics-and-analysis.htm
31 https://stateofgreen.com/en/news/danish-companies-obtain-the-most-green-patents/

Danish companies were also particularly strong in green patents at the United States Patent and Trademark Office (USPTO), where Danish companies had **65 patents per million inhabitants published**, 2 more than 2nd placed South-Korea (63).

The Danish Hydrogen market is currently experiencing significant growth, with **several large-scale projects announced in recent years.**[33] These projects have a collective capacity of 7 GW, which exceeds the level of capacity expansion that the Danish Energy Agency bases its projections on. This suggests that there will be an increased demand for green electricity in the future, which will drive further growth in the Danish hydrogen market. On top of that, on January 24th, 2023, GreenGo Energy announced that it will develop an energy park in Ringkøbing-Skjern municipality, where the company will realize 2GW of Power-to-X.

It's worth mentioning that the hydrogen pipeline used for transport entails a monopoly, meaning that establishing a fully and competent hydrogen infrastructure requires effective and appropriate market regulation to ensure equal access to the system and low prices for consumers of the PtX products.[32] It is worth noting, that the companies operating in the hydrogen industry are not all newly established companies or start-ups, but rather big companies trying to find new streams of revenue. Overall, the Danish hydrogen and PtX markets are in a strong position to capitalize on the growing global demand for green fuels. With a well-established industry, a strong tradition of innovation, and significant growth potential, these markets represent a promising opportunity for companies looking to invest in the green energy sector. Table 4 gives an overview of the major announced and ongoing hydrogen projects in Denmark. The data is gathered from Hydrogen Denmark data bank. Currently, according to Hydrogen Denmark's data bank, **there are 2,41 MW hydrogen production in operation with 44 announced projects for the future. Electrolysis production capacity of Danish factories is around 400 MW/year.**

32 Danish Power-to-X strategy. 2022.

Table 4 Major Hydrogen projects in Denmark[33]

Project (company) name	Location	Owners / Stakeholders	Capacity	End-use	Production start-up	Value chain[34]
BrintØ	North Sea, Denmark	Copenhagen Infrastructure Partners (CIP), COWI	10GW	Green hydrogen / Power-to-X	2030	Production Transformation
Skovgaard Idomlund	Idomlund	Skovgaard Energy, Ørsted	2,85GW	Power-to-X	--	Production Transformation
Megaton	Ringkobing-Skjern	GreenGo Energy, COWI, Arkitema, New Power Partners	2GW	Green hydrogen Power-to-X	--	Production Transformation Heating
Green Fuels for Denmark	--	Ørsted, Copenhagen Airports, A. P. Moller-Maersk, DSV Panalpina, DFDS, SAS, Everfuel, NEL, Molslinjen, Topsoe, COWI, Københavns Kommune, Region Hovedstaden	1,3GW	Green hydrogen Green jet fuel	1st phase 2025 2nd phase 2027 3rd phase 2030	Production Transformation
Green Hydrogen Hub	Northern Jutland	corre.energy, Eurowind, Gas Storage Denmark, Everfuel	1GW	Power-to-X	1st phase 2025 2nd phase 2030	Production
H2 Energy Europe	Esbjerg	H2 Energy Europe	1GW	Power-to-X	2024	Production Transformation
HØST	Esbjerg	CIP, DNV	1GW	Power-to-X	2026	End-use

In 2020, a consortium consisting of leading Danish companies covering the whole value chain of hydrogen – production, distribution, and consumption, released a "**Green Fuels for Denmark**" project of developing a hydrogen fuel facility based on electrolysis. The project expects achieving a capacity of 1,3 GW in 2030. In 2030, the project should deliver over 250 000 tonnes of sustainable fuels for buses, trucks, maritime vessels, and airplanes annually. The consortium consists of both demand and supply side of the project, with companies such as Copenhagen Airports, A.P. Moller-Maersk, DSV Panalpina, DFDS, SAS, and Ørsted being part of the project. **The project has received a considerable funding of EUR 81 million (DKK 600 million) from the IPCEI program.**[35,36]

Over the next 5 years, it is anticipated that several segments from the Danish hydrogen value chain will receive considerable funding and investments. One of the most notable is the Power-to-X segment as the country has already published a strategy promoting it. The strategy included **world's first Power-to-X Tender**[37], which earmarked EUR

[33] Hydrogen Denmark has a constantly updating list for all hydrogen projects in Denmark. Available: https://brintbranchen.dk/brintprojekter-i-danmark/
[34] Please refer to Figure 2
[35] https://hydrogen-central.com/orsted-danish-power-x-flagship-project-green-fuels-denmark-dkk-600-million-part-of-denmarks-participation-in-the-european-ipcei-programme/
[36] https://stateofgreen.com/en/news/leading-danish-companies-join-forces-on-an-ambitious-sustainable-fuel-project/
[37] https://www.offshorewind.biz/2022/09/12/denmark-working-on-worlds-first-power-to-x-tender/

170 million to support the realization of green hydrogen and clean fuel production solutions.[38] Danish companies are trailblazers in the industry, and it is expected that the government wants to support their companies' market position in the future too. Several funding initiatives to support the market introduction of Power-to-X have already been implemented in the country during the 2020s, and it is expected that more funding will follow. There are already several projects announced in hydrogen production and as the country aims to reduce its GHG emissions rapidly, it must further increase its investment in green hydrogen production. It is extremely likely that additional funding opportunities shall be given for infrastructure developments such as hydrogen storage facilities and the government aims to convert parts of its gas pipelines into hydrogen pipelines. The Research & Development -sector and innovation as whole is expected to be the most efficient way to receive fundings in the green hydrogen field, according to a representative from State of Green.

By 2050, Denmark has a goal of being climate neutral, leading to an increasing need for hydrogen and renewable energy. It is likely that PtX will have a significant role in aviation and most of the shipping industry by 2050. National reduction potential by 2050 is more than 3,5 million tonnes of CO_2. The government is pushing for a climate-neutral shipping sector by 2050.[39]

Whereas many countries are only currently discussing or planning future education for the hydrogen industry or have limited individual courses available, Denmark has already made significant progress in this area. For example, Aalborg University currently has a "Fuel Cells and Hydrogen Technology" master's degree available[40] which highlights that the research institutes have understood the need of skilled personnel working with hydrogen in the near future. Skilled labour is seen as a bottleneck for many different countries, including the Netherlands and the other Nordic countries. By being a forerunner in education, **Denmark can be expected to be able to answer the present gap of educated people in the field of hydrogen.**

As the country has ambitious goals for green hydrogen production and there are several different national funding programs available**, it is expected that each part of the value chain is able to receive funding in the following 5 years**. Especially renewable energy production, infrastructure, and transportation are in need of funding. On 24th of March the German Vice Chancellor and Danish Minister of Climate, Energy and Utilities reached an agreement to **support the development and implementation of hydrogen infrastructure projects for potential operators and users.[41]** This further proves that especially infrastructure is a segment receiving public support in the next 5 years.

6.1.2.1 The Danish Power-to-X strategy

The Danish PtX strategy lays out four objectives to support the development of PtX technologies as a way to help Denmark become a more climate-neutral society through indirect electrification. The strategy aims to boost the use of PtX in sectors where direct electrification is not possible, such as segments of the industrial, heavy road transport, shipping, and aviation sectors.[42] The four objectives as outlined in the strategy are:

Power-to-X must be able to contribute to the realisation of the objectives in the Danish Climate Act
The government believes that PtX is necessary in the green transition and that it should primarily be promoted in sectors where direct electrification is not feasible. This could indicate that these sectors will receive funding from the

[38] https://www.ethics.dk/ethics/eo#/2b3ea81c-1ca9-4d3d-b563-b87f629fb79c/homepage
[39] https://www.reuters.com/business/sustainable-business/denmark-us-12-other-nations-back-tougher-climate-goal-shipping-2021-11-01/
[40] https://www.en.aau.dk/education/master/energy-engineering/fuel-cells-and-hydrogen-technology
[41] https://stateofgreen.com/en/news/denmark-and-germany-to-build-green-hydrogen-pipeline-by-2028/
[42] The Government's strategy for Power-to-X. 2022. Available: https://ens.dk/sites/ens.dk/files/ptx/strategy_ptx.pdf

government in the next 5 years. The strategy also notes that PtX fuels have the potential to provide the cheapest CO_2 reductions in certain sectors and that between 2022 and 2050, PtX will likely play a significant role in aviation, the majority of shipping, and a portion of the Danish Defence's emissions. Additionally, PtX products have the potential to be used in the production of materials and chemicals, such as e-fertilizers, but these products are not primarily produced in Denmark, so their effects will not contribute to Danish national reductions, which might make them less important for the country. The Danish Energy Agency believes that PtX products can contribute up to 2 million tonnes of CO_2 reductions by 2030.

The regulatory framework and infrastructure must be in place for Denmark to utilise its strengths and allow PtX to perform on market terms in the long run.

The government plans to push for ambitious requirements for the aforementioned fit-for-55 package, including the aviation and shipping sectors, which will result in a higher national and international demand for PtX products. The production costs of hydrogen & PtX will lower in a long term. It will also be necessary to create the appropriate framework conditions for production, transport, storage, and use of hydrogen & other PtX products, and to be able to document the green value of PtX products and have that value reflected in the market price. The government also aims to ensure that Danish hydrogen can compete with biofuels and foreign PtX products by creating appropriate economic and regulatory frameworks. To achieve this, the government plans to invest EUR 170 million (DKK 1,25 billion) towards operating support to produce hydrogen and other PtX products, and to enter into dialogue with the EU commission on allocating EUR 46 million (DKK 344 million) of REACT-EU funds and the Just Transition Fund to establish a national investment funding scheme for innovative green key technologies with a particular focus on PtX and hydrogen, including green production and demonstration projects. **Since 2019 the government has invested EUR 54 million (DKK 400 million) into research, development, and demonstration of PtX solutions** via the EUDP grants and Danish Energy Agency's energy storage funding pool.

The integration between PtX and the Danish energy system must be improved.

The integration includes developing the necessary infrastructure and regulatory framework to ensure that PtX can be effectively integrated into the existing energy system and that it can be used to support the integration of renewable energy sources such as wind and solar power. This will involve coordinating the development of PtX technologies with other elements of the energy system, such as electricity transmission and distribution networks, and working with other stakeholders to ensure that PtX can be used to support the transition to a more sustainable energy system.

Enable Denmark to export PtX products and technologies.

The fourth objective includes developing a competitive Danish PtX industry that can produce high-quality products and technologies that can be sold on the global market. It also involves working with other countries and international organisations to promote the use of PtX products and technologies, and to support the development of international standards regulations that will facilitate the trade of PtX products and technologies.

On top of the Power-to-X strategy, State of Green is working on a white paper on Power-to-X, which will expand on their previous white paper: "Green Hydrogen is Danish Hydrogen"[43]. The new document is expected to be published somewhere near September.

[43] https://stateofgreen.com/en/publications/green-hydrogen-is-danish-hydrogen/

6.1.3 Production methods

- The country is focusing on the development of green hydrogen, with the government establishing initiatives to support the development and deployment of green hydrogen technologies.
- Denmark's location, with 50% of its electricity generated from wind and solar power together with development of energy islands, provides great potential for green hydrogen electrolysis.
- Companies and government are mainly targeting green hydrogen production, but there is also the potential for blue hydrogen production. A white paper on CCU/S published by State of Green.

Denmark, like all the Nordic countries, has ambitious goals on their greenhouse gas emissions and has set a target of reducing the GHG emissions by 70% by 2030, leading up to a 100% reduction by 2050 compared to 1990-levels. The ambitious goals require the development of green or blue hydrogen for the country to have massive reductions in its emissions. To achieve the goals, Denmark published its hydrogen and Power-to-X -strategy in late 2021 as mentioned in chapter 6.1.2. The strategy mainly focuses on the Power-to-X possibilities, which the Danish Government seems to see as the most potential segment of hydrogen economy, and the country's CO_2 reductions. Denmark's geolocation gives it a wide range of possibilities for creating green hydrogen. Approximately 50% of the electricity produced in the country is derived from wind and solar power, and this represents just the initial phase of its green energy initiatives. Denmark is building energy islands of 13 GW capacity, expected to start their first phase of operations between 2030-2033 with a capacity of 3 GW, which has a great potential for hydrogen electrolysis too.[44] The renewable energy produced from the energy islands would contribute to a 600% increase in renewable energy sources, boding well for the outlook of green hydrogen production in Denmark[45]. **It is worth mentioning, that Danish companies and the industry as a whole is mainly, or fully, focusing on green hydrogen.** If blue hydrogen gets more acceptance within the regulators and the EU, this might cause problems for Danish companies who most likely will not be able to transform into blue hydrogen producers in a fast manner.

The Danish Government has stated that green hydrogen will play a key role in the country's energy transition and has established several initiatives to support the development and deployment of green hydrogen technologies. This includes investments in research and development, support for demonstration projects, and the establishment of partnerships with industry and other stakeholders.

In addition to green hydrogen, Denmark is also exploring other sustainable hydrogen production methods, including blue hydrogen. The country recognizes that these methods can play a role in the transition to a more sustainable energy system but views green hydrogen as the preferred option due to its lower carbon footprint and its potential to contribute to the reduction of greenhouse gas emissions. Even if the main target for the country is to produce green hydrogen, it does have a lot of sources for CO_2 in southern parts of the country, and it has been published that the country aims to trade hydrogen for CO_2 with Germany[46] in the future. There has also been a CCU/S White paper been published by State of Green.[47]

[44] Green hydrogen is Danish hydrogen – How Denmark is developing the green fuels of the future. State of green. 2022. Available: https://stateofgreen.com/en/publications/green-hydrogen-is-danish-hydrogen/

[45] The Government's strategy for Power-to-X. Danish Ministry of Climate, Energy and Utilities. 2021. Available: https://ens.dk/sites/ens.dk/files/ptx/strategy_ptx.pdf

[46] https://energywatch.com/EnergyNews/Policy___Trading/article14350488.ece

[47] Carbon capture, utilisation, and storage. State of Green. 2022. Available: https://stateofgreen.com/en/publications/carbon-capture-utilisation-and-storage/

6.1.4 Trade

- The country will most likely be a net exporter of hydrogen and its derivatives.
- According to Gas for Climate, Denmark would export somewhere between 25 to 70 TWh of hydrogen by 2050.
- Trading agreement signed with Germany, a pipeline to start operating by 2028. The country has a goal to provide 25% of Germany's hydrogen needs.
- Potential to export hydrogen to the Netherlands via pipeline or vessels. If done via pipeline, most likely through Germany to the Netherlands.

Where Denmark has great ambitious' and remarkable good position to produce green hydrogen and its derivatives due to its excellent wind and solar-power potential, the country does not have great amounts of off takers for the products. The off-take readiness is also rather low, according to the experts interviewed for the study. The country is currently in discussions with Germany regarding hydrogen exports. Denmark and Germany are aiming to trade CO_2 and H_2 together so that Denmark would provide hydrogen for Germany and would receive CO_2 from Germany. On 24th of March, **Denmark and Germany agreed to build a land-based pipeline, making it possible for green hydrogen transportation from 2028 onwards.**[48] Denmark aims to provide 25% of the German green hydrogen needs through the soon-to-be established pipelines. According to the Minister of Climate, Energy, and Utilities in Denmark, the country has **the potential to become a leading green energy producer in Northern Europe** and can leverage its upcoming self-sufficiency in green electricity to produce and export green fuels. To achieve this, investments in infrastructure are necessary, and Danish companies are prepared to take on this challenge.

According to Gas for Climate[49], **Denmark would be a net exporter of hydrogen, exporting somewhere around 25 to 70 TWh of H_2 by 2050,** towards Central and Western Europe in two different scenarios. According to State of Green, Denmark's sweet spot is to export specialised hydrogen technology and infrastructure, as well as exporting hydrogen as whole. Denmark and its related industries have a strong focus on the production of not only hydrogen, but also its derivatives, such as green ammonium and e-fuels. It is expected that the country is aiming to export these products, as a small country like Denmark does not have the demand for the final products. It is worth mentioning, that some experts in Denmark believe that **Denmark as a country would be an innovation and piloting centre for hydrogen products, but that the bigger scale-up projects would happen somewhere around Europe.** This would eventually lead to a situation where Danish knowledge would be exported instead of the final products. According to the latest news, announced projects, and Danish official ambitions', Denmark would likely produce enough hydrogen and PtX products to export them.

Hydrogen Denmark has published a data bank[50] on Danish hydrogen numbers, stating that in 2030, Denmark would have a production capacity of around 22 533 MW, with consumption being only around 2 300 MW, **signalling great excess production and thus great export possibilities for the Danish companies.**

[48] https://stateofgreen.com/en/news/denmark-and-germany-to-build-green-hydrogen-pipeline-by-2028/
[49] Assessing the benefits of a pan-European hydrogen transmission network. Moultak et al. 2023. Available: https://gasforclimate2050.eu/news-item/gas-for-climate-consortium-kicks-off-a-large-energy-system-modelling-study-assessing-the-benefits-of-a-pan-european-hydrogen-transmission-network/
[50] https://brintbranchen.dk/brintprojekter-i-danmark/

6.1.5 Infrastructure

- Transmission operated by Energinet; distribution operated by Evida.
- Presently no hydrogen pipelines, establishment of these are required for the hydrogen economy to flourish. Natural gas infrastructure is in place, possible to transform into hydrogen pipelines.
- Energinet is an active participant in European Hydrogen Backbone project.
- Some refuelling stations available, all operated by one company: Everfuel.

For Denmark, the transmission system for both, electricity and natural gas is owned, operated, and developed by **Energinet,** which is an independent public enterprise owned by the Danish Ministry of Climate and Energy. Energinet takes account of the security supply, the climate, and the environment, while also ensuring open and equal access for all users of the network. The distribution of electricity is operated by a number of different regional distribution companies. Both gas and electricity transmission grids are connected to the wider European energy market through interconnectors with neighbouring countries. These interconnectors allow for the import and export of energy as needed to balance supply and demand. The transmission grids in Denmark have been designed to integrate a high penetration of renewable energy sources into the grid, to support the country's goal of achieving 100% renewable energy by 2050. Denmark's distribution grid covers most of the country. **Evida** is the national gas distribution company which owns the distribution infrastructure. Evida's task is to design, operate and maintain the gas distribution network throughout the country as part of Denmark's critical infrastructure.[51] The utilization of hydrogen and multi-quality gases offers a promising pathway for decarbonizing both the Danish gas grid and economy. For this purpose, **it is essential to establish pipelines that facilitate hydrogen production and offtake, including potential export scenarios.** These pipelines can either be retrofitted onto the existing infrastructure or constructed as new dedicated ones. The collaboration between the transmission system operator Energinet and the distribution system operator Evida is critical in enabling the decarbonization of domestic energy usage and the export of hydrogen to Germany. Additionally, it will also facilitate the transmission of hydrogen from the North Sea, Norway, and Sweden to the rest of Europe. The optimization of the gas grid model based on production and offtake scenarios will be necessary to maximize efficiency and achieve sustainable goals.[52] Total amount of investments in the domestic pipeline infrastructure is expected to amount around EUR1,10 billion. These investments are highly recommended and according to Deloitte, every 1 DKK invested in the Danish hydrogen pipeline results in a socio-economic gain of DKK1,98 (EUR0,27), signalling a very positive net-value for the investments.[53] Energinet has also been active on the studying phase of the **European Hydrogen Backbone** which would be essential for the Danish hydrogen economy to grow, opening several possibilities for cost effective transportation of the produced green hydrogen. In March 2023, **Germany and Denmark signed an agreement for hydrogen pipeline which is expected to start operations by 2028.[54]** The pipeline aims to boost the adoption of green hydrogen as a sustainable energy source and is expected to further boost investments in the Danish hydrogen landscape.

Currently, according to **LBST**, a company that has operated a hydrogen refuelling stations -database since 2005, Denmark has 10 refuelling stations operating in the country[55], all owned by the same company, **Everfuel.** In the latter half of 2022, Everfuel announced it had received partial funding for building eight new hydrogen refuelling stations from which 5 will be located in Denmark. This funding was provided by the EU CEF AFIF program.[56] A subsidiary of

[51] https://evida.dk/om-evida/
[52] Techno-Economic Analysis of a Danish Hydrogen Infrastructure. DNV Denmark A/S. 2022. Available: https://evida.dk/media/an1dmo1k/dnv-report-energy-system-modelling-for-hydrogen-production-and-offtake.pdf
[53] Cost-benefit analyse a fen dansk brintinfrastruktur. Deloitte. 2022. Available: https://evida.dk/media/adjgkjrs/deloitte-hydrogen-cba-report-dk-v6b.pdf
[54] https://fuelcellsworks.com/news/germany-and-denmark-sign-agreement-for-hydrogen-pipeline-by-2028/
[55] https://www.h2stations.org/
[56]https://news.cision.com/everfuel-a-s/r/everfuel-receives-grant-for-building-eight-hydrogen-stations,c3630817

Norwegian Hydrogen AS, **Vireon**, has announced it aims to be become the largest supplier of hydrogen for heavy transport in the Nordics[57] and the company has opened an office in Denmark too. However, the company is a newly established subsidiary, and they have no refuelling stations under construction yet.

Energinet's Power grids needs analysis -document states that majority of Denmark's power grid was built in the mid-20th century and **is now nearing the end of its lifespan**. Many components, particularly those at high voltage levels, need to be replaced or upgraded. This reinvestment is particularly urgent for facilities that are in poor condition.[58]

6.1.6 Policies

- Denmark is introducing regulations to promote renewable energy fuels and is aiming to develop a national regulation for the hydrogen markets in the country.
- The current legislation and regulatory frameworks for the hydrogen economy in Denmark are not sufficient and need to be further developed.
- The Danish Government offers significant financial incentives for companies to invest in R&D and innovation, while also supporting the country's transition to a more sustainable economy.
- The new law for electricity production is expected to significantly boost green hydrogen production, but the temporary suspension of offshore wind projects has created uncertainty for wind-power companies in Denmark.

The Danish Government introduced regulation of renewable energy fuels for vehicles starting in 2022, which helps promote climate-friendly fuels. There is also a decision made that will incorporate ILUC values into the national fuel regulation by 2025. **The country aims to initiate a 360-degree review of Denmark's legislation in relation to hydrogen and to develop a national regulation for the hydrogen markets in Denmark.[59]** It is also notable, that most of the companies in the field of hydrogen or Power-to-X -products in Denmark are requesting adjusted framework conditions and regulation that is transparent for the actors rather than public sector funding. All parts of the hydrogen value chain: Production, transporting, storing, and utilisation require robust regulation in many areas, such as safety, market, environment, et cetera. However, currently **there is not enough regulation regarding the hydrogen economy in the country yet.**

Current legislation has not been developed with the speed of hydrogen and PtX technology's development. Meaning that the legislation and regulatory frameworks must be developed further in the country. The complex legislation can lead to a situation where investors are uncertain about the framework they are about to be working in, which, can create delays in the construction of PtX plants. National regulations should make building PtX -plants in Denmark as smooth as possible, however, this is presently not necessarily the case in Denmark. Currently, there is no documentation system on whether carbon containing PtX products can be categorised as green or not. The government aims to develop a national regulation to ensure transparent market conditions and to create opportunities for existing natural gas pipes to be converted to transport hydrogen. According to the information provided in the Danish Hydrogen Strategy, the launch of the EU's gas and hydrogen package in December 2021 includes a proposal for the design of competition regulation for hydrogen at the European level. This suggests that pan-European rules for hydrogen are still being developed and will not be implemented in Danish law until the end

[57] https://www.norwegianhydrogen.com/news/vireon-as-to-become-the-largest-supplier-of-hydrogen-for-heavy-transport-in-the-nordics
[58] Long-Term Development Needs in the Power Grid. Energinet's long-term development plan 2022 – Needs Analysis. Energinet. 2022.
[59] The Danish Power-to-X strategy. 2022. Available: https://ens.dk/sites/ens.dk/files/ptx/strategy_ptx.pdf

of 2025. Denmark, however, recognizes the need for some form of competition regulation for hydrogen pipeline transport even before the pan-European rules are implemented in order to ensure fair terms of competition.[60]

Denmark has a favourable tax climate promoting commercial research, with corporate tax rate of 22% being the key component of the country's favourable tax climate. To further bolster its attractiveness to businesses, the Danish Government has implemented **a permanent R&D deduction of 130%, aimed at promoting commercial research and accelerating green investments.** This measure offers significant financial incentives for companies to invest in R&D and innovation, while also supporting the country's transition to a more sustainable economy. In addition, companies conducting R&D in Denmark may qualify for a cash reimbursement of 22% of losses related to those costs, up to a maximum tax value of DKK 25 million.[61]

In early 2023, the Danish Government enacted a new law for electricity production that is expected to bolster hydrogen production. Previously, it was not possible to establish a direct connection between electricity production sites, such as wind turbines, and their usage points, such as electrolysers. As a result, connecting electricity production machines to the Danish electricity grid was necessary. However, with the newly adopted law, direct connections are now permissible. The adaptation of this law is expected to significantly boost green hydrogen production, as hydrogen producers can now build wind turbines solely for the purpose of generating electricity for hydrogen production. As the EU's regulations continue to evolve towards a situation where green hydrogen production can only be considered green if the electricity used for production goes in accordance with the rules mentioned in chapter 5.1, direct connections may become the only viable option to ensure that the produced hydrogen is green in the near future.

Unfortunately, the beginning of 2023 was not favourable for Danish wind-power producers, as the country temporarily suspended the administrative processing of all offshore wind projects under the open door scheme due to concerns about their compatibility with state aid regulations. [62] As a result, over 13 GW of offshore energy projects were put on hold, as the Danish Energy Agency announced that the proceedings would be temporarily suspended until further clarification of EU legal issues. By March 2023, some of the projects, such as the **Jammerland Bugt**, **Lillebælt South**, **Omø South**, and **Nordre Flint** offshore wind farms, had been unsuspended as the Danish Energy Agency resumed their assessment. However, the future of the remaining projects remains uncertain, and wind-power companies are urging Denmark to provide further clarification on its regulations.

[60] Danish Power-to-X strategy. 2022.
[61] https://investindk.com/insights/denmark-a-global-leader-in-green-patents
[62] https://www.offshorewind.biz/2023/02/06/denmark-suspends-open-door-offshore-wind-scheme/

6.2 Market characteristics

6.2.1 Networks

As the Danish field is well-established throughout the whole value chain with more than 70 companies operating in it, it also has several networks that are working to promote the development and use of hydrogen and PtX technology. These organisations are typically made up of a diverse group of stakeholders including government agencies, private companies, and research institutions.

1. **State of Green**

State of Green is a public private partnership between government, research institutions and Danish private actors. It's goal is to promote Denmark's green and sustainable solutions and technologies to the world. The initiative aims to showcase Denmark's expertise and experience in areas such as energy efficiency, renewable energy, circular economy, and sustainable urban planning among others. State of Green works as a one-stop shop to more than 500 Danish solution providers, connecting foreign companies with Danish players driving the global transition to a sustainable, low-carbon, resource-efficient society.[63]
State of Green has direct contact details available:
info@stateofgreen.com & +45 7210 0179.
Further details are available at: https://stateofgreen.com/en/contact/

2. **Hydrogen Denmark**

Hydrogen Denmark is a business organisation bringing all hydrogen and PtX stakeholders in Denmark together. The association has 35 members, representing 90% of the value chain of hydrogen production. All the members work with hydrogen, electrolysis, and fuel cells in connection with the transport, energy storage or production green fuels. The forum consists primarily of companies, but also of research institutions, public institutions, and network organisations. Becoming part of Hydrogen Denmark opens various opportunities to gather information from the Danish hydrogen industry. A member gets access to Hydrogen Denmark's weekly newsletter and becomes part of the network, getting to have an influence on the work of the network. Hydrogen Denmark welcomes new members to their cluster and are happy to invite foreign companies to their events too. [64]
Hydrogen Denmark has direct contact details available:
info@brintbranchen.dk & +45 3920 2003

3. **Energy Cluster Denmark**

The national Danish cluster network for innovation and organisation, Energy Cluster Denmark, focuses on energy production. It focuses on production and transmission of electricity, energy storages, integration of renewables in the power system, extraction of oil and gas, and development of new energy production technologies. Even if it does not mention to be focused strictly on hydrogen or PtX, both technologies are needed in several focus points the organisation has. The cluster is a member-based organisation with more than 290 members, from start-ups to large companies and from universities to knowledge institutions[65]. The Danish Energy Cluster welcomes companies to visit them, trying to create connections across the world. Since 2008, they have hosted more than 1300 delegations from all over the world.
Energy Cluster Denmark's has listed contact details for their experts on their website available at:
https://www.energycluster.dk/en/kontakt/

[63] https://stateofgreen.com/en/
[64] https://brintbranchen.dk/om-brintbranchen/
[65] https://stateofgreen.com/en/solution-providers/energycluster/

4. Green Hub Denmark

Green Hub Denmark is a public-private partnership located in Aalborg that focuses on promoting green innovation, sustainable business models, and large-scale testing to address climate challenges and help the government achieve its goal of reducing CO_2 emissions by 70%. The initiative has received around EUR1 billion in funding from its national and international partners, who have extensive networks. By connecting businesses, consumers, researchers, utility companies, and authorities, the hub aims to create a top-notch platform for green growth and a sustainable societal transition by developing, testing, and implementing sustainable technologies. Green Hub is governmentally funded. The partners consist of businesses, research institutes, the utility sector, and public authorities.[66]

5. GreenLab

GreenLab is a green and circular energy park, a technology enabler, and a national research facility. GreenLab is partly state funded, and it aims to test theories in practice while looking for viable green solutions to the world's biggest challenges. The businesses located in GreenLab are supplied with sustainable energy from multiple energy sources in the form that suits their production. GreenLab is doing Power-to-X and sector coupling in practice, being a home to one of the world's first and largest commercial Power-to-X facilities in 2023, reaching 12MW by 2023 and starting construction of another 100MW in the following year. The park is an official regulatory test zone and has dispensation from electricity regulations, making it able to test and scale new technologies freely.

6. Invest in Denmark

Invest in Denmark is part of the Ministry of Foreign Affairs of Denmark. The organisation assists foreign companies who consider establishing business activities in Denmark. They offer a free and confidential gateway to setting up a business in Denmark, from entry to further expansion. Their services are free of charge and all discussions and services are done under full confidentiality. Invest in Denmark has several locations in Europe, North America, and Asia as part of the Ministry of Foreign Affairs of Denmark. In their locations, companies can meet advisors with corporate backgrounds, industry insights and well-connected networks ready to advise companies on every aspect of starting a business in Denmark. **It is notable, however, that the organisation aims to help companies who are establishing an office or a subsidiary into Denmark.** The organisation has direct contact details for their personnel available at:
https://investindk.com/contact

7. The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping

The Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping is an independent research and development center focused on accelerating the transition towards a net-zero future for the maritime industry. The center, in collaboration with its partners, is driving the development and implementation of new technologies, building confidence in new concepts, and maturing viable strategic ways to drive the required systemic and regulatory change. The center has established partnerships with companies from both, Denmark and the Netherlands, as well as other countries to advance research and development in the area of zero-carbon shipping.
The center has contact details available at their website:
https://www.zerocarbonshipping.com/contact/
They can be contacted directly through their e-mail address info@zerocarbonshipping.com (General inquiries)

[66] https://greenhubdenmark.dk/en/about-green-hub-denmark/

6.2.2 Events

Denmark has several annual events, workshops and forums regarding hydrogen and its derivatives. Major events have been listed in Table 5. On top of these events, different trade organisations as well as Danish Maritime and Aviation society have held workstreams, networks, forums and smaller events that are connected to hydrogen, and are expected to host more in the near future. Please **contact the Dutch Embassy in Denmark for latest updates** on hydrogen related events.

Table 5 Hydrogen events in Denmark.

Event	Date	Location	Website
WindEurope, Annual event	25.4. – 27.4.	Copenhagen	https://windeurope.org/annual2023/
Made in Denmark, Annual event	3.5.2023	Copenhagen	https://brintbranchen.dk/kom-med-til-aarets-brint-og-ptx-konference-3-maj/
Hydrogen & P2X 2023, Annual event	14.6. – 15.6.2023	Copenhagen	https://fortesmedia.com/hydrogen-p2x-2023,4,en,2,1,22.html
ICHBET 2023: 17. International Conference on Hydrogen-Based Energy Technologies	10.7. – 11.7.2023	Copenhagen	https://waset.org/hydrogen-based-energy-technologies-conference-in-july-2023-in-copenhagen

1. **WindEurope**

WindEurope is a large, world-class conference with over 60 sessions and more than 10 000 participants participating in it. Organized in collaboration with Green Power Denmark, the annual event gathers representatives of the biggest companies and public authorities together. The event is held in Copenhagen in spring, this year from the 25th of April to the 27th of April. The event has a lot of interest and interested participants are recommended to book their tickets rather sooner than later. This year the event was completely sold out.[67]

2. **Made in Denmark**

Hydrogen Denmark holds annual events for interested parties, and this year the event Made in Denmark is held in Copenhagen on the 3rd of May. The conference will be a mix of presentations and exciting debates between some of the industry's strongest players. The conference and lunch before that are free for members of the Hydrogen Denmark (Brintbranchen), but it is also possible to buy tickets to the event.[68]

3. **Hydrogen & P2X**

Hosted by a Polish company **Fortes**, the Hydrogen & P2X event is an annual event held in Denmark's capital, Copenhagen. The conference will be held for the 4th time in June 2023. In 2022, there were more than 200 participants with 30 presentations from industry end-user, the 2023 event is expected to be even bigger. In the event, there is a

[67] https://windeurope.org/annual2023/
[68] https://brintbranchen.dk/kom-med-til-aarets-brint-og-ptx-konference-3-maj/

possibility to network and exchange ideas with industry leaders. The event also acts as a platform to discusses new regulations, current and forthcoming market situation and more.[69]

4. ICHBET

ICHBET or **International Conference on Hydrogen-Based Energy Technologies** is an annual event held from July 10th to July 11th this year. The event aims to bring together leading academics, researchers et cetera to share their experiences and research of results of their latest studies. The event will go through several lately published studies and their results, giving valuable information on the current academic status of hydrogen.[70]

[69] https://fortesmedia.com/hydrogen-p2x-2023,4,en,2,1,22.html
[70] https://waset.org/hydrogen-based-energy-technologies-conference-in-july-2023-in-copenhagen

6.2.3 SWOT Analysis

Table 6 SWOT Analysis, Denmark

STRENGTHS	WEAKNESSES

• Danish companies strongly positioned throughout the value chain.
• High level of knowledge on green energy in Denmark.
• Great offshore wind resources.
• Access to biogenic CO_2.
• Robust energy system.
• Strong government support and funding opportunities through programs like EUDP and Innovation Fund Denmark
• Abundant renewable energy resources, particularly wind and solar power
• High levels of capacity expansion already announced, with several large-scale projects in the pipeline.
• Strong R&D HUB
• Long term commitment from the government. The country has history of stable regulatory environment.
• Favourable Tax Climate promotes commercial research.
• **Focus on PtX**[71]
  • PtX improves system flexibility.
  • PtX provides a large spectrum of end-products that are compatible with existing infrastructure and equipment.
	• Current legislation is not presently able to accommodate the rapid developments taking place in the field of hydrogen production.
	• No established hydrogen infrastructure for transporting or storing hydrogen.
	• The market is subject to change depending on regulations and laws, which may change over time.
	• Final customer's preferences regarding hydrogen (in cars, for example) is not known. Most likely household consumers won't be part of the off takers.
	• **Focus on PtX** [72]
	  • PtX lacks cost competitiveness due to electricity price and electrolysis CAPEX.
	  • PtX technologies have low production efficiency.
	  • PtX lacks upscaling and manufacturing production capacity.

OPPORTUNITIES	**THREATS**
• Access to biogenic CO_2. There is need to develop ways to gather and transport the CO_2. • The government has a will to develop suitable regulation framework. • The development of hydrogen-powered vehicles, particularly in the maritime and aviation sectors, presents a significant opportunity for Danish companies and their business partners. • A rapidly growing market opens possibilities for new technologies and expertise. • Companies with innovative hydrogen applications, acting as an off-taker, could have opportunities to access the Danish market, as there will likely be more hydrogen production than consumption. • Health & safety parameters can be factored as opportunities for Dutch companies. • Denmark is a PtX knowledge hub. • Existing district heating networks can benefit from excess heat from the PtX processes	• Monopoly in the hydrogen transportation pipes can lead to higher prices. • Danish companies have high specialization in hydrogen patents, competition is well-established in selected sectors. • The lack of regulation framework could negatively affect the development of the market. • The fluctuation of the price of fossil fuels could make hydrogen less competitive in the short term. • The lack of a fully developed hydrogen infrastructure and refuelling stations could make it difficult for hydrogen-powered vehicles to gain acceptance among consumers. • Electricity prices have been increasing recently, if the prices will remain high, production of hydrogen will be expensive. • Uncertainty upon fuel market offtake. • Uncertainty regarding support schemes. • Main focus on green hydrogen, if blue hydrogen becomes more accepted it could be problematic for Danish companies

[71] Power-to-X in Denmark: An Analysis of Strengths, Weaknesses, Opportunities and Threats. Skov, I., Schneider, N., Schweiger, G., Schöggl, J-P. 2023.

[72] Power-to-X in Denmark: An Analysis of Strengths, Weaknesses, Opportunities and Threats. Skov, I., Schneider, N., Schweiger, G., Schöggl, J-P. 2023.

6.3 Opportunities for Dutch businesses

6.3.1 Segments providing opportunities

- Denmark's hydrogen economy is gaining momentum as the country aims to achieve carbon neutrality by 2050, which provides significant opportunities for Dutch companies to bring their expertise to the table.
- Dutch companies can collaborate with Danish universities and research institutions to develop cutting-edge solutions that meet the rapidly growing market demand in the hydrogen economy.
- Dutch companies can also provide their expertise in building hydrogen infrastructure, equipment for electrolysers, and off-take solutions to the Danish hydrogen market.
- Denmark's Hydrogen Valley, a cluster of companies and research institutions, can provide Dutch companies with a network and knowledge of the Danish hydrogen industry.
- The Danish value chain is looking for innovative and sustainable solutions that can help the Danish hydrogen market to flourish from production to infrastructure to off-take. A lot of investors for Power-to-X projects, highlighting the need of knowledge, sub suppliers et cetera.

As previously represented in this study, the Danish hydrogen economy is gaining momentum as the country aims to achieve its carbon neutrality goals by 2050. As a result, the demand for innovative and sustainable solutions is on the rise, providing significant opportunities for Dutch companies to bring their expertise to the table. The Danish hydrogen economy provides numerous opportunities for Dutch companies by leveraging their strengths in research, infrastructure, equipment, and off-take solutions. The Danish Power-to-X segment is experiencing significant interest and investment, as it is a critical element in Denmark's transition to a low-carbon economy. However, **the focus has shifted towards the need for knowledge and innovation, rather than just funding.** Danish companies are looking to collaborate with foreign companies to bring their expertise to the table and help overcome the technical and economic challenges associated with scaling up Power-to-X technologies. The Danish Government is also supporting the industry's growth by providing funding for research and development activities. Overall, the Danish Power-to-X segment offers significant opportunities for companies with expertise in this field to collaborate with Danish companies and contribute to the country's efforts towards a sustainable future.

One of the more crucial segments providing opportunities for Dutch businesses in the Danish hydrogen economy is research and education. Denmark has a strong tradition of R&D, with a focus on sustainable technologies. Dutch companies specializing in hydrogen technologies can collaborate with Danish universities and research institutions to develop cutting-edge solutions that meet the rapidly growing market demand. As mentioned earlier, Danish companies are one of the most innovative companies on earth when it comes to hydrogen, collaborating with these companies could be fruitful for both parties. However, the lack of a sufficient labor pool of skilled workers constitutes a challenge for Denmark´s plans for its hydrogen sector, but also for its green transition more broadly. This will need to be addressed in order to achieve the many goals presented.

Dutch companies can also provide to the development of infrastructure for hydrogen production, storage, and distribution. The Netherlands has a well-developed infrastructure for natural gas and one of the largest hydrogen pipelines in the globe, attesting to great knowledge on the infrastructure. This expertise can be utilized to build hydrogen infrastructure in Denmark, facilitating the transition to a hydrogen-based economy. Denmark has locations for hydrogen storage, but **innovations and knowledge regarding the storage** and **efficiency** of storage and transportation are needed in Denmark as well. While Danish companies already are strong with natural gas pipelines, **Energinet** and **Evida** can be expected to be pleased to talk with companies with knowledge on infrastructure. The country has an opportunity to bid for infrastructure projects, and the forementioned companies will decide between

the possible suppliers. **There's a clear need for sub suppliers for valves, compressors, and construction of the pipelines.**

Dutch companies specializing in the equipment for electrolysers can also find opportunities in Denmark's hydrogen market. The growing demand for electrolysers and other equipment required for hydrogen production and storage presents opportunities for Dutch companies to offer their expertise and technology.

Denmark has established a Hydrogen Valley, a cluster of companies and research institutions that collaborate on hydrogen technologies and development of them. Dutch companies can bring their knowledge of hydrogen technologies to the Hydrogen Valley and benefit from the existing network and knowledge of the Danish hydrogen industry.

One of the biggest gaps in the Danish value chain are the off-take solutions, which refer to the utilization of hydrogen or its derivatives in various applications. Innovative ways of benefitting from the off-take products are needed in the country. The Danish value chain is looking for innovative and both, financially and environmentally sustainable solutions that can help the Danish hydrogen market to flourish from production to infrastructure to off-take. Dutch companies can provide their expertise to develop and implement these solutions.

The Danish transportation industry, namely the maritime sector, is currently looking at suppliers for hydrogen based fuels and all knowledge regarding such products, their usage and efficiency regarding it are needed in Denmark. The Danish maritime industry is actively exploring opportunities to transition to low-carbon and carbon-neutral fuels, such as e-fuels and green hydrogen. The industry recognizes the urgent need to decarbonize in order to meet ambitious emissions targets and tackle climate change. **Leading companies in the industry, such as AP Moller Maersk, have set bold sustainability targets and are actively investing in research and development to explore new possibilities for reducing emissions.** These developments present significant opportunities for companies across the value chain, from fuel producers to shipbuilders, to collaborate and invest in the development of low-carbon and carbon-neutral shipping solutions.

6.3.2 Recommendations for market entry

- The key factor for market entry in Denmark is to identify local partners.
- Culture between the Netherlands and Denmark is quite similar.
- The Dutch Embassy and Invest in Denmark are helping Dutch companies to enter the markets.
- Several subsidies and incentives open for companies investing in hydrogen.
- Different currency should be taken into consideration.

According to Transparency International, **Denmark is the least corrupted country in the world**.
Denmark is an attractive country for foreign companies to invest in due to its stable political and economic environment. The country has a strong tradition of free trade and a business-friendly culture, making it an easy place to do business. Denmark also has a highly skilled workforce and a well-developed infrastructure, including a world-class transportation system, advanced telecommunications network, and modern energy infrastructure. Furthermore, **Denmark ranks consistently high in global surveys of ease of doing business, innovation, and sustainability.** The country is also known for its high-quality education system, producing top graduates in engineering, science, and technology fields. With a commitment to green growth, Denmark offers a supportive environment for companies looking to invest in clean technologies such as hydrogen, with the government actively promoting the transition to

a low-carbon economy. All these factors make Denmark an ideal destination for foreign companies seeking to expand their operations and tap into the Scandinavian and European markets.

According to insights from Danish professionals, **the key factor for market entry in Denmark, as well as accessing incentives and subsidies, is to identify and connect with a local partner**. Danish companies are highly motivated to collaborate, and the professionals we interviewed emphasized the importance of finding a partner within the country. Interestingly, the professionals also highlighted the similarities between the cultures, values, and working styles of Denmark and the Netherlands. This suggests that Dutch companies may find it easy and enjoyable to collaborate with Danish partners, creating opportunities for mutually beneficial partnerships and driving innovation in the green hydrogen space**. Invest in Denmark provides its own step-by-step guide to opening a business in Denmark, for their guide, please refer to their website:**
https://investindk.com/publications/step-by-step-guide-to-do-business-in-denmark

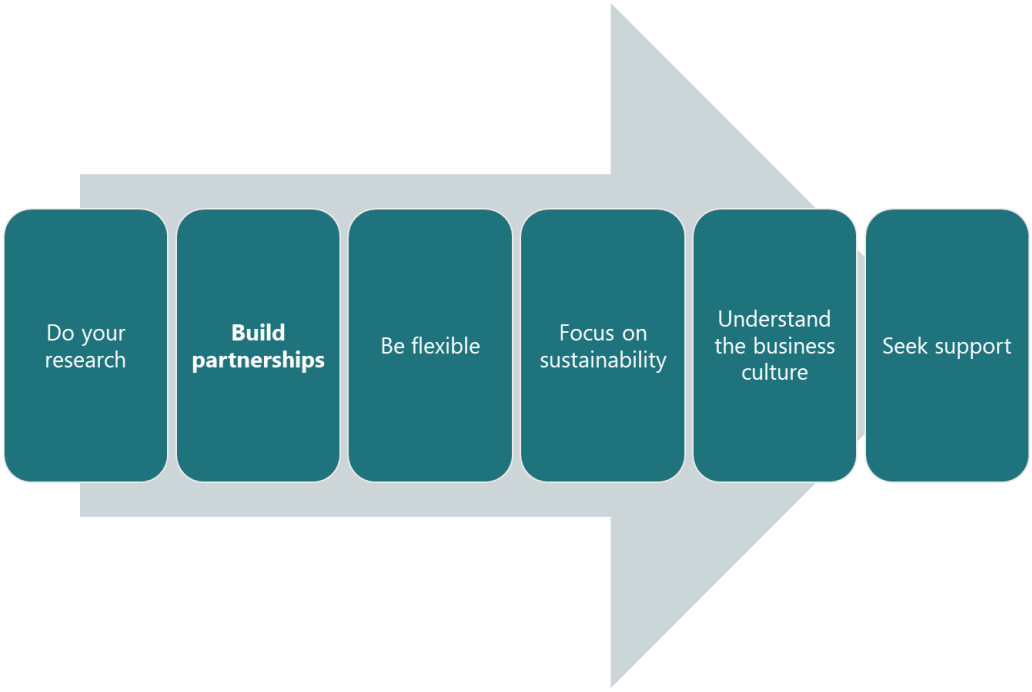


Figure 8 Steps on entering Danish markets.

When entering the Danish markets, companies should consider at least the following 6 steps that are illustrated in the figure above:

1. *Do your research.*

Before entering the Danish market, a company should conduct extensive research to understand the local market conditions, consumer behaviour, regulatory environment, competition, and possible collaboration possibilities. These steps will help to tailor products or services to meet the specific needs of the Danish markets. This market study should be helpful, so reading through chapters 4 – 6 is highly recommended.

2. *Build partnerships.*

As mentioned earlier as well, **the key factor in entering the markets is to establish partnerships with local businesses and stakeholders**. This is a critical step to successfully enter the Danish market. Collaborating with local partners can help a company to navigate the regulatory environment, build a local network, and gain credibility with customers. Denmark and the Netherlands share many cultural similarities, which facilitates partnerships between companies from both countries. Joint ventures are the recommended form of collaboration, and **numerous ongoing projects in Denmark are still seeking potential partners.** When establishing a subsidiary in Denmark, it is highly advisable to hire local employees, as Danish business culture values directness, openness, and low hierarchy. While

English is widely spoken in Denmark, having Danish-speaking personnel can be crucial for building partnerships and expanding networks. To find possible networks and networking events, please refer to chapters 6.2.1 and 6.2.2. Major projects are listed in Table 4.

3. *Be flexible.*

Danish consumers are known for being tech-savvy and environmentally conscious, and they expect businesses to adapt to changing market trends quickly. The Danish markets in hydrogen are rapidly evolving and thus being flexible and monitoring the statuses of the markets is essential to enter the market properly.

4. *Focus on sustainability and safety.*

Denmark's ambitious goals to become carbon-neutral and to be a sustainable country are important points for the Danish public. To succeed in the Danish market, foreign companies should prioritize sustainable practices and safety. Focus on communicating your environmental aspects as well as effects on social and governance topics to the public.

5. *Understand the Business culture.*

The Danish business culture is known for being egalitarian, transparent and consensus driven. Be prepared to engage in open and direct communication and respect the Danish work-life balance. Danish culture is very similar to the Dutch culture. Punctuality is appreciated and important. **The business culture is relatively open, which opens possibilities to information sharing and knowledge exchanges**.

6. *Seek support.*

Different networks and organisations listed in chapter 6.2.1, namely **State of Green** and **Invest in Denmark** are providing support to foreign companies to enter the Danish market. Whereas State of Green is specialized in connecting companies with Danish solution providers and partners, Invest in Denmark provides support on networking opportunities, and guidance on legal and regulatory issues. The organisation also provides help guidance and support on how to access different funding programs in Denmark. In addition to the aforementioned entities, there exist **regional organisations like Copenhagen Capacity** that strive to entice foreign companies, investments, and skilled professionals to various regions in Denmark, in order to foster long-term and sustainable growth. To reach these organisations, please investigate the contact details given in chapter 6.2.1.

The Dutch Embassy in Denmark can offer valuable support to Dutch companies looking to enter the Danish hydrogen market. The Embassy can provide information on the Danish market, including local business culture, regulations, and market opportunities as well as facilitate introductions to local business networks and hydrogen organisations. In addition, the Embassy hosts events and seminars on various topics related to doing business in Denmark, such as market entry, regulations, and investment opportunities. For further information, please contact kop-ea@minbuza.nl.

6.3.2.1 Available Incentives and Subsidies

Denmark has emerged as a leading player in the green energy transition, and the country is committed to achieving a fully renewable energy mix by 2050. However, to achieve this ambitious goal, Denmark needs to significantly scale up its green hydrogen infrastructure, particularly in areas such as transportation and equipment. This presents an exciting opportunity for Dutch companies to bring their expertise and technologies to the Danish market. **According to our research, Danish professionals are highly receptive to partnering with Dutch companies, as both countries share similar cultural values and ways of working.** Furthermore, the Danish Government has introduced various incentives and subsidies to promote commercial research and accelerate green investments, including a **permanent R&D deduction of 130 percent and a cash reimbursement of 22% of tax losses related to R&D**

costs. This highlights the country's commitment to supporting the growth of the green hydrogen sector and creating a favorable business environment for companies.

Danish professionals are eager to collaborate with Dutch companies and leverage their expertise to accelerate the growth of the green hydrogen sector in Denmark. Dutch companies can expect a warm welcome in the country, and by partnering with Danish companies, they can access local knowledge and expertise while contributing to the development of a sustainable future for both countries.

The EUR 170 million Danish scheme to support renewable hydrogen production was accepted by the EU commission at the beginning of 2023. The scheme is supporting the upscaling of the production of renewable hydrogen and its derivatives. The scheme will support the construction of up to 100 – 200 MW of electrolysis capacity in Denmark. **The tender will be open to all companies planning to construct new electrolysers in Denmark.** It will be a direct grant for a ten-year period, and the beneficiaries will have to prove compliance with EU criteria for the production of renewable fuels of non-biological origin.[73] the Danish Energy Authority (DEA), which is managing the auctions on behalf of the Danish state, has engineered a budget-control mechanism into the tender design, that aims to limit the ten-year premiums to the equivalent of EUR 1,18/kg. The scheme hopes to subsidise around 100-200MW of electrolysis capacity.[74]
The tender application page is available at: Udbud for støtte til produktion af Power-to-X (ethics.dk)
The Danish Government will now launch a series of competitive tenders this year, in which producers can bid for fixed-price grants for the green hydrogen derivatives they produce from specific projects over a ten-year period.[75]

The Energy Technology Development and Demonstration Program (EUDP) is a Danish Government initiative that aims to support private companies and universities in developing and demonstrating new energy technologies. The program provides funding to eligible participants in accordance with EU state aid rules. It is important to note that **while foreign companies and universities can participate in EUDP-funded projects, the main applicant must be a registered Danish company or university.** EUDP provides support for a wide range of energy technologies, including renewable energy technologies, **conversion technologies such as fuel cells and hydrogen** and other energy related projects.[76] As such, hydrogen companies from the Netherlands may benefit from the EUDP funding scheme in Denmark by partnering with Danish companies or universities to participate in EUDP-funded projects related to hydrogen technologies. This could potentially provide opportunities for Dutch companies to gain access to funding and expertise to develop and demonstrate their hydrogen technologies in Denmark, which could lead to further market opportunities and collaborations in the hydrogen sector.

The Danish Government has also **earmarked EUR 45 million (DKK 344 million) for innovative green technologies** via funds from the REACT-EU initiative and the Just Transition Fund.[77] The EUR 45 million earmarked by the Danish Government for innovative green technologies is aimed at supporting companies and organisations that are working on sustainable and innovative projects. The funds have been allocated through the REACT-EU initiative and the Just Transition Fund, which are both focused on promoting sustainable development and transitioning to a low-carbon economy.

[73] European Commission Press release – Commission approves EUR170 million Danish scheme to support renewable hydrogen production.
[74] https://www.hydrogeninsight.com/production/green-hydrogen-producers-could-bag-over-2-kg-in-new-danish-subsidy-auction-but-safety-mechanism-aims-to-push-support-lower/2-1-1438144
[75] https://www.hydrogeninsight.com/electrolysers/denmarks-170m-green-hydrogen-subsidy-scheme-gets-the-green-light-from-the-european-commission/2-1-1405552
[76] https://ens.dk/en/our-responsibilities/research-development/eudp
[77] Northwest European Hydrogen Monitor. International Energy Agency.

7 Finland

7.1 Policy landscape

7.1.1 Energy mix

- Finland has one of the cheapest renewable energies in Europe.
- Forecasted production by 2030 140 TWh of electricity, fully from renewables.
- Large geographical area with low population density opens significant possibilities for windfarms, supporting the growth of wind power in the country. Ambitious plans for offshore wind power as well.
- Stable electricity grid with only one bidding zone helps scaling.
- A support project for solar power published in March 2023.

Electricity generated in Finland is already one of the greenest in the world. Finland has ambitious goals for renewable electricity production and as illustrated in Figure 9, in 2022 Finland's electricity mix consisted mostly of nuclear power (30%) with several other sources in use as well. In 2022, Finland generated around 82TWh of electricity. The future of Finnish electricity production is green, and wind-power is seen as the biggest source by 2030, with 50% share of the energy mix in 2030. In 2030, the country is expected to generate 140 TWh of electricity.[78] This, together with the future investments in solar- and hydropower means that Finland has a great potential on the green hydrogen production. **In 2022, Finland was the 5th biggest installer of onshore wind, way above its size.[79]**

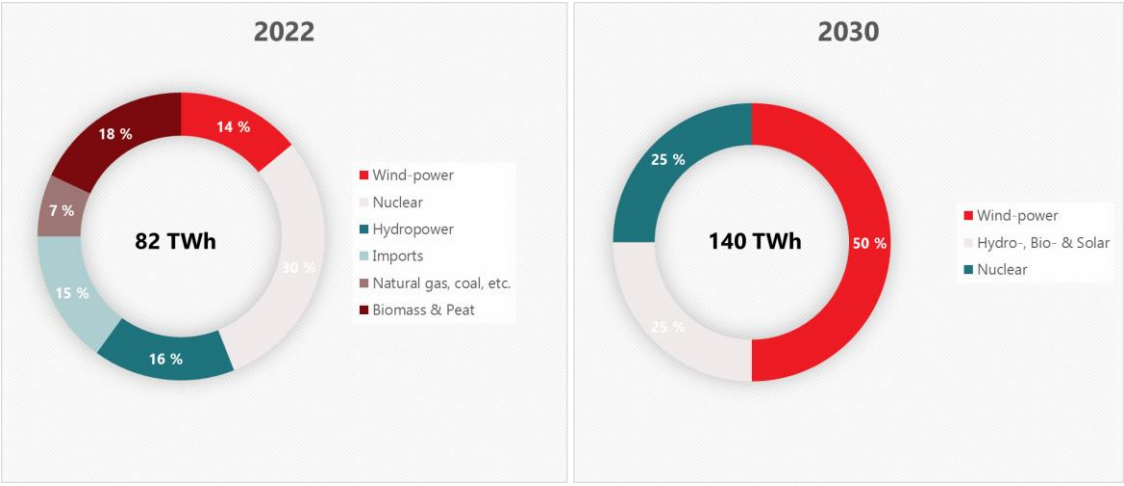


Figure 9 Electricity supply in Finland 2022 & 2030 (Fingrid, YLE)

The country's geographical location and infrastructure gives great possibilities for effective and massive scaling of affordable onshore wind power, which is one of the main elements of industry-scaled hydrogen production. Already by 2022, there has been many published projects on wind power with a total planned capacity of 21,3GW. If 100% of the published projects went through, the total amount would be more than the whole Finnish capacity was in 2021. In Finland, the electricity market was made more competitive by separating the parts of the market that had a monopoly (electricity distribution networks) from the parts that were open to competition. The strength of the system has been developed by collaboration between market participants. **Finland only has 1 bidding zone within the country,** unlike its reference countries, which helps the country to scale up the production compared to other comparable countries such as Sweden. In order to fully harness the potential of Finland's renewable energy resources, significant investments in the national grid are necessary. Fingrid, the country's electricity grid operator, has announced a plan to invest approximately EUR 3 billion between 2020 and 2030 to upgrade the grid. While the

[78] https://yle.fi/a/74-20012175?utm_source=social-media-share&utm_medium=social&utm_campaign=ylefiapp
[79] Global Wind Report 2023. Global Wind Energy Council. 2023. Available: https://gwec.net/globalwindreport2023/

current state of the grid is relatively stable, it is not capable of accommodating the full-scale utilization of solar and wind potential in Eastern Finland for example. Eastern Finland also has problems on investing in new wind power farms, as the turbines are problematic for the Finnish Defence Forces[80]. Thus, **Eastern Finland is seen to have a disadvantageous position with wind power compared to other locations in Finland.**

As per the database compiled by the Confederation of Finnish Industries, it has been noted that **several offshore wind power projects have been announced in Finland.** With an investment worth EUR 22 billion, the majority of these projects are scheduled to be operational by 2030. Companies such as **Ilmatar** and **OX2** have announced some of the largest wind power investments in the country.[81] This development is indicative of the country's strong potential and commitment towards leveraging renewable energy sources to meet its power requirements.
The same database lists 16 solar power projects as well, from which majority are already in use or are starting their operations within 2 years. According to Solar Power Europe, solar investments are extremely attractive everywhere in Europe, including Finland, even in high interest rate market situations. Finnish solar target results are, however, much below its potential and according to Solar Power Europe, the ambitions should be raised, including through the setting of solar auctions.[82] The country has announced its first solar auction when it announced that **Luxembourg supports Finnish solar energy projects by EUR 40 million through EU mechanism**. The projects will be selected through competitive tendering carried out by the European Commission and the European Climate, Environment and Infrastructure Executive Agency, CINEA.[83]

7.1.2 Outlook of the hydrogen industry

- A lot of varying information on projects, from EUR 1 billion to EUR 10 billion.
- Finland has a goal to become a leading hydrogen producer in the EU.
- Hydrogen strategy part of the country's climate and energy strategy from 2022. Hydrogen Cluster Finland also working on hydrogen plans.
- Ambitious goals, government's resolution on hydrogen announced capability to produce up to 10% of the EU's need by 2030. Industry believes capability is a lot more, up to 45% of the European needs.
- Country's electricity prices are at significant advantage for green hydrogen production. Access to clean water and biogenic CO_2 also a strength.

In 2022, Finland once again secured the top position in the yearly global ranking of sustainable development for the second consecutive year. The ranking measures the progress of countries towards achieving the Sustainable Development Goals under the 2030 Agenda. Finland has made significant strides towards achieving the social sustainability goals, but it still has room for improvement in terms of ecological sustainability.[84] Finland's continued top ranking in the global sustainable development index is a positive signal for the country's efforts towards sustainability. This achievement can also be seen as a positive factor that attracts green hydrogen investments to the country, as investors are increasingly looking for locations that prioritize sustainable development. Finland is one of the 13 countries that have announced to be part of a coalition with a goal to reduce maritime sector emissions to zero by 2050. This can be done by using Power-to-X products.[85]

[80] Karjunen, H. et al. South-East Finland Hydrogen Valley Project report. 2022. LUT University.
[81] https://ek.fi/tutkittua-tietoa/vihreat-investoinnit/
[82] EU Market Outlook for Solar Power. Solar Power Europe. 2022.
[83] https://tem.fi/en/-/luxembourg-supports-finnish-solar-energy-projects-by-eur-40-million-through-eu-mechanism
[84] https://valtioneuvosto.fi/en/-//10616/finland-once-again-ranks-first-in-international-comparison-of-sustainable-development
[85] https://www.reuters.com/business/sustainable-business/denmark-us-12-other-nations-back-tougher-climate-goal-shipping-2021-11-01/

There are more than 70 companies currently operating in the field of hydrogen. Clear minority of the companies operating in the field are focusing solely on hydrogen solutions. The most prominent cluster, Hydrogen Cluster Finland, has 75 members composed of companies originating or operating in Finland as well as organisations working with hydrogen in Finland. Hydrogen Cluster Finland is further described in chapter 7.2.1. A list of some significant companies working on Finnish hydrogen economy are listed in Table 7. Please note that the list is not comprehensive and does not include all actors on the field. Even though majority of Finnish companies are in need of collaboration and are willing to collaborate, these companies can also be identified as competitors if a Dutch company aims to enter the markets in any specific part of the value chain.

Table 7 Some players of Finnish hydrogen value chain.

Energy	**Production**	**Infrastructure & Supply**	**End-use**	**Technology, services & support**
UPM-Kymmene Oyj	Neste Oyj	Gasgrid Finland Oy	Neste Oyj	Hankotec Oy
Gasum	ABB Oy	Elomatic Oy	SSAB Europe oy	Elomatic Oy
Fortum Oyj	Elomatic Oy	Flexens Oy Ab	Wärtsilä Oyj	Vexve Armatury Group
AGCO Power	P2X Solutions Oy	Viafin GAS Oy	Metsä Group	ABB Oy
Wärtsilä Oyj	Flexens Oy Ab	Vireon (Norwegian Hydrogen A/S)	Elomatic Oy	Sweco Finland Oy
Energiequelle GmbH	UPM-Kymmene Oyj		St1 Nordic Oy	AFRY Finland Oy
Oy Linde Gas Ab	St1 Nordic Oy		Ovako Oy Ab	Vaisala Oyj
EPV Energia Oy	Hycamite TCD Technologies Oy		Skanska Oy	YTM-Industrial Oy
Helen Oy	Oy Linde Gas Ab		Outokumpu Oyj	Rejlers Finland Oy
Viafin GAS Oy	Woikoski Oy		Kemira Oy	Siemens Oy
Pori Energia Oy	Wärtsilä Oyj		Borealis Polymers Oy	Convion Oy
Ilmatar Energy Oy	Beneq Group Oy		Air Liquide Finland Oy	Auma Finland
OX2 Finland Oy	Ren-Gas Oy		Botnia H2Tec Services	Etha Wind
CPC Finland Oy	Solvay Chemicals Finland Oy		ET Fuels	Energiforsk
	Orkla Suomi Finland Oy Ab		UPM-Kymmene Oyj	

It can be said that the Finnish industry has been late on the green hydrogen economy and on investments in it, but lately, there has been plenty of investments announced, with a total worth of investments varying from EUR 1 billion to EUR 10 billion, depending on the source.[86]

Hydrogen Cluster Finland has announced that its members can now showcase 24 hydrogen projects in varying ranges. The overall investments are expected to reach EUR 1 billion, 600 to 1 100MW in capacity and 1,5million tonnes of CO_2 reduction. However, the cluster warns that there will most likely be challenges as regulation, value chain and the industry as a whole is still in its development phase. All in all, **the industry believes that 10 percent of the European hydrogen production could be produced in Finland, although it would mean some EUR 50 billion worth of investments for the wind power and hydrogen economy.**[87]

[86] https://www.hs.fi/talous/art-2000009260626.html
[87] https://h2cluster.fi/hydrogen-projects-opening-up-the-market-in-finland/

In 2022, Helsingin Sanomat created a list of ongoing hydrogen projects in Finland. According to the newspaper, there are investments worth of over EUR 2 billion announced in Finland. This figure is a conservative estimate only including projects which have secured, or are extremely close to secure, funding for their projects.[88] At the beginning of 2023 **the construction of Finland's first industrial-scale green hydrogen production facility began.** The facility will be constructed by a Finnish company called **P2X Solutions**, and it will generate some 20MW of green hydrogen and synthetic methane in Harjavalta, southern Finland.[89]

The most optimistic view of the incoming investments in Finland was published by Yle at the end of 2022, where the Finnish national public broadcasting company had gathered investments worth **of around EUR 10 billion** that are being planned in Finland. However, this number of investments is not in line with other sources and can be deemed as over-positive. Most of the hydrogen off-take projects announced in Finland are connected to steel producing, where hydrogen would be used to decrease the CO_2 emissions of steel production.[90]

Currently, there are three steel production projects using hydrogen announced in Finland, two in the Gulf of Bothnia area and one in Inkoo, Southern Finland. **Blastr Green Steel** has announced green steel projects worth of EUR 4 billion in Inkoo, creating 1 200 jobs. The project is currently in its preliminary study phase and has an operation start planned for 2026. **SSAB** has announced a project worth of EUR 2 billion in Raahe and **Outokumpu Oyj** is planning a EUR 100 million green steel production site in Tornio, Northern Finland. The Confederation of Finnish Industries has created a database that gather major investments on green transition, and it lists 20 hydrogen projects as well as 3 projects on green steel, where hydrogen would be in use too. The list values the investments' worth to be around EUR 10 billion. **The most significant hydrogen projects in Finland are listed in Table 8.** The project names are hyperlinks which lead to their announcements.[91]

[88] https://www.hs.fi/talous/art-2000009260626.html
[89] https://www.reuters.com/business/energy/construction-finlands-first-green-hydrogen-plant-begins-2023-01-20/
[90] https://yle.fi/a/74-20014811
[91] Based on data obtained from Confederation of Finnish Industries (03.04.2023). Data available at: https://ek.fi/tutkittua-tietoa/vihreat-investoinnit/

Table 8 Major hydrogen projects in Finland

Project (company) name	Location	Owners / Stakeholders	Capacity	End-use	Production start-up	Value chain[92]
ET Fuels – Green methanol	Ranua	ET Fuels	--	Green methanol for maritime	--	Production Transformation
Flexens	Kokkola	Flexens Oy, Kip Infra Oy, Kokkolan Energia Oy	300MW	Green hydrogen and ammonia	2027	Production Transformation
CPC Finland	Kristiinakaupunki	Prime Capital AG	200MW	Green methanol	2025	Production Transformation
Porvoo green hydrogen	Porvoo	Neste Oyj	120MW	Green hydrogen	2025	Production
Lahti Power-to-gas	Lahti	Nordic Ren-Gas Oy, Lahti Energia Oy	120MW	Green methanol, green hydrogen, district heating	2026	Production Transformation Heating
Naantali hydrogen plant	Naantali	Elomatic Oy, Green NortH2 Energy	100MW	e-fuels for maritime and heavy duty transport	2026	Production Transformation
Blastr Green Steel	Inkoo	Blastr Green steel	--	Green steel	2026	End-use
FFS – Towards Fossil-free Steel	Raahe	SSAB Oy	--	Green steel	Appx. 2030	End-use

In a March 2023 report, **the VTT Technical Research Centre provides a comprehensive overview of the 47 hydrogen-related projects currently underway in Finland.** The majority of these projects are focused on green hydrogen production, with projected electrolyser capacity totalling more than 760 MW_{el}, according to publicly available information. Of these projects, five are already in operation or under construction, while 25 are in the pre-feasibility or feasibility stage.[93] The significant growth in the number of announced projects, as well as the continued interest and investment in the Finnish hydrogen market, highlights the country's potential as a key player in the (green) hydrogen economy. According to the study, if half of the maximum wind capacity in Northern Ostrobothnia is utilized by 2035, the net hydrogen potential in the region would be 30,3 TWh/a (0,9 Mt/a) after accounting for electrolyser losses, assuming that all net electricity potential is converted to hydrogen. In the event that the full potential of wind capacity is realized, the net hydrogen potential would be 61,5 TWh/a, or 1,8 Mt/a, nearly double Finland's national target for hydrogen production (1,0 Mt/a). The number of projects announced by the last quarter of 2022 compared to the latest information dated on the end of April 2023 **signals great growth in projects and shows great trust of Finland being a suitable location for (green) hydrogen production and usage.**

Currently, there are no green e-methanol production facilities operating in Finland. The closest one to production is a pilot plant of **St1**, which secured a funding of EUR 35,4 million from the Finnish Ministry of Economic Affairs and Employment. The flagship plant will be located in Lappeenranta, and LUT University has been a vital part of the research done for the plant. The funding is provided from the European Recovery and Resiliency Facility (RFF). The plant aims to start its operations in 2026, producing more than 25 000 tonnes of synthetic methanol yearly. The

[92] Please refer to Figure 2

[93] Pre-study on transition to hydrogen economy, specifically in Northern Ostrobothnia. Kiviranta, K. et al. 2023. Available: https://raaseu.jict.fi/sites/raaseu.jict.fi/files/tiedostot/ajankohtaista/Pre-study%20on%20transition%20to%20hydrogen%20economy%2C%20specifically%20in%20Northern%20Ostrobothnia_final_0.pdf

investment is worth of some EUR 100 million.[94] At the start of 2023, Irish firm **ET Fuels** announced its plans for an e-methanol project in Northern Finland near the town of Ranua. The company is investing EUR 800 million to establish a production site that will generate green methanol for the maritime sector. The investment is driven by **Finland's abundant and cost-effective wind energy, as well as its safe operating environment**, according to Ranua's Mayor, Tuomas Aikkila. The dean of Electrical Engineering at LUT University, Olli Pyrhönen, also highlights the exceptional wind power in Finland, which is attracting many potential investors looking for investment opportunities in the hydrogen industry.[95]

There are only a dozen clean hydrogen production sites in Finland with an addition of a few sites that generate high purity hydrogen as by-product. The largest producers, and consumers, are **Neste Oyj** refineries in Porvoo and Naantali. The other produce-sites are listed on table 9.[96]

Table 9 Current hydrogen production sites

SMX or POX	Electrolysis	By-product (electrolysis)
Neste, Porvoo (100 000t/a)	Woikoski, Kokkola (1000t/a)	Kemira Chemicals, Joutseno (10 000t/a)
AGA, Porvoo (30 000t/a)		Kemira Chemicals, Äetsä (10 000t/a)
Kemira Chemicals, Kuusankoski (10 000t/a)		Kemira Chemicals, Kuusankoski (1000t/a)
UPM Biofuels, Lappeenranta (10 000t/a)		AGA, Harjavalta (1000t/a)
Terrafame, Sotkamo (10 000t/a)		Haminan Energia, Hamina (1000t/a)
Eastman, Oulu (10 000t/a)		Nouryon, Oulu (3000t/a)
AGA, Hämeenlinna (1000t/a)		

In its latest publication, Hydrogen Cluster Finland (HCF) affirms Finland's competitive advantage in providing clean electricity at a rate that is unparalleled in Europe, despite the current energy crisis resulting from the conflict in Ukraine. Driven by wind power production, which is estimated to be more than 30% cheaper in Finland than in the reference countries, **the country's electricity prices are at a significant advantage.** Hydrogen Cluster Finland, however, notes that Finland must take a pragmatic approach to realizing a hydrogen-based economy. Leveraging the country's vast technical expertise, Finland has the potential to become a major hydrogen producer and provider of related technologies and solutions. By establishing reliable connections to the European hydrogen market and promoting local production with high-value processing, Finland can increase its carbon handprint by exporting Finnish technology and services. Hydrogen Cluster Finland's latest report underscores **Finland's capacity to generate up to 45% of the required clean hydrogen for the REPowerEU program, highlighting the country's immense potential as a leader in the green hydrogen industry.**[97] It should be noted that the figure referred to is not an official number published by the Finnish authorities, but rather a target set by the business side, namely the Hydrogen Cluster Finland. This target is significantly more ambitious than the official figures and may be regarded as overly optimistic.

[94] https://www.st1.com/st1-is-planning-a-synthetic-methanol-pilot-plant-in-lappeenranta-finland
[95] https://yle.fi/a/74-20014894
[96] National Hydrogen roadmap 2035
[97] Finland – European Leader in Clean Hydrogen Economy 2030. 2023. Hydrogen Cluster Finland. Available: https://h2cluster.fi/documents/

In February 2023, Boston Consulting Group together with Climate Leadership Coalition (CLC) published a report on Finnish Green transition. The "*Finland's Moonshots for Green Growth"* report states that **Finnish green hydrogen-enabled solutions have an export potential of EUR 10-12 billion by 2035.** Finland is a competitive country for producing green hydrogen-enabled solutions including green steel, synthetic fuels, and green ammonia-based fertilizers. Finland is uniquely positioned to succeed in the industry as they have access to growing renewable electricity, freshwater and have strong engineering capabilities. For this to happen, the government must eliminate unnecessary regulatory barriers, accelerate permits and zoning processes and provide coordinated support for first movers in scaling emerging technologies around different parts of the value chain.[98]

7.1.2.1 Carbon neutral Finland 2035 – national climate and energy strategy

Finland has a roadmap for hydrogen since 2020, and Finland's hydrogen strategy was published in 2022 as part of the country's climate and energy strategy. Hydrogen Cluster Finland is currently working on its own industrial strategy for hydrogen, which is expected to be published on autumn 2023**. Finland has published a government's decision in principle on hydrogen, and in 2023 the country adopted a resolution on hydrogen, where it was stated that Finland could produce 10% of EU's green hydrogen in 2030.**[99] The statement is in line with Boston Consulting Groups' assumptions as well as with Hydrogen Cluster Finland's expectations.

Finland aims to be the first developed fossil free country in the globe by 2035. The country has released its strategy on becoming carbon neutral under the name "Carbon Neutral Finland 2035". The strategy includes discussion on national hydrogen goals and targets that promote the hydrogen economy and electro fuels and has set quantitative targets for hydrogen electrolysis capacity. The country's target is to have at least 200MW of electrolysis equipment used in 2025 and at least 1 000MW in 2030, considering the commercialisation of hydrogen technology. **The carbon neutrality targets also include a target set for electro fuels: 3 percent of all transport fuels used should be electro fuels by 2030.** The Finnish Hydrogen Cluster believes that the targets are conservative, and that the Finnish hydrogen production could be scaled up to 1 000MW by 2025, based on incoming projects examination. Finland will pilot the use of hydrogen in transport, especially in heavy-duty road and waterborne transport. The country is phasing out of Russian fossil energy, which has become increasingly important topic since the spring of 2022. The strategy encourages companies operating in Finland to cooperate in the development of competence and joint projects and to build networks internationally.

In Finland there are several university-courses available to study hydrogen and hydrogen economy. These courses are held under the FiTech-university network described further in chapter 7.2.1. Vaasa University of Applied Sciences will also start its own education on hydrogen economy in the near future. On the hydrogen research field, Finnish research institutes and central universities have agreed on a new partnership by establishing **Hydrogen Research Forum Finland**, a forum which aims to promote Finnish hydrogen competence. The partnership includes Aalto University, LUT University, VTT Technical Research Centre of Finland, Åbo Akademi University, the universities of Jyväskylä, Turku, Tampere, Vaasa, as well as University of Oulu, which is coordinating the forum's operations.[100]

[98] https://www.bcg.com/publications/2023/moonshots-for-green-economy-in-finland/green-hydrogen-enabled-solutions

[99] https://valtioneuvosto.fi/en/-//1410877/government-adopts-resolution-on-hydrogen-finland-could-produce-10-of-eu-s-green-hydrogen-in-2030

[100] https://www.oulu.fi/en/news/academic-hydrogen-research-forum-finland-established

7.1.3 Production methods

- Finland aims to produce green hydrogen and its derivatives.
- The EU Commission's proposal for renewable hydrogen is favourable for the Finnish production.
- Wind power and to some extent solar power expected to be main source of energy for hydrogen production.
- No natural gas resources, blue hydrogen production not so relevant.

Finland aims to develop green hydrogen rather than grey or blue. However, there are 3 nuclear power plants in the country with the latest one, Olkiluoto 3, starting its full-scale production starting from April 2023, meaning there is a possibility for the country to produce pink hydrogen too. The main target for the country is to produce green hydrogen where the electricity provided will come from wind power, as presented in chapter 6.1.1. The energy generated by nuclear power will also help hydrogen production plants that are planning to use electricity straight from the grid. The EU Commission has proposed rules for renewable hydrogen as presented in chapter 5.1. **The recent regulations can be viewed as a favourable development for the Finnish export sector.** This is due to the fact that the country's electricity composition will fall well within the specified limitations, **enabling domestic firms to produce green hydrogen across the nation with grid-sourced electricity.** This provides a notable competitive edge, as compared to other European markets where separate renewable hydrogen production facilities are typically required, creating logistical challenges and higher hydrogen production costs.[101] Currently, a majority of announced projects are aiming to use electricity from the grid, but there are also large-scale plans for building wind farms or solar farms to provide electricity for the electrolysing process. Blue hydrogen, which is produced from natural gas combined with carbon capture and storage, is not a viable option as Finland has no domestic natural gas resources. Instead, the focus is on developing green hydrogen produced from renewable electricity and water.

7.1.4 Trade

- Information on hydrogen production targets varying because of the speed of growth in Finland.
- The government's aim for Finland to produce at least 10% of the total amount of hydrogen produced in Europe.
- VTT states that North Ostrobothnia region alone could be able to produce 10%.
- The Finnish industry believes it can produce up to 45% of the EU's needs, meaning a lot of excess production.
- Possibility to transport hydrogen via pipelines or by vessels and ships in the future.

Based on a study conducted by the Hydrogen Cluster Finland (HCF) the utilization of green hydrogen could enable greenhouse gas reduction of around 4-6 million tonnes of CO_2 equivalent in Finland per annum. HCF also states, that the Finnish carbon handprint could be exceeded significantly through export. **The industry believes that Finland could produce 10% of the total hydrogen produced in Europe by 2030.** This could open possibilities for the Netherlands, that is in vast need of hydrogen, as it can only produce 30% of the needed hydrogen by itself, leaving a gap of 70% to production and demand in the country. [102]

In March 2023, VTT Technical Research Centre of Finland published a study stating that **North Ostrobothnia in Finland alone should be able to produce at least 10% of the EU's zero-emission hydrogen in 2030.** Meaning that Finland's total production could be way above the 10% goal set by Hydrogen Cluster Finland. The area's

[101] https://www.businessfinland.fi/ajankohtaista/uutiset/horisontti-eurooppa/2023/uusiutuvalle-vedylle-saannot-euroopan-komissiolta
[102] https://h2cluster.fi/wp-content/uploads/2021/09/H2Cluster-whitepaper-pressrelease-092021-eng.pdf

renewable electricity production continues to grow strongly, and in addition to the already significant wind power capacity, planned wind farm projects will amplify wind energy production in North Ostrobothnia.[103]

The Finnish Government has published an outlook on the current situation of the Finnish hydrogen economy, which includes five different scenarios for the future of hydrogen production. The research forecasts that, in 2050, the amount of used green hydrogen varies from 6,4TWh (minimum) to 132,9TWh (maximum), depending on different expectations. All the scenarios expect that Finland will be carbon neutral by 2035. The biggest differences in the future need for hydrogen arise from differences between the demand of the steel industry, refinery of oil and biofuels, and exports of hydrogen and e-fuels. According to the paper, it takes around 6 to 14 TWh of hydrogen to fulfil the needs of the Finnish industry and transportation, including international transportation. The maximum amount of demanded hydrogen (132,9TWh) would only be possible if there were no limitations on the exports of hydrogen and e-fuels. This is however more than unlikely.[104] If Finland were to produce green hydrogen according to the highest possible estimate, that would create a significant market for exports as there would be more than 100TWh of extra production in the country.

However, according to Hydrogen Cluster Finland[105], the country must aim not to export the hydrogen itself, but rather create higher value for the value chain through development of high-value added technologies, solutions, and power-to-x products. As the forementioned statement is given by the most significant hydrogen cluster in the country with the most significant actors as part of it, it can be expected that the Finnish hydrogen companies are not that much interested in the hydrogen exports, but rather want to export their knowledge and technologies that are developed through R&D.

Gasgrid, in collaboration with Fingrid[106], has developed three hydrogen economy scenarios for Finland. In the first scenario, Finland establishes a strong regional hydrogen economy and becomes a significant exporter of P2X products. However, due to a lack of necessary hydrogen transmission infrastructure, Finland cannot take advantage of large amounts of hydrogen storage in Central Europe, increasing the profitability of domestic hydrogen storage. In the second scenario, Finland becomes a major exporter of hydrogen to Europe and builds transmission pipelines in Northern Sweden and Central Europe. This scenario allows Finland to utilize large hydrogen storage facilities in Central Europe, which reduces the profitability of domestic hydrogen storage. In the third scenario, Finland establishes a leading hydrogen ecosystem, becomes a significant exporter of hydrogen and P2X products, and builds hydrogen transmission pipelines in both Northern Sweden and Central Europe. This infrastructure allows Finland to utilize large hydrogen storage facilities in Central Europe, further reducing the profitability of domestic hydrogen storage. In all scenarios, several hydrogen storage facilities will be built, and **Finland is expected to export hydrogen via pipeline to Northern Sweden**.

According to a recent publication by Gas for Climate[107], **Finland is poised to become a significant net exporter of hydrogen by 2050, with the potential to export more than 70 TWh annually to Central Europe and parts of Northern Sweden.** This expectation is based on well-defined and well-working H_2-interconnections. This aligns with Finland's own goals of adding significant value to the global hydrogen value chain by 2050 and creating over 10 000

[103] Pre-study on transition to hydrogen economy, specifically in Northern Ostrobothnia. Kiviranta, K. et al. 2023. Available: https://raaseu.jict.fi/sites/raaseu.jict.fi/files/tiedostot/ajankohtaista/Pre-study%20on%20transition%20to%20hydrogen%20economy%2C%20specifically%20in%20Northern%20Ostrobothnia_final_0.pdf

[104] Valtion Rooli Vetytaloudessa – loppuraportti, 2022

[105] Hydrogen Cluster Finland White Paper, 2021

[106] Scenarios: Energy transmission infrastructures as enables of hydrogen economy and clean energy system. Fingrid & Gasgrid. 2022. Available: https://gasgrid.fi/wp-content/uploads/Gasgrid-Fingrid_hydrogen_economy_draft_scenarios.pdf

[107] Assessing the benefits of a pan-European hydrogen transmission network. Moultak et al. 2023. Available: https://gasforclimate2050.eu/news-item/gas-for-climate-consortium-kicks-off-a-large-energy-system-modelling-study-assessing-the-benefits-of-a-pan-european-hydrogen-transmission-network/

high-value jobs in the country. The production of green hydrogen in Finland is projected to range from 6,4 TWh (worst-case scenario) to 132,9 TWh (best-case scenario) by 2050, reflecting the country's commitment to developing a robust and sustainable hydrogen infrastructure. **Latest figures imply that together with Sweden, Finland would be able to produce around 11 to 12 Mt of green hydrogen,** meaning that the two countries alone would be able to produce 110 – 120% of the EU's 2030 target. Trade is expected to be done through pipelines from Finland to the Baltics and from there to Central-Europe. A pipeline between Finland and Sweden is under planning as well.

7.1.5 Infrastructure

- No current pipeline infrastructure, first refuelling station to start operations in 2024.
- Existing natural gas pipelines not suitable for hydrogen because of locations.
- National gas grid provider, Gasgrid Finland, has established a subsidiary for hydrogen infrastructure development.
- Electricity grid in good shape, only one bidding zone is a strength.
- First demonstration project currently moving forward.

For the transmission system, two of the most important factors are to be considered. Firstly: How to transport gas into the hydrogen production plants and secondly, how to transport the generated hydrogen from the plants to actual use. Current consumers of hydrogen are mostly located in South to South-Eastern Finland, like Neste refineries in Porvoo and Naantali, or UPM BioVerno production plant in Lappeenranta, whereas the potential production sites for new wind-power are mostly in the north. This is an important factor that one should consider, not only due to the long transmission distance and losses, but also due to the shortage in north-to-south grid capacity, creating a congestion referred in RED II[108]. However, **Fingrid**, the Finnish national electricity transmission grid operator, is investing in the Finnish Electricity grid for approximately EUR 3 billion by 2030 to make sure that the grid's transport capacity would be enough to secure the Finnish grid to be part of the general supply area. The ongoing development of the Finnish inland hydrogen transmission network is organized into three distinct regions: the Bothnia Bay and West Coast regions, which boast ample renewable energy sources and identified hydrogen demand; South and Southeast Finland, where existing and anticipated hydrogen demand is prevalent; and the Southwest Finland and Satakunta regions, where hydrogen demand and renewable energy sources are expected to materialize. Notably, the transmission infrastructure around Bothnia Bay is anticipated to be operational by 2030, thereby **enabling hydrogen transportation between Finland and Sweden**. By 2040, there are additional plans to expand the hydrogen transmission network in northern regions to reach even further north, with the possibility of constructing additional North-South pipelines.[109]

Gasgrid is in response for the entire Finnish gas transmission network. In June 2022, Gasgrid Finland published news where it stated it is going to develop a national hydrogen infrastructure, enabling the creation of new investments and jobs, and supporting Finland's energy security.[110] According to Finnish Minister of Finance, Annika Saarikko, this opening puts Finland at the forefront of hydrogen economy. Also, the Minister of Economic Affairs, Mika Lintilä, ensures that the Finnish Government wants that "*measures are taken to promote investments required for the transfer and distribution of hydrogen.*"[111] **In 2022, Gasgrid founded a subsidiary focusing on hydrogen transportation. The Finnish Government assigned the company a mission to develop both, the national infrastructure and**

[108] Hydrogen roadmap of Finland, 2020
[109] https://ehb.eu/page/country-specific-developments#finland-gasgrid-finland
[110] https://gasgrid.fi/en/2022/06/22/gasgrid-finland-to-develop-a-national-hydrogen-infrastructure-enabling-the-creation-of-new-investments-and-jobs-and-supporting-finlands-energy-security-and-self-sufficiency/
[111] https://gasgrid.fi/en/2022/06/22/gasgrid-finland-to-develop-a-national-hydrogen-infrastructure-enabling-the-creation-of-new-investments-and-jobs-and-supporting-finlands-energy-security-and-self-sufficiency/

international infrastructure collaborations. The government also asked Gasgrid to promote the development of hydrogen markets in the Baltic Sea area. Gasgrid and its subsidiary are currently working to develop the Finnish hydrogen transportation infrastructure but are also promoting possibilities for Nordic connections as well as connections from the Baltic countries to Finland. In its project development, Gasgrid aims for the hydrogen infrastructure to enable an open hydrogen market as early as 2030. Gasgrid states, that having a national as well as international hydrogen infrastructure, the European energy independency will increase. Hydrogen is a great opportunity for the growth of Finnish economy and thus these investments in the hydrogen grid are needed.[112] At the beginning of 2023, Gasgrid Finland published its first hydrogen transmission pilot project, which aims to construct a pipeline to enable the hydrogen generated at Kemira Oyj's plant in Joutseno to be transported to Ovako's Imatra Oy Ab's steel mill in Imatra along Gasgrid's hydrogen pipeline. The project received EUR 9,5 million support in RRF energy investment under the EU's NextGenerationEU funding instrument.[113]

Gasgrid Finland and Swedish energy supplier Nordion Energi are collaborating to establish a hydrogen route connecting both countries. The joint venture, called **the Nordic Hydrogen Route**, aims to drive decarbonization, promote regional green industrialization, encourage economic development, and foster European energy independence. By developing a cross-border hydrogen infrastructure in the Bothnian Bay region, the project seeks to accelerate the growth of the hydrogen economy and attract new investments to support Europe's energy transition while improving access to cost-effective domestic green energy.[114] The Nordic Hydrogen route enables Finnish hydrogen to be transported towards Sweden, where the consumption need is expected to grow faster than in Finland. The project is planned to span the distance from Vaasa, Finland, to Kiruna, Sweden. The proposed pipeline is expected to have significant impact on the regional hydrogen market, potentially opening up new opportunities for industry players and investors alike. Further research and analysis will be necessary to determine the potential implications and opportunities associated with this pipeline project.

Figure 10 Gasgrid Finland's international hydrogen projects.[115]

Gasgrid Finland is also part of the **Nordic-Baltic Hydrogen Corridor** project, in which the European gas transmission system operators **Gasgrid** (Finland), **Elering** (Estonia), **Conexus Baltic Grid** (Latvia) **Amber Grid** (Lithuania), **GAZ-SYSTEM** (Poland) and **ONTRAS** (Germany) are **developing a hydrogen supply infrastructure from Finland to Germany.**[116] The project supports the diversification of energy supplies, enabling the EU to reach its target of producing 10 Mt of domestic renewable hydrogen by 2030. The corridor can transport green hydrogen from the Baltic Sea area to supply consumption points

[112] https://clc.fi/fi/2023/03/12/case-gasgrid-vetyverkolla-eroon-fossiilisista-polttoaineista/
[113] https://gasgrid.fi/en/2023/02/15/finlands-first-hydrogen-transmission-project-moves-forward-demonstration-project-will-create-conditions-for-hydrogen-infrastructure-development-in-finland/
[114] https://nordichydrogenroute.com/project/
[115] https://gasgrid.fi/en/2022/12/16/from-vision-to-action-six-partners-have-signed-a-cooperation-agreement-to-develop-nordic-baltic-hydrogen-corridor/
[116] https://fuelcellsworks.com/news/amber-grid-launches-international-tender-for-hydrogen-corridor-pre-feasibility-study/

and industrial clusters along the whole corridor as well as in central Europe, where it can be further transported into the Netherlands.[117]

The expansion of transportation and its infrastructure is crucial to accelerate the growth and proliferation of the hydrogen economy. **A recent study by the esteemed VTT Technical Research Centre of Finland[118] highlights that limited electricity transmission capacity could impede the expansion of wind and hydrogen generation capacity in Finland.** Given this scenario, hydrogen transportation via pipeline from decentralized wind farms to final usage locations could be a viable solution. Such pipelines could efficiently transport large amounts of energy in the region and, in turn, allow for the release of transmission grid capacity for additional wind farms. Notably, hydrogen pipelines necessitate significantly less land than high voltage transmission lines, and Gasgrid Finland's subsidiary is well-positioned to facilitate their construction. The proposed pipelines would establish a vital connection between North Ostrobothnia and the pan-European hydrogen gas pipeline network.

Already between the years of 2014 and 2015, Woikoski Oy built two hydrogen refuelling stations in Finland, but these stations are no longer in use. However, **P2X Solutions Oy has announced their plans to build hydrogen refuelling stations to Harjavalta and Järvenpää by 2024. The Finnish Energy Authority provided EUR 790 000 grant for P2X Solutions' fuelling station in Järvenpää.[119]** In addition, **Vireon**, a subsidiary established by Norwegian Hydrogen AS, is planning on building a refuelling station network in Finland and the Baltics and has recently announced its plans on building a refuelling station in Jyväskylä.[120] Vireon entered the Finnish market by buying a refuelling facilitator, HydRe. HydRe was a Finnish company with some significant leads and Vireon is supposed to continue forward with these plans.

7.1.6 Policies

- Stable, long-lasting political framework.
- Climate Act was enacted in 2022 and lays out the framework for Finland to achieve its climate goals and become carbon neutral by 2035.
- No current hydrogen regulations, although the current legislation mentions hydrogen.
- The country has a temporary primary position on authorisation processes for green transition projects.

It is clear that **Finland needs to have more clarified regulations regarding the usage and production of hydrogen.** At the moment, there is no clear regulation for the hydrogen economy. According to research conducted by VTT, the research and technology centre in Finland, the current legislation in Finland contains limited mentions of hydrogen. The mentions are mainly limited to the distribution obligation of renewable fuels and clean vehicle procurement targets.[121] These findings highlight **the need for further development of the regulatory framework for the hydrogen economy in Finland.** Finland does have the distribution obligation of renewable fuels already in place unlike the EU or most of its members, and **more mentions of renewable hydrogen are expected to be included in the Finnish legislation when the EU directives are adapted**. In their study, VTT highlights several barriers to the hydrogen economy in Northern Ostrobothnia. These barriers can be widened to concern the whole of

[117] https://gasgrid.fi/en/2022/12/16/from-vision-to-action-six-partners-have-signed-a-cooperation-agreement-to-develop-nordic-baltic-hydrogen-corridor/

[118] Pre-study on transition to hydrogen economy, specifically in Northern Ostrobothnia. Kiviranta, K. et al. 2023. Available: https://raaseu.jict.fi/sites/raaseu.jict.fi/files/tiedostot/ajankohtaista/Prestudy%20on%20transition%20to%20hydrogen%20economy%2C%20specifically%20in%20Northern%20Ostrobothnia_final_0.pdf

[119] https://p2x.fi/en/p2x-solutions-will-construct-the-first-hydrogen-fueling-station-in-the-greater-helsinki-area-in-jarvenpaa/

[120] https://www.ksml.fi/paikalliset/5698064

[121] Pre-study on transition to hydrogen economy, specifically in Northern Ostrobothnia. Kiviranta, K. et al. 2023. Available: https://raaseu.jict.fi/sites/raaseu.jict.fi/files/tiedostot/ajankohtaista/Pre-study%20on%20transition%20to%20hydrogen%20economy%2C%20specifically%20in%20Northern%20Ostrobothnia_final_0.pdf

Finland, especially regarding political and legal aspects. Finland has complex requirements for public funding and there are only a few support instruments for scaling up innovations. On top of these, there is uncertainty in several legal aspects, such as EU regulation on CCU/S, uncertainty about safety regulations, slow permitting process, and legal proceedings. The permitting process problem was responded by the government as they published permit and appeal procedures priority for green transition investment projects.[122] However, the industry side has highlighted that the permitting process should be faster and more proactive. There is a need for knowledge on permitting issues and several companies would need consultancy on issues like this.

The current EU agreements and EU legislation give Finland some possibilities to use its national means of control to promote the hydrogen economy. **For the projects of green transition, the government of Finland has promised a temporary primary position on authorisation processes, with a target that all authorisations of green transition projects will receive an answer within 12 months since opening the case.** The primary position on authorisation could be highly important for future investments, as for example SSAB has announced that it will prioritize investments between Raahe (Finland) and Lulea (Sweden) depending on how fast the permitting process is for each country and site. The CEO of SSAB has stated that the Finnish targets, plans and permitting processes are a strength for Finland compared to Sweden.[123]

Finland held its parliamentary elections in April 2023, where the National Coalition Party "*Kansallinen Kokoomus*" won the elections and started negotiations on formation of the government. Before the elections there was a risk regarding the Finnish Carbon Neutrality Goals, as the country's 2nd most popular party, The Finns "*Perussuomalaiset"* had stated that their aim is to postpone the Finnish climate neutrality goals. Postponing the climate neutrality 2035 -goal would have significant effects on the country's policies. However, according to the Finnish Association for Nature Conservation, the leader of the National Coalition Party, Petteri Orpo, has stated that with the new government, **Finland will hold to its carbon neutrality goal and the 2035 goal will not be postponed.**

In december 2020, **Finland signed the EU's hydrogen manifest**. Since the beginning of 2023, the Finnish Government has offered priority to certain green transition projects in the permit processing of regional administrative agencies from the years 2023 to 2026. This priority also includes hydrogen projects.[124] This helps permit processes regarding hydrogen production, storage, and utilization. 2023 is also a remarkable year for the transportation industry, as electric fuels are included in the distribution obligation starting in 2023. The aim of the distribution obligation is to reduce emissions from transport[125].

The Finnish Climate Change Act 423/2022, also known as the Climate Act, was enacted in 2022 and lays out the framework for Finland to achieve its climate goals and become carbon neutral by 2035. The Act sets targets for reducing greenhouse gas emissions and establishes a national Climate Committee to monitor progress and provide recommendations for how to achieve the targets. The Act specifies 3 emission reduction targets: 60% by 2030, 80% by 2040 and 90%, but aiming for 95%, by 2050 compared to the levels in 1990[126].

The visionary and forward-thinking Nordic nation has devised a comprehensive and ambitious Sustainable Growth Programme, dedicated to fostering and nurturing the development of hydrogen and Carbon Capture and Utilization and Storage (CCUS) initiatives. This programme, boasting a substantial allocation of EUR 150 million, represents a substantial and significant funding package that empowers the advancement of hydrogen solutions across various segments of the hydrogen value chain. This initiative serves as a catalyst for the growth and expansion of the

[122] https://ym.fi/en/-/finland-boosts-green-transition-in-permit-and-appeal-procedures-priority-given-to-investment-projects
[123] https://yle.fi/a/3-12672407
[124] https://valtioneuvosto.fi/hanke?tunnus=YM019:00/2022
[125]https://valtioneuvosto.fi/en/-/1410877/lower-distribution-obligation-for-transport-fuels-to-continue-in-2023?languageId=en_US
[126] https://ym.fi/en/climate-change-legislation

hydrogen industry within the region and positions the nation as a leader in the field.[127] The funding is part of EUR 530 million program arranged by **Business Finland[128]** which grants around EUR 150 – 170 million per year between 2021 and 2023, leading to overall funding proposed to be granted totalling to around EUR 530 million. From this total amount, around EUR 150 million was earmarked for low-carbon hydrogen and carbon capture and utilisation.

To develop a robust hydrogen economy in Finland, it is crucial to ensure that the country's renewable energy production projects are seamlessly executed, and necessary permits are obtained in a timely manner. The smooth implementation of such projects is essential to enhance production capacity and meet the increasing demand for hydrogen fuel. Many experts in the Finnish hydrogen economy industry believe that a streamlined approach to renewable energy production can facilitate the flourishing of the hydrogen economy, making Finland a competitive player in the global market.[129]

The Hydrogen Cluster Finland has recently released a set of recommendations for policymakers, outlining key steps to ensure the country secures favourable EU decision-making and attracts international investments in the hydrogen sector. These recommendations emphasize the importance of developing a comprehensive and robust hydrogen-economy strategy, supported by decisive and clear actions towards its implementation.[130] With these steps, **Hydrogen Cluster Finland believes that Finland can become a leading hydrogen economy of Europe by 2030.**

Finland has the lowest corporate tax rate of 20% among the Nordic countries, which is also one of the lower ones in the EU.[131] The Finnish Tax Administration has a predictable and company friendly approach. The Tax Administration strongly focuses on modern, pre-emptive approach instead of retrospective traditional tax audits. **The Administration has also a dedicated team helping foreign companies in tax matter, fully free of charge.**

7.2 Market characteristics

7.2.1 Networks

Presently the most prominent networks in Finland are the esteemed Hydrogen Cluster Finland, FinH_2 and the pioneering cross-border network, BotH_2nia, which extends its reach into Sweden. In addition to these established networks, Finnish companies and organisations are actively pursuing the creation of new networks with the aim of further advancing their capabilities and competitiveness in the global market. In line with the Finnish carbon neutrality ctrategy, these companies are encouraged to collaborate and build networks both domestically and internationally, to drive the development of competencies and jointly undertaken projects.

1. **Hydrogen Cluster Finland (HCF)**

The Hydrogen Cluster Finland is one of the most important networks of companies and associations promoting hydrogen economy in Finland. Out of the three networks in the country, HCF is the biggest with most companies covering the whole value chain of hydrogen. Several of the companies which are part of the cluster are international companies operating in Finland, such as **ABB, AFRY, SSAB** and **Siemens.** The cluster also has major Finnish companies' operating globally as part of it, such as **Neste, St1, Wärtsilä and UPM.** HCF is a platform for companies and industrial associations to come together, share information, collaborate on projects and initiatives, and develop

[127] https://stm.fi/en/-//1410877/energy-investments-of-finland-s-sustainable-growth-programme-promote-the-green-transition
[128] https://www.businessfinland.fi/en/campaign-sites/sustainable-growth-program-for-finland
[129] https://clc.fi/fi/2023/03/12/case-neste-vihrea-vety-uudistaa-teollisuuden-ja-talouden/
[130] Finland – European Leader in Clean Hydrogen Economy 2030. 2023. Hydrogen Cluster Finland. Available: https://h2cluster.fi/documents/
[131] https://taxfoundation.org/corporate-tax-rates-europe-2023/#:~:text=Hungary%20(9%20percent)%2C%20Ireland,tax%20rate%20of%2021.5%20percent.

a cohesive business strategy for the advancement of the hydrogen economy. Its purpose is to foster business opportunities and support the transition towards hydrogen economy. The network has more than 70 members varying from start-ups to the largest companies in Finland. The members are all originated or at least operating in Finland. HCF aims to work with new technologies and innovations. Thus, they are expected to be well represented at the world's leading startup event, Slush Helsinki.
HCF welcomes new members, and their contact details can be found from their website, available at:
https://h2cluster.fi/contact/

2. Climate Leadership Coalition (CLC)

CLC is one of the most influential climate networks in the Nordics. Climate Leadership Coalition is the largest non-profit climate business network in Europe. Their 71 Finnish members employ 400 000 people globally. The coalition has several research centres and universities as part of it, such as **VTT Research Centre, University of Vaasa, Turku and Eastern Finland, et cetera.** The coalition also has a large number of large enterprises as its members, like **St1, Neste, Nokia, et cetera.** The coalition arranges several member-only events, including events regarding hydrogen and PtX. CLC is also part of the European Clean Hydrogen Alliance. The coalition welcomes new members as part of it, with annual pricing depending on the size of the company or organisation. If one wishes to have more information on becoming a member, please head to the link below:
https://clc.fi/members/#become-a-member

3. Both$_2$nia

Both$_2$nia is a cross-border network of different actors in the field of hydrogen and fuel cells, that aims to promote the deployment of this technology in the Bothnia region of Finland and Sweden. The network is focused on promoting the use of hydrogen and fuel cells to decarbonize various sectors, such as transportation and industry, and to create new business opportunities. This network is established by the Euroregion Bothnia, which is an institution that promotes cross-border cooperation in the Bothnia region of Finland and Sweden. Both$_2$nia is set to become the largest hydrogen cluster in Europe with aim to boost the Nordic hydrogen industry. At moment it has a wide range of different sized companies as part of it, including large companies like **Gasgrid Finland, Helen OY, SSAB Europe Oy,** and **Wärtsilä** Corporation. It organises events, acts as a common platform for the evolving hydrogen industry in the north, enabling active dialogue between the members of the network. **The vision of the public-private network is to create an access to Central European Markets, like Germany, Denmark and the Netherlands.**
Both$_2$nia's contact details can be found on their website, available at:
https://www.both2nia.com/en/info

4. FinH_2

FinH_2 is a cooperative effort between VTT Research Institute, LUT University, Aalto University, Business Finland and 18 key stakeholders from various sectors, including major companies like **ABB, Neste, Fortum** and **Kemira**. The primary goal of the project is focused on developing new, sector-coupled electrolyser solutions that provide a competitive advantage for the Finnish industry and drive new investments and increased business opportunities in international markets for Finnish companies. The project is also working on creating a networked R&D platform that aims to bring together different actors from the hydrogen ecosystem, and to increase the overall competitiveness of the Finnish industry. **The FinH_2 project is also supported by funding from Business Finland**, which aims to help companies to develop and commercialize innovative hydrogen solutions. The projects stakeholders are focused on all parts of the value chain from production to consumption or applications. It includes small and medium companies which are either domestic, international companies operating in Finland or Finnish companies with branches or operations in foreign countries too. According to VTT, "*there are already many companies in Finland whose products are suitable for hydrogen business, and there is certainly demand for them around the world as well. In addition, the aim [of the FinH_2 project] is to accelerate the domestic production of entire systems*."

The FinH2 project is a notable initiative that focuses on developing an efficient and profitable hydrogen production process. The project aims to design and construct a sector-coupling PEM electrolysis system that utilizes waste heat and improves the overall efficiency of the hydrogen production process. To gain practical experience in industrial applications of hydrogen technology, the project has established a pilot system at the Helen power plant. One of the major challenges faced by the industry is the availability and cost of precious metals that are essential for the construction of PEM electrolysers. To address this issue**, the project is developing a new type of catalyst solution that reduces the dependence on these precious metals.** Additionally, the project is also exploring alternative solutions to improve the efficiency and reduce the cost of alkaline electrolysis. These include raising the operating temperature and voltage to enhance the performance of the electrolysis system.
FinH_2 has listed contact details of the most important personnel in their website, available at:
https://www.finh2.fi/contacts/

5. Invest in Finland

Invest in Finland is a government-funded organisation that provides assistance and support to foreign companies interested in investing in Finland. Their primary goal is to promote Finland as an attractive investment destination by collecting and disseminating information about the country's business environment, market opportunities, and incentives. They work closely with both national and international organisations to facilitate investment and business opportunities in Finland.
Invest in Finland specializes in five key focus industries, which are bio & circular economy, cleantech, health & wellbeing, ICT & digitalization, and travel. These industries have been identified as areas where Finland has significant expertise, innovation, and potential for growth. By promoting these industries, Invest in Finland aims to attract foreign investment and create jobs and economic growth in Finland.[132] As green hydrogen is classified as a cleantech technology, it is likely that they would be interested in helping companies investing in green hydrogen in Finland. Invest in Finland can help companies to connect with potential partners, suppliers, and customers in the Finnish cleantech industry. Invest in Finland also provides information regarding taxes, business environment and has a cost calculator helping foreign companies to get an overview of different employee types and costs in Finland.
The organisation has listed contact details for their industry experts, available at
https://www.businessfinland.com/how-we-can-help/contact/
Invest in Finland can also be contacted **via phone**: +358 204 695 555.

6. VTT Research Centre of Finland

VTT has a hydrogen technologies and fuel cell research service available. VTT partners with companies from all stages of the hydrogen value chain to develop new H_2-based solutions and offer consultation, testing, and validation services. VTT provides analysis and cost-efficient solutions for decarbonization and solves technical challenges in relation to hydrogen production, storage and utilization.
More information and further contact details are available at:
https://www.vttresearch.com/en/ourservices/hydrogen-technologies-and-fuel-cells-research

7. BalticSeaH_2

The BalticSeaH_2 project aims to establish a large-scale, cross-border hydrogen in the Baltic Sea region, centered in the southern regions of Finland and Estonia. This innovative project seeks to create an integrated hydrogen economy in the region, facilitating the reduction of carbon dioxide emissions from various industries and promoting energy self-sufficiency. The area's connection to the wider market of the Baltic Sea region makes it an attractive investment opportunity for hydrogen projects. The project consortium boasts 44 partners from nine countries around the Baltic Sea area, including Finland, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Norway, and Sweden. CLIC Innovation Oy and Gasgrid Finland Oy are the coordinating partners for the project, with a total proposed investment

[132] https://www.businessfinland.fi/en/for-finnish-customers/about-us/invest-in-finland

of EUR 33 million, of which an estimated EUR 25 million will be provided by the European Union's Clean Hydrogen Partnership. The financing agreement is currently being prepared, with the project's anticipated launch scheduled for the summer of 2023. The BalticSeaH_2 project represents a significant step towards establishing hydrogen valleys in Europe, under the umbrella of the REPowerEU program.[133]

8. FITech

FITech offers university courses free of charge for degree students and adult learners in Finland, including courses regarding hydrogen (economy). The courses are focused on degree students and adult learners in Finland, for adults already working or planning a career change. All of the technical universities are part of the FITech network, including Aalto University, LUT University, Universities of Oulu and Vaasa, which are seen as the top power-to-x and hydrogen universities in Finland. Currently, FITech has started its FITech Hydrogen study module, which includes several courses on the hydrogen economy from Finnish universities. The courses are held in English and are held online. The purpose of the module is to give a comprehensive understanding of hydrogen economy and hydrogen value chain, as well as related technical, economic, and political questions. The module's main courses are from Aalto University, the University of Vaasa, the University of Oulu and Tampere University. On top of these, there are additional courses from LUT University, the university of Jyväskylä, and Åbo Akademi. FITech can be contacted directly from their e-mail: info@fitech.io

7.2.2 Events

Currently, there are only a few mentionable events published to be held in Finland. However, organisations such as **Business Finland**, **Hydrogen Cluster Finland, and BothH_2nia** actively promote green hydrogen and Power-to-X and have held workshops and webinars regarding these topics. It is expected that Business Finland will host such events in the future too. Business Finland has also hosted trade missions to the Netherlands, highlighting the common goal of the two countries to cooperate in the future.[134] The cross-border network **BothH_2nia,** which was explained in more detail in chapter 7.2.1., arranges several events around Finland each year. The network has announced three future events for 2023 and there have been several events held within the first four months of the year 2023.[135]
Please **contact the Dutch Embassy in Finland for latest updates** on hydrogen related events.

Table 10 Hydrogen events in Finland

Event	Dates 2023	Location	Website
Energy Week, annual event	20.3. – 24.3.2023	Vaasa	*https://www.energyweek.fi/energyweek-energyvaasatalks/*
Teknologia, annual event	7.11. – 9.11.2023	Helsinki	*https://teknologia.messukeskus.com/companies/?lang=en*
Slush, annual event	30.11. – 1.12.2023	Helsinki	*https://www.slush.org/events/helsinki/*

[133] https://gasgrid.fi/en/2023/02/06/southern-finlands-hydrogen-valley-development-project-is-progressing-as-planned/
[134] https://www.businessfinland.fi/en/whats-new/events/business-delegations/2023/trade-mission-to-the-netherlands
[135] https://www.both2nia.com/en/events

1. **Vaasa Energy Week**

Vaasa EnergyWeek is a highly significant **annual event** in the Nordic energy sector, attracting energy professionals from various countries to discuss a wide range of topics related to the present and future of the industry. The event is organized collaboratively by around thirty organisations. The conference offers a unique platform for experts to exchange insights, explore new ideas, and share best practices. In 2023 the event attracted a record number of visitors from 44 different countries.

For contact information, please head to https://www.energyweek.fi/contact-information/

2. **Teknologia 23**

Teknologia exhibition is an annual technology exhibition in Finland. The event is for those working within industry and technology, who want to develop their skills, knowledge, and network. Teknologia is a meeting point for all professionals where innovations and new products can be seen at one time under the same roof. Key topics of the events are the green transition, Delivery Networks, Hydrogen industry, and Artificial Intelligence. It is expected that majority of companies that work with hydrogen in Finland and in the Nordics are represented in the event.

More information and contact details are available at:

For Exhibitors | Teknologia 23 | 7–9 Nov 2023 (messukeskus.com)

3. **Slush**

Slush is one of the largest start-up and tech events in the world. It takes place annually in Helsinki, Finland, and bring together thousands of entrepreneurs, investors, and tech enthusiasts from all over the world. The event features talks and panels by industry leaders as well as networking opportunities. Slush attracts a wide range of investors looking for the next big thing in tech. While it has not been officially confirmed, it is highly likely that hydrogen technology and innovations will be featured at Slush 2023. Hydrogen Cluster Finland, a leading organisation in promoting hydrogen technologies and innovations, is expected to participate in the event, indicating that there will be a strong focus on hydrogen-related topics.

For more information about Slush, please head to their website at: https://www.slush.org/events/helsinki/

7.2.3 SWOT Analysis

Table 11 SWOT Analysis, Finland

STRENGTHS	WEAKNESSES
• The government's willingness to encourage companies to cooperate internationally. • Strong expertise in the industry and the energy sector overall. • The country has been an active contributor to fuel cell technology for decades. • Ability to export hydrogen technology. • Good availability of reliable, low-cost, clean energy. • Strong transmission grid. • Stable and easy-to-predict regulatory environment. • High share of renewables in energy supply mix with goal of carbon neutrality by 2035. • Large amounts of clean water. Removing salt from seawater requires energy but is necessary for water to be used in electrolysis. • Cheaper to build wind-power in Finland compared to other European countries. • One of the cheapest countries in the EU for solar power. • Gas transport in tube trailers exceptionally cost effective. • Well-established networks. • Access to Bio-CO_2. • Same currency with the Netherlands (Euro). • Highly EU-integrated country with a willingness to solve European problems together with EU-members.	• Geolocation not close to natural gas or natural hydrogen storages or close to main markets. • Less hydrogen experience outside of industry. • No hydrogen uses in traffic & transportation. • Fuelling stations etc. expensive to build because of long distances. • Production and off-take locations differ. • Small internal markets as of now. • Potential export markets are located far away. • Exports of hydrogen requires new hydrogen pipelines or other ways of transporting hydrogen outside of Finland. • The availability of skilled employees does not answer to the needs. • Natural gas grid is focused on Southern-Finland, H_2 production mostly located in Northern Finland. • Lower ambitious' from the government on hydrogen production compared to other Nordic countries. • Lack of regulation regarding green hydrogen and synthetic fuels. • Applying process for funding can be slow. • Less private funding opportunities available compared to other Nordic countries.
OPPORTUNITIES	**THREATS**
• Replacing the use of natural gas, coal and oil as fuels and raw materials in industry and transport. • Great potential to build more renewable energy production sites. • Enabler for CO_2-free steel production. • Cost-efficient decarbonisation of existing hydrogen use. • Lowering the cost of logistics for industry. • Value chain missing producers of equipment. • Collaboration with foreign companies encouraged for the creation of hydrogen economy. • National company established for developing transportation infrastructure. • Possibility for industries to off-take hydrogen once the market is established. • Possibilities to produce more than 10% of the EU's overall production by 2030. • Rapidly growing renewable energy production. • Green hydrogen economy can employ more than 100 000 persons indirectly, according to Hydrogen Cluster Finland. • Estimated investment potential currently EUR 50 billion. • International collaboration necessary for majority of the companies. • The country is well positioned to produce green hydrogen even after the EU Commision's consideration of green hydrogen or RFNBO production.	• Low prices for fossil fuels and CO_2 allowances à cheaper to produce hydrogen with fossil fuels and buy CO_2 allowances than to produce green H_2 or create CCU/CCS. • RED III directive could prove to be unfavourable for Finland. • IPCEI allocates less money for smaller economies, meaning less fundings available for a small economy like Finland. • As hydrogen economy is in its developing phase, the legislation is still work in progress. • Uncertainty for the needs and possibilities of infrastructure. • Missing experience of electricity and hydrogen grid co-planning. • The government most likely cannot invest in development as much as bigger European countries can. • Scaling of electrolyser-production is late. • High prices of hydrogen technology. • Lack of marketing and sales skills might limit growth on future investments. • Results of the parliamentary elections for the 2023 – 2027 convocation could see the country postpone its green transition goals. • Availability of large-scale electrolysers. • Lack of investments could lead to decrease in willingness and speed of development. • Challenges in the availability of raw materials and components, and the delivery times can be quite long.

7.3 Opportunities for Dutch businesses

7.3.1 Segments providing opportunities

- Collaboration between the Netherlands and Finland can help drive the development of the hydrogen industry and attract qualified personnel.
- Dutch companies can provide significant value in infrastructure development, safety, electrolyser equipment, and sharing their experiences with successful hydrogen valleys.
- Collaboration on transportation and infrastructure development is crucial to realize the full potential of the opportunity for both countries.
- Finnish peaceful and stable funding environment could attract foreign investments into the country.
- Majority of Finnish companies are in need of international collaboration, whether it is funding of the projects, joint ventures or knowledge exchange.

The Finnish hydrogen economy is ripe with opportunities for Dutch businesses, with several segments in the value chain providing potential areas for collaboration. These segments include research, infrastructure, safety, equipment for electrolysers, and hydrogen valley & hub knowledge. The Finnish business landscape is increasingly recognizing the importance of collaboration with international partners in order to drive growth and innovation. In particular, **several Finnish companies have identified a need for international collaboration,** whether it be in the form of funding for projects, joint ventures, or knowledge exchange. The benefits of such collaboration are numerous, ranging from increased access to capital, to the sharing of expertise and technology, to the establishment of new markets and distribution channels. Whereas for example Denmark is in vast need of knowledge exchange, Finnish hydrogen landscape is also in need of foreign investments.

Furthermore, Dutch companies have extensive knowledge and experience in CO_2 storage and utilization, which could be leveraged to support the development of sustainable hydrogen production processes. In addition to these areas, Finnish companies would benefit from **the knowledge and expertise of Dutch companies in electrolyser technology, infrastructure design planning (pipelines, storage, and refuelling stations), and gas grid knowledge.** Dutch companies have been at the forefront of electrolyser development, with several large-scale projects underway in the Netherlands. Additionally, Dutch companies have extensive experience in the design and planning of hydrogen infrastructure, leveraging their expertise in gas grid planning and implementation.

In the research segment, there is a significant need for **innovative solutions** that can drive the development of the hydrogen economy. Dutch businesses can bring their expertise in research and development to the table, collaborating with Finnish counterparts to develop cutting-edge solutions that will help drive the industry forward. As both countries have a challenge on finding qualified personnel and capable labour, this collaboration could also potentially help with attracting and finding qualified personnel for joint hydrogen projects. As both Finnish and Dutch companies are aiming to find solutions for global problems, knowledge exchange between the two countries should be more than suitable.

Dutch companies possess valuable expertise in **the design and construction of hydrogen production facilities** and are well-versed in navigating the permitting processes necessary for their successful operation. Given the complexity of the Finnish regulatory landscape, partnering with Dutch counterparts could provide Finnish companies with the necessary design know-how and permitting knowledge to facilitate the establishment of hydrogen production facilities. Such collaboration could also result in the development of innovative, cost-effective solutions that leverage the strengths of both countries' industries, unlocking new opportunities for growth and expansion in

the rapidly evolving hydrogen sector. Dutch companies are well-positioned to provide technology knowledge and integrator services, leveraging their extensive experience in the development and implementation of hydrogen projects.

Infrastructure is another area where Dutch companies can provide significant value. Finland is in the process of developing its hydrogen transmission network, and Dutch businesses can bring their extensive experience in infrastructure development and management to bear, ensuring that the network is built and operated in an efficient and effective manner. The Finnish hydrogen gas network developer Gasgrid has announced its first demonstration pipeline, but a lot more needs to be done in order to grow the Finnish hydrogen economy. Dutch companies with knowledge, skills and resources on hydrogen infrastructure could attend in tenders that are most likely going to be opened for the hydrogen gas grid building. The country will also need **additional resources for building refuelling stations**, especially after the TEN-T network's goals of building a refuelling station for every 200km's in the country.

Safety is of paramount importance in the hydrogen economy, and Dutch companies can provide valuable expertise in this area. Collaborating with Finnish businesses, Dutch companies can develop solutions that ensure the safe and efficient handling, storage, and transportation of hydrogen, helping to build public acceptance in the industry.
The demand is especially high for knowledge on hydrogen storage solutions as Finland does not have any suitable geological formations for inexpensive hydrogen storage. Moreover, Finland is in dire need of the Dutch expertise in **experimenting and testing with materials for piping to prevent corrosion and leaking.**

Equipment for electrolysers is another area where Dutch businesses can provide significant value. With the development of the hydrogen economy, there is a growing demand for high-quality, efficient electrolysers, and Dutch companies can bring their expertise in this area to the Finnish market. This provides opportunities for Dutch companies producing electrolyser components such as stacks and membranes.

Finally, **hydrogen valley knowledge** is another area where Dutch businesses can provide valuable insights and expertise. With several successful hydrogen valleys in the Netherlands, Dutch businesses can share their experiences and knowledge, helping to accelerate the development of the Finnish hydrogen economy. The Netherlands have established several hydrogen hubs across the country, with Rotterdam and Groningen serving as some of the most significant. The hubs have been designed to facilitate the development of hydrogen technologies and related infrastructure, bringing together stakeholders from various sector, such as energy, transport, and industry. Finnish companies looking to develop hydrogen hubs could benefit from Dutch expertise in this area. This includes knowledge on how to plan and design circular economy solutions, such as using renewable energy sources to power hydrogen production and incorporating carbon capture and storage technologies to ensure a low-carbon footprint. By leveraging the expertise and experience of the Dutch companies, Finnish companies can accelerate the development of their own hydrogen hubs, enabling the country to meet its ambitious carbon reduction targets and contribute to the transition to a more sustainable future.

Collaboration between the Netherlands and Finland in the hydrogen economy presents a unique opportunity for both countries. **The Netherlands is expected to have a significant demand for green hydrogen in the coming years, and Finland has the potential to produce more than it consumes.** However, to realize the full potential of this opportunity, both countries will need to collaborate on the transportation of hydrogen or its derivatives from Finland to the Netherlands. This will require political support and the development of infrastructure between the Nordic countries as well. With the right collaboration, both Dutch and Finnish businesses could benefit greatly from this opportunity, while also contributing to the development of a more sustainable future. In a report published by LUT University, it is stated that Finland has peaceful and stable funding environment which could attract foreign investments into the country.

7.3.2 Recommendations for market entry

- Recommended to contact local actors, such as the Hydrogen Cluster Finland to build relationships.
- Finland is one of the most competitive and open economies in the world.
- Companies are eager to cooperate in order to find solutions to EU-wide problems.
- The Dutch Embassy in Finland helps Dutch companies with market entry.
- Finland is the only Nordic country which has euro as its currency.

According to Business Finland, Finland is one of the wealthiest countries and most stable and safe societies in the world. The country is at top of many international economic, technological, and social rankings. The Finnish Government is seen as exceptionally business-friendly, and the country has relatively cheap and stable green energy, creating competitive operating costs in the field of hydrogen. The country has a stable and safe political environment, a competent workforce, and high-quality services as well as a progressive mindset. According to Transparency International[136], Finland is the 2nd least corrupt country in the world, just behind Denmark. Dutch companies are warmly welcomed in Finland and **Dutch companies can access the same benefits as Finnish companies if they were to join the market.** Opening a legal entity takes a couple of weeks. Dutch companies can benefit from the clusters such as Hydrogen Cluster Finland and BotH2nia, and high-level expertise that **aims to maximize the benefits of R&D and international cooperation.** Finland is one of the most competitive and open economies in the world.[137] The country together with local companies are willing to find large international solutions for global problems, including the energy sector. As **Finland is the only Nordic country that uses the euro as its currency**, it offers a stable and predictable economic environment for Dutch companies looking to invest. This eliminates the currency exchange risk that comes with investing in other Nordic countries that have their own currencies. Between Finland and the Netherlands, there is some active collaboration ongoing already. For example, the Finnish oil refining company **Neste** together with German electrolyser manufacturer **Sunfire** has opened a green hydrogen plant in the port of Rotterdam.[138] The Finnish electrolyser manufacturer **Convion Oy** has announced its collaboration with **Shell Global Solutions International** to develop, validate and commercialise electrolysers supplied by Convion. Convion will deliver an electrolyser demonstrator to Shell's Energy Transition Campus **in Amsterdam**.[139]

The Finnish hydrogen market offers many opportunities for companies looking to enter the sector. **There are various ways for market entry, such as knowledge exchange, export, import, investment, partnerships, and more.** One strategy for entering the Finnish hydrogen market is to identify potential partners or projects and contact these companies directly. Some major projects in Finland are represented in this study's Table 8. However, before any market entry strategy is pursued, **it is crucial to gain background information on the Finnish hydrogen sector and its key players**. This can include understanding the regulatory framework, market trends, and the competitive landscape. In this study, we highlight some key projects and players in the Finnish hydrogen market, as well as seminars and clusters that can provide valuable insights and networking opportunities. By attending the events listed earlier, companies can gain a better understanding of the Finnish sector and establish relationships with key players. The actors in the Finnish hydrogen field listed in Table 7 together with members of the Hydrogen Cluster Finland can be seen as both, major competitors but also major companies to collaborate with. As stated earlier, Finland as a country and Finnish companies understand the need for collaboration to tackle future problems and to find solutions to global problems.

[136] https://www.transparency.org/en/cpi/2022
[137] https://www.businessfinland.fi/en/publications/invest-in-finland/business-guide-for-companies-planning-to-establish-in-finland
[138] https://www.sunfire.de/en/news/detail/renewable-hydrogen-project-multiplhy-worlds-largest-high-temperature-electrolyser-from-sunfire-successfully-installed
[139] https://convion.fi/convion-and-shell-form-partnership-to-commercialise-solid-oxide-electrolysers-soec/

The Dutch Embassy in Finland can offer valuable support to Dutch companies looking to enter the Finnish hydrogen market. The Embassy can provide information on the Finnish market, including local business culture, regulations, and market opportunities as well as facilitate introductions to local business networks and hydrogen organisations. In addition, the Embassy hosts events and seminars on various topics related to doing business in Finland, such as market entry, regulations, and investment opportunities. For further information, please contact hel-ea@minbuza.nl.

Moreover, **Business Finland's Team Finland** provides support and advice to foreign companies looking to establish presence in the Finnish market.

When entering the Finnish markets, companies should consider at least the following 5 steps that are illustrated in Figure 11.

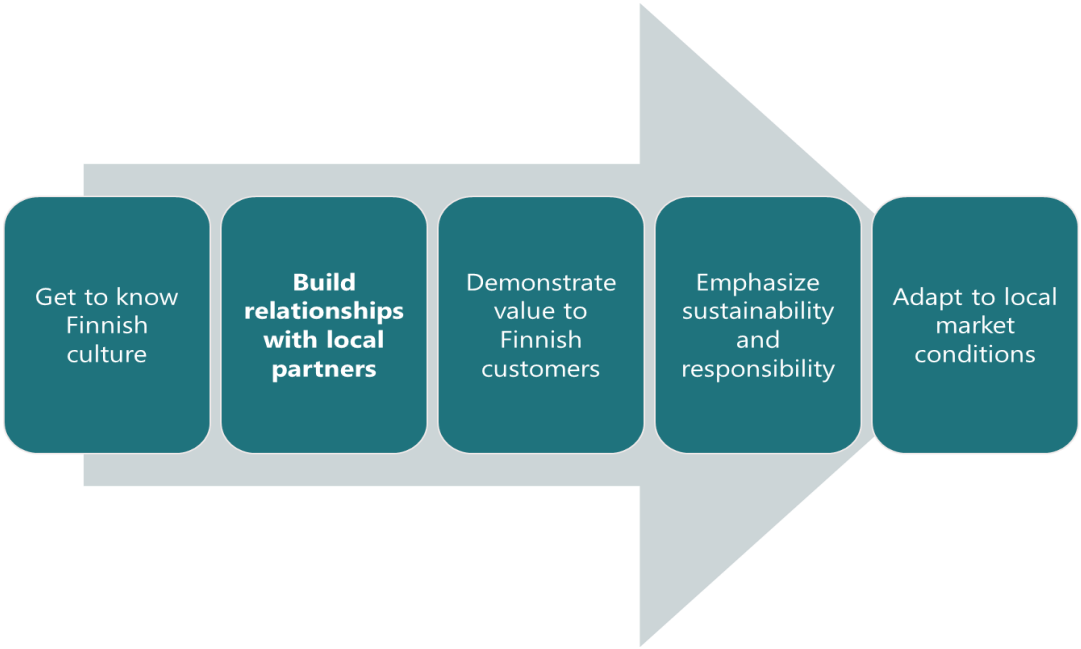


Figure 11 Steps to join the Finnish market.

1. *Get to know Finnish culture.*

Finnish culture is known for its reserved and formal nature, with an emphasis on punctuality, honesty, and direct communication. It's important to take the time to research and understand these cultural nuances before doing business in Finland. Additionally, familiarize yourself with the local business practices and regulations, and be prepared to adapt your approach accordingly. Finns have a strong sense of national identity, but their customs and manners are Pan-European. **Most Finns in business speak fluent English, with the country having the third-best English skills among adults worldwide.** However, there are still several events and meetings held only in Finnish. Communication style is polite yet straightforward, with a preference for short and to-the-point meetings. Everyone is expected to be well-prepared, and appointments with Finnish associates should be set up in advance. Finnish working life is characterized by equality and high value on work. Observing timetables and respecting agreements are important, and a signature makes an agreement binding. Many company processes are performed via electronic services, including payments and transfers. Public authorities also offer electronic services that require electronic identification. **It is also essential to ensure your company is aligning with the Finnish regulations.** Before commencing operations, it is important to check whether a licence or declaration is needed and what other requirements apply in the field of the company's project.[140]

140 https://www.businessfinland.fi/en/publications/invest-in-finland/business-guide-for-companies-planning-to-establish-in-finland

2. *Build relationships with local partners.*

Networking and collaborating are key to success in Finland. Look for local partners who can help you navigate the market. **Don't hesitate to contact the earlier mentioned organisations such as Hydrogen Cluster Finland, Invest in Finland or the Dutch Embassy in Finland.** To find relationship and to establish connections and gain visibility, it is recommended to participate in the Finnish events described further in chapter 7.2.2. The Finnish business world has a high level of English proficiency, and most employees across various industries and companies are fluent in the language. As the hydrogen economy is a global matter and Finnish environment is open and international, companies should be able to network and build relationships solely in English. Building relationships can facilitate communication, build trust, and enhance collaboration with Finnish stakeholders in the hydrogen industry. **The Finnish companies and the hydrogen industry as a whole are highly in favour and in need of collaboration.**

3. *Demonstrate value to Finnish customers.*

Finland is seen as a consumer society, **where the main determinant of purchase is quality**. Emerging consumer trends are related to environmental protection and progressive values.[141] Finnish customers value quality, reliability, and innovation. Focus on highlighting how your products or services can meet these criteria and emphasize how your offering can solve a particular problem.

4. *Emphasize sustainability and environmental responsibility.*

Finland and majority of its inhabitants are committed to sustainability and reducing carbon emissions. Highlight how your offering can contribute to these goals. Be prepared to demonstrate your commitment to sustainability through your own business practices. Keep in mind that sustainability is not only about environmental sustainability, but also about social sustainability and safety**. Finland has a strong culture of integrity and transparency**, with a reputation for having the 2nd least amount of corruption in the world. Finnish citizens and businesses take pride in this fact **and are highly critical of any actions that are perceived as unethical or corrupt.** Companies that engage in "shady" actions or attempt to circumvent laws and regulations are likely to face public scrutiny and reputational damage. Therefore**, it is important for companies operating in Finland to maintain high ethical standards and act with transparency in order to build and maintain trust with stakeholders.**

5. *Adapt to local market conditions.*

While you may already have a successful business model in the Netherlands, it's important to be flexible and adapt to local market conditions in Finland. Take time to research the competitive landscape, pricing expectations and customer preferences. Consider localizing your marketing materials and messaging to resonate with Finnish customers. **Business Finland's Team Finland (Invest in Finland) as well as Dutch Embassy in Finland offer services that helps you in the process of adaptation to the Finnish markets.** The Finnish Tax Administration also provides services regarding tax-related questions, fully free of charge.

7.3.2.1 Available Incentives and Subsidies

Foreign-owned companies operating in Finland are eligible for a wide range of incentives from both the government and the EU, on an equal footing with Finnish-owned companies. Invest in Finland and their national network can help companies find out more about these incentives. **The Economic Development, Transport and Environment Centres (ELY Centres), with 15 regional offices, provide advisory, training, and expert services, as well as funding for various investments and development projects.** ELY Centres can contribute to funding development projects and provide aid for SMEs, but large companies may also qualify if they have a significant employment impact

[141] https://www.lloydsbanktrade.com/en/market-potential/finland/marketing

in the region. Business development aid can be granted for improving the establishment and operation of a company, know-how, internationalization, product development, or process enhancement. Start-up companies can also receive subsidies for establishing and expanding their operations during the first 24 months. Overall, these incentives can help foreign-owned companies in Finland to establish and expand their business operations more easily.[142]

Below, on Figure 12, Development areas in Finland are introduced. Finland has 3 Development areas. **Foreign investors can benefit from several different types of aids, mainly for the areas I and II.**

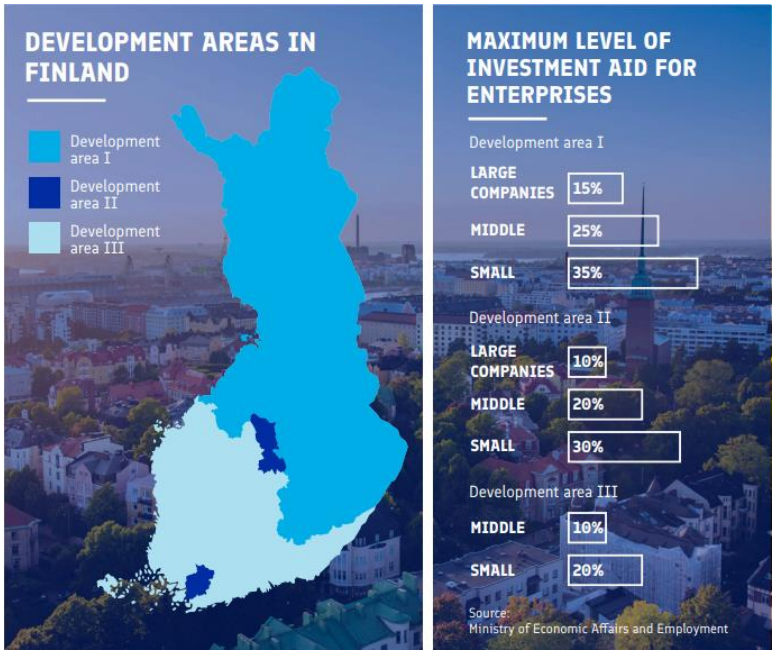


Figure 12 Development Areas in Finland[142]

Tekes, the Finnish Funding Agency for Technology and Innovation, is a reliable source of funding for companies, research organisations and public sector service providers conducting innovative and challenging projects in Finland. **Tekes provides low-interest loans and grants to fund R&D work in various fields**, including technology, service, design, business, and social innovation. Startups, SMEs, and large companies can benefit from Tekes' incentives, potentially leading to global success stories.

Business Finland has launched and will launch several financing programs for innovations. Finland's recovery and resilience plan includes energy-investment fundings, for instance a 2nd call was open from 15.3. – 26.5.2023, including EUR 93,4 million earmarked for subsidies. **The application round supports large-scale energy investments, and only projects with more than EUR 5 million in relevant costs will be processed.** In projects related to electrification or low carbonization of industry, the application can also be submitted for projects where acceptable costs exceed EUR 1 million, but priority is given to those projects whose relevant costs exceed EUR 5 million. The program is funded by the EU under the NextGenerationEU program.[143]

Business Finland has also announced that **it will launch a Hydrogen and Batteries – Dual Helix of Decarbonization program in the spring of 2023.** Before the launch, there is a call open for ideas, aiming to find new and innovative ideas that promote hydrogen and battery-related development and future export business.[144]

[142] Incentives to foreign companies investing in Finland. Invest in Finland. 2023. Available: https://www.businessfinland.fi/48cd06/globalassets/julkaisut/invest-in-finland/fact-sheet-incentives.pdf

[143] https://tem.fi/-/haku-avautuu-investointitukea-energiainfrastruktuuri-investointien-seka-teollisuuden-sahkoistamisen-ja-vahahiilistamisen-hankkeille

[144] https://www.businessfinland.fi/en/whats-new/calls/2023/call-for-ideas-data-economy-hydrogen--batteries-immersive-customer-experience

Finnish Ministry of Economic Affairs and Employment, **TEM, has announced a call for large new technology demonstrations** for projects with more than EUR 5 million in CAPEX to be opened in April 2023, having a deadline in August. The call will have an overall budget of EUR 200 million, from **which EUR 100 million is earmarked for new energy technology projects related to hydrogen**. The funding is applied through Business Finland's electronic system.[145] Foreign companies may be able to apply for the funding, either by having a joint project with a Finnish company or by having a subsidiary in the country. However, the details regarding foreign companies and joint applications have not been confirmed. Similar projects with CAPEX under EUR 5 million can apply for an **Energy aid programme**. Energy aid can be granted for projects or studies conducted in Finland that aim to promote one of the following topics: renewable energy production; energy savings or more efficient energy production or use; recovery of waste heat; or decarbonisation of energy systems.[146]

Finnish Energy Agency is also providing subsidies for investments, as they have before with P2X Solutions on building the first hydrogen refuelling station.[147] On top of the regional subsidies and funding programs, **Finland is also part of a second Important Project of Common European Interest (IPCEI)** -program to support research and innovation, first industrial deployment, and construction of relevant infrastructure in the hydrogen value chain. The project is called **IPCEI Hy2Use** and it is further explained in chapter 5.5. In Finland, the Ministry of Economic Affairs and Employment, in collaboration with Business Finland, has been responsible for overseeing the EU application process. As part of the Sustainable Growth Programme for Finland, the country's projects associated with the hydrogen economy's value chain have received funding through the EU's Recovery and Resilience Facility.

In February 2023, the Ministry of Economic Affairs and Employment of Finland has announced **a EUR 40 million funding program** for solar energy projects. The projects will be selected through competitive tendering carried out by CINEA. Projects with a capacity of 5-100 megawatts may participate in the call for tenders. The projects with the lowest price that meet the criteria detailed in the application documents will be successful in the competitive tendering. The application period for this funding will begin in the spring 2023, and the Commission together with the Ministry will organise an information event in the spring. Precise date has not been announced until the publication of this document.[148] This tender could be suitable for companies working with hydrogen, as solar power is fully green and renewable and could be used for green hydrogen production.

[145] https://tem.fi/uuden-energiateknologian-ja-suurten-demonstraatiohankkeiden-investointitukien-haku
[146] https://tem.fi/en/energy-aid
[147] https://p2x.fi/en/p2x-solutions-will-construct-the-first-hydrogen-fueling-station-in-the-greater-helsinki-area-in-jarvenpaa/
[148] https://tem.fi/en/-/luxembourg-supports-finnish-solar-energy-projects-by-eur-40-million-through-eu-mechanism

8 Iceland

8.1 Policy landscape

8.1.1 Energy Mix

- Iceland's electricity generation is almost 100% from renewable energy sources.
- Iceland is shifting focus towards the development of green fuels, such as green hydrogen and other electro fuels like ammonia, methanol, and methane, to reduce carbon emissions and achieve ambitious climate goals.
- Iceland has favourable wind conditions in many parts of the country, particularly in the highlands, making it an ideal location for onshore wind power development. However, there are concerns and criticisms of onshore wind power development in Iceland, including negative environmental impacts and visual impacts on Iceland's unique and pristine landscapes.

In Iceland, electricity generation is predominantly sourced from renewable energy, with a mix of geothermal and hydropower being the primary sources. According to Orkustofnun, a government agency under the Ministry of the Environment, Energy and Climate, the breakdown of electricity generation by source in 2020 was as follows:

Table 12 Electricity production by energy source, 2020, Iceland

Source	Electricity Production (MWh)	Electricity Production (%)
Hydroelectric	13 156 972	68,77
Geothermal	5 960 602	31,18
Wind	6 660	0,03
Fuel	3 067	0,02

As seen, almost 100% of Iceland's electricity generation comes from renewable energy sources, with hydropower being the dominant source followed by geothermal energy. Wind power, while currently a minor contributor to Iceland's electricity generation, has been growing in recent years and is expected to play a larger role in the future.

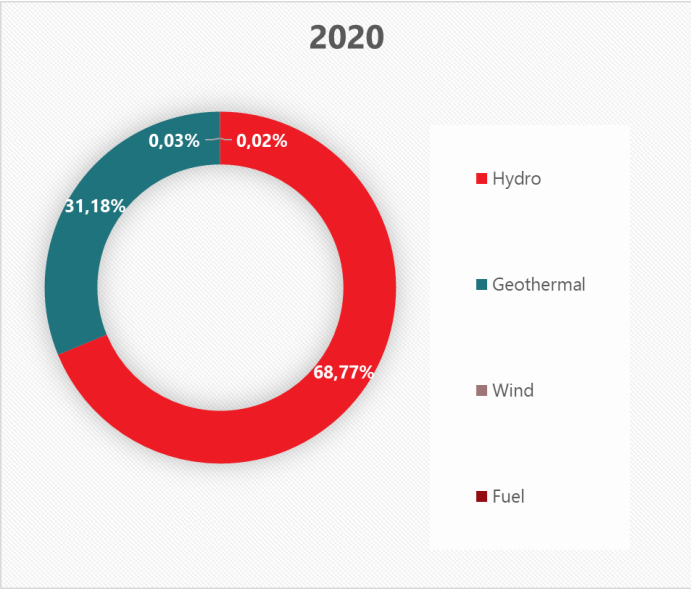


Figure 13 Electricity production by energy source in Iceland, 2020

Icelanders are very conscious of the environment, climate change and sustainability in general. Iceland has set ambitious goals and action plans to fight climate change and aims for 55% cuts in carbon emissions by 2030 and **carbon neutrality no later than 2040**. Back in 2021, the CEO of **Landsvirkjun**, the National Power Company of Iceland, stated that Iceland is fortunate to have abundant renewable energy resources which it has harnessed responsibly over the years. Iceland has completely decarbonized its power and heating sector, resulting in 85% of its energy being sources from renewables. The remainder comes from imported fossil fuels primarily for land freight, shipping, and aviation. Iceland recognizes that complete electrification of certain such sectors may not be feasible due to their high energy demands and technical limitations. As a result, **the country is shifting its focus towards the development of green fuels**, such as green hydrogen and other electro fuels like ammonia, methanol, and methane. These fuels can be produced using renewable energy sources, such as geothermal and hydropower, and can provide an alternative to fossil fuels, particularly in sectors where electrification is not a viable option. By focusing on the development of green fuels, Iceland aims to reduce its carbon emissions and achieve its ambitious climate goals while maintaining energy security and promoting economic growth[149].

While Iceland primarily relies on geothermal and hydroelectric power to generate energy, it also holds significant potential for producing hydrogen and other e-fuels through wind energy. **Iceland offers ideal conditions for wind turbines,** compared to most other parts of the world. Calm weather conditions are almost newsworthy, and the infrastructure of the electric power system is perfectly aligned for the addition of a new energy source, such as wind power. Iceland has favourable wind conditions in many parts of the country, particularly in the highlands, which could make it an ideal location for onshore wind power development. Landsvirkjun's research in recent years at the lava field Hafið near the Búrfell Mountain has presented the interesting fact that during winter, when the water level in the reservoirs is at its lowest, the efficiency of wind turbines is at its peak. Some advocates argue that the development of onshore wind power could be an important addition to Iceland's energy mix, particularly as the country seeks to reduce its carbon emissions and meet its ambitious decarbonization goals. However, there are also concerns and criticisms of onshore wind power development in Iceland. Some critics argue that onshore wind power could have negative environmental impacts, particularly on bird and wildlife populations, as well as the noise pollution in its surroundings. Others have raised concerns about the visual impact of wind turbines on Iceland's unique and pristine landscapes, particularly in areas that are popular for tourism. Additionally, some critics have argued that onshore wind power may not be a cost-effective option for Iceland's energy mix, particularly given the country's abundant geothermal and hydropower resources. They argue that the costs associated with developing and maintaining onshore wind power projects may not be justified by the energy they produce, particularly given the limited domestic demand for electricity in Iceland. Though, Landsvirkjun has high hopes that in the future, wind power will be the third pillar in the company' electric power system, along with hydroelectric power and geothermal energy. Landsvirkjun is developing two wind power stations: **the Blanda Wind Power Station** and the redesigned **Búrfell Wind Power Station**. The focus has been on reducing any negative impact on the environment for these two viable options, which offer a strategic addition to the electric system by giving it a splendid support[150]. Overall, **the debate around onshore wind power in Iceland is complex and multifaceted.** While there are potential benefits to developing onshore wind power, there are also legitimate concerns and criticisms that need to be considered.

[149] https://www.worldclimatesummit.org/post/green-hydrogen-and-e-fuels-are-key-for-the-energy-transition-in-iceland-and-europe
[150] https://www.landsvirkjun.com/news/regulatory-environment-for-wind-power

8.1.2 Outlook of the Hydrogen Industry

- Iceland aims to achieve net-zero greenhouse gas emissions by 2040 and become an oil and gas free economy by 2050 by relying on hydrogen for transportation.
- The country has two operational hydrogen refuelling stations.
- Iceland is taking initiatives in the aviation industry to reduce carbon emissions by incorporating hydrogen and battery-powered planes.
- The government is working to align stakeholders, promote the development of the hydrogen and e-fuels sector, and publish a hydrogen roadmap to guide the industry's growth and development.
- Due to the availability and affordability of energy, Iceland has the potential to attract projects that can take advantage of this energy source, making it an attractive location for industrial projects.
- Aviation a very important sector as an application for hydrogen and other sustainable aviation fuels.

Iceland has set two major targets to achieve in its energy sector - achieving net-zero greenhouse gas emissions by 2040 and becoming an oil and gas free economy by 2050[151]. The country has a unique energy market and has **the potential to become the world's first country to rely on hydrogen for transportation.** Iceland has a unique energy market primarily because of its abundant and renewable geothermal and hydroelectric resources, as mentioned earlier. This has several implications for the energy market and hydrogen in the country.

- Firstly, the abundance of domestic resources means that Iceland has a very secure energy supply and is less vulnerable to price shocks or supply disruptions that can affect other countries that rely on imported energy sources. This provides a significant advantage for the country in terms of energy security and independence.
- Secondly, the use of renewable resources means that Iceland's energy mix has a very low carbon footprint, and the country has been able to significantly reduce its greenhouse gas emissions. This not only reinforces Iceland's commitment to sustainability but also positions the country as an attractive location for the production of green hydrogen.
- Finally, the unique market structure of the Icelandic energy market is characterized by a few large vertically integrated utilities that own and operate most of the country's energy infrastructure. This structure has allowed for effective coordination and management of the country's energy resources and has contributed to the country's energy security and independence. This can facilitate the development of the hydrogen industry. These utilities have the necessary expertise and resources to develop and operate hydrogen production facilities and infrastructure.

Therefore, the development of hydrogen as a clean energy carrier in Iceland is closely linked to the country's unique energy market, its abundant renewable resources, and its plan to leverage these resources to promote sustainable development and combat climate change. Another distinctive characteristic of the Icelandic market is its scalability, as both hydropower and geothermal energy are highly scalable. Due to the availability and affordability of energy in Iceland, the country has the potential to attract projects that can take advantage of this energy source. Geothermal power plants are an excellent means of meeting baseload energy demand, providing stable and predictable power output, which facilitates energy planning with remarkable accuracy. This **stability makes Iceland an attractive location for industrial projects**, such as the aluminium industry, which consumed up to 70% of the produced electricity in Iceland in 2013[152]. In this context, hydrogen is a clear pathway to take economic advantage of Iceland's energy potential. The country's energy market is smaller than other Nordic countries, but its unique situation provides an opportunity for growth.

[151] https://www.cnet.com/tech/tech-industry/iceland-buses-come-clean-with-hydrogen/
[152] https://nea.is/geothermal/electricity-generation/

As the demand for clean energy continues to grow globally, hydrogen and e-fuels have emerged as promising alternatives to traditional fossil fuels. Iceland, with its ample and renewable energy sources, is in **a prime position to capitalize on this opportunity**. One crucial question that arises is whether hydrogen or e-fuel export from Iceland is realistic. The answer to this question is a resounding yes. Iceland's energy company, Landsvirkjun, has been approached by international companies seeking to develop hydrogen export projects in Iceland, which indicates that **the country is not only an option but a competitive one.** Moreover, it creates a real opportunity for Iceland to contribute to the fight against climate change via exports of green e-fuels that replace fossil fuels abroad[149].

Recently in March 2023, Landsvirkjun and **Linde** signed a collaboration agreement that will facilitate the energy transition in Iceland through the development of clean hydrogen and e-fuel projects. The production of e-fuels is technically complex and a novel field for Landsvirkjun. Therefore, it has joined forces with Linde, which has extensive knowledge of the chemical industry, hydrogen production via electrolysis, as well as the operation of green industrial parks. Linde already supplies Icelandic customers with locally produced oxygen, nitrogen, carbon dioxide and operates a cylinder filling site[153]. This marks an important step in Iceland's decarbonization efforts and demonstrates the high interest in e-fuels locally and such projects will be pivotal in decarbonizing the transport sector and industry in Iceland and worldwide. In 2021, Icelandic utility company **HS Orka** and UK based **Hydrogen Ventures Ltd**. announced plans to **develop a production plant for green methanol** using green hydrogen to power the marine sector, as well as domestic and commercial vehicles such as cars, vans, and lorries. The project will focus on using geothermal energy to produce green hydrogen, which will then be used in the production of synthetic fuels. The project will be executed in two phases, beginning with a 30MW input in the first phase, followed by a second phase of significantly larger scale aimed at producing green hydrogen[154]. **Projects like these could also lead to potential collaborations between Iceland and the Netherlands** in various aspects of the hydrogen value chain in the future.

Within transportation, one of the areas where more initiatives have been taken in the recent times is the use of hydrogen in aviation. **Icelandair,** an Icelandic aviation company, has taken significant steps towards reducing carbon emissions and has made a commitment to cut its emissions by 50% by 2030 compared to the 2019 levels[155]. The company has focused on utilizing sustainable fuels such as hydrogen and battery-powered planes for domestic routes. In 2022, the airline announced its plans to incorporate hydrogen and battery-powered planes as part of its strategy. This move is a part of the company's broader efforts towards sustainability and reducing its carbon footprint. To achieve this goal, Icelandair has signed letters of intent with two aviation startups: **Heart Aerospace**, a Swedish company that is developing a 30-seat regional aircraft powered by batteries and a backup conventional engine, and **Universal Hydrogen**, a Los Angeles-based company that is converting Icelandair's existing 37-seat turboprop plane to use a hydrogen fuel-cell system[156]. By leveraging the potential of hydrogen and other sustainable fuels, **Icelandair aims to lead the way in the aviation industry's transition towards cleaner and more sustainable operations.** Furthermore, **IðunnH_2**, a hydrogen development company in Iceland, is aiming to construct a **commercial-scale sustainable aviation fuel (SAF) production facility** near Keflavík International Airport by 2027. The planned facility will be located in Helguvík Harbour and will utilize e-kerosene, a type of SAF produced by combining green hydrogen generated from Iceland's abundant renewable energy sources with existing CO_2 captured from an industrial CO_2 capture facility. The company's goal is to contribute to reducing carbon emissions in the aviation industry.

The hydrogen and e-fuels value chain are a new and emerging industry, and the biggest challenge facing this sector is the chicken-and-egg problem of which comes first, demand or supply. Iceland is no exception to this, and

[153] https://www.landsvirkjun.com/news/landsvirkjun-and-linde-join-forces
[154] https://www.chemengonline.com/green-hydrogen-and-methanol-project-announced-in-iceland/?printmode=1
[155] https://www.icelandair.com/blog/our-commitment-to-the-environment/
[156] https://www.canarymedia.com/articles/air-travel/iceland-land-of-fire-and-ice-and-carbon-free-flights

stakeholders are working to mobilize the entire value chain to achieve the final shift from fossil fuels. Landsvirkjun is taking the lead in this effort to bring together stakeholders from across the value chain to promote the adoption of hydrogen and e-fuels. To realize Iceland's goal of becoming fossil fuel free by 2050, the government is also working to align stakeholders and promote the development of the hydrogen and e-fuels sector. **The government plans to publish a hydrogen roadmap,** which will serve as a key document to guide the industry's growth and development. The roadmap will help to identify key challenges and opportunities and will set out a framework for promoting the adoption of hydrogen and e-fuels in Iceland. The first step in this process will be to get the first ship and truck running on e-fuels, and to encourage other stakeholders to follow suit. By working together, stakeholders in Iceland's hydrogen and e-fuels sector can create a thriving industry that will help to support the country's transition to a sustainable, fossil fuel-free future[149].

8.1.3 Infrastructure

As of 2020, Iceland had two hydrogen production sites in operation[157].

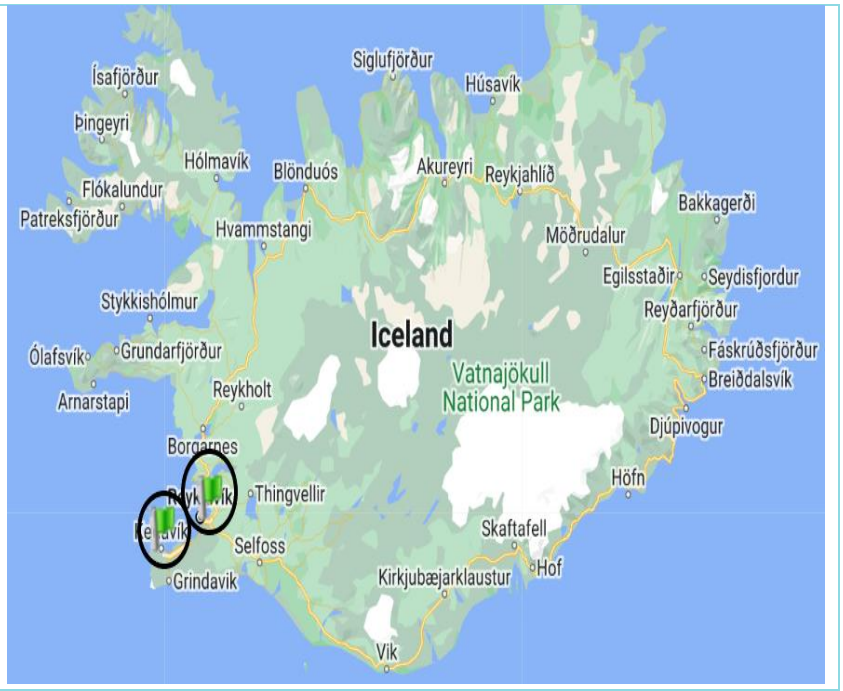
- **The Svartsengi geothermal power plant**, which is operated by **Carbon Recycling International**, has a production capacity of 1500 Nm^3/hr. All of the hydrogen produced at this site is currently being used for the production of methanol (e-fuels), both for the local market and for export.
    - Currently, there is no other industrial use of hydrogen.

- **The Hellisheiði geothermal power plant**, which is operated by **ON Power**, has a production capacity of 150 Nm^3/hr. All the hydrogen produced at this site is currently being used for transport activities.

To support its climate neutral initiative, Iceland opened the world's first hydrogen filling station in Reykjavik in April 2003. The station was later revamped in 2019 using EU funding. **Shell** operates the hydrogen filling station, and it has been a significant milestone in Iceland's hydrogen journey. The country's efforts to reduce greenhouse gas emissions using hydrogen are a critical step towards achieving its targets and becoming a leader in sustainable energy[158]. Currently there are **two operational hydrogen refuelling stations in Iceland**, serving approximately 30 cars that runs on hydrogen.

[157] http://newenergy.is/wp-content/uploads/2020/06/A-2030-vision-for-H2-in-Iceland-released.pdf
[158] https://newenergy.is/en/portfolio/ectos/

Table 13 Operational Hydrogen filling stations in Iceland

Operational Hydrogen filling stations-Iceland[159]	
Orkan Skeljungur station Vesturlandsvegur-Shell	
Orkan Fitjum Keflavik - Shell	

8.2 Market characteristics

- While green e-fuels are currently more expensive than traditional fuels worldwide, a combination of government incentives and technological advancements will improve their competitiveness.
- Iceland has the potential to become energy independent and self-reliant through the production of cost-competitive green e-fuels and may even export them to Europe.

The transition to green e-fuels is often met with questions about its cost competitiveness. Will it make economic sense for companies in Iceland to switch to these sustainable alternatives? According to the CEO of Landsvirkjun, the answer is yes[149]. While it is true that green hydrogen and e-fuels are currently more expensive than traditional fuels worldwide, a combination of government incentives and technological advancements will improve their competitiveness. This has been the case with renewable power sources such as wind and solar power and will likely be the case with green e-fuels as well.

In Iceland, **there is also a need to consider the cost competitiveness of locally produced green e-fuels versus potentially imported alternatives.** If the goal is to become energy independent and self-reliant, the production of e-fuels needs to be cost-competitive, which can only be achieved through economies of scale. Otherwise, Iceland may end up importing what could have been produced locally, which is why **Landsvirkjun is actively exploring the feasibility of exporting green e-fuels to Europe**[149].

[159] https://www.h2stations.org/stations-map/?lat=49.763948&lng=12.582221&zoom=4

8.2.1 Networks

Currently, there is not a significant amount of activity in Iceland when it comes to hydrogen-related events and conferences. While the country has been exploring the potential for hydrogen and e-fuel production and export, it appears that there is not yet a robust network of conferences or events focused specifically on this topic. However, given the growing interest in hydrogen as a clean energy source and Iceland's unique energy mix, it is possible that we may see an increase in related events and conferences in the future.

However, **Icelandic New Energy Ltd. (INE)** is a company that promotes the use of hydrogen fuel in Iceland. The company was formed in 1999 following a declaration from the Government of Iceland declaring (in 1998) that Iceland would like to explore the possibility of exchanging from a fossil fuel paradigm in transport to utilising hydrogen. The goal of the company was research and demonstration projects connected to hydrogen. The company has a unique knowledge and experience. It is the only company in the world that has operated a hydrogen refuelling station, hydrogen Internal Combustion Engine Vehicles (ICEV), Fuel Cell Electric Vehicles (FCEV), Battery Electric Vehicle (BEV), marine application both with hydrogen and batteries and simultaneously conducted various economic, environmental, and social research. Also, INE has been consultant to government institutions both national and foreign and to various companies. The company also engages in educational seminars and other activities.

Icelandic New Energy has now established a vision describing the role of H_2 in Iceland's energy transition – a vision until 2030. It is viewed as a living document where new technical developments can be incorporated. It is also the first building block towards a full-scale Roadmap of H_2 in Iceland until 2050. **To obtain more information about the hydrogen market in Iceland and establish a network, Dutch companies can connect with Icelandic New Energy.**

8.2.2 SWOT Analysis

Table 14 SWOT Analysis, Iceland

STRENGTHS	WEAKNESSES
• Abundant renewable energy resources, including geothermal and hydropower, which can be used to produce green hydrogen. • Strong commitment to decarbonization, with a goal of becoming carbon neutral by 2040. • Strong technological expertise in the energy sector, including in geothermal energy and hydrogen production. • Established infrastructure for the electricity grid, which could potentially be used for hydrogen distribution.	• High production costs compared to other fuels, which could limit the economic viability of a hydrogen industry in Iceland. • Limited financial resources, which could make it difficult to invest in the necessary infrastructure for a hydrogen industry. • Uncertainties around the demand for hydrogen. • Environmental concerns around the production of hydrogen from fossil fuels and potential leaks.
OPPORTUNITIES	**THREATS**
• Potential for exporting green hydrogen to other countries, particularly in Europe, which have set ambitious decarbonization targets. • Growing demand for hydrogen in certain sectors, such as the shipping industry, where it could be used as a low-carbon fuel. • Potential for partnerships and collaboration with other countries and companies in the hydrogen industry, which could provide opportunities for knowledge sharing and investment.	• Competition from other hydrogen producing countries, such as Norway and Denmark, which have also invested in the development of a hydrogen industry. • Limited infrastructure for hydrogen transportation and storage, which could limit the potential for exports and domestic use. • Technological uncertainties around the most efficient and cost-effective methods of producing and using hydrogen. • Potential for changes in the government policy or regulations, which could impact the development of a hydrogen industry in Iceland.

8.3 Opportunities for Dutch businesses

- Sectors that have the possibility to provide opportunities for Dutch businesses to enter the hydrogen market in Iceland.

The future of energy is moving towards clean and renewable sources, and hydrogen has emerged as a promising alternative to fossil fuels. As the world transitions to a low-carbon future, countries and companies are seeking opportunities to invest in green hydrogen and e-fuels. Iceland, with its abundant sources of renewable energy, has the potential to become a major player in the hydrogen market. This presents an opportunity for Dutch companies to enter the Icelandic hydrogen market and become involved in involved in various aspects of the value chain, from the production of electrolysers to the transportation of the hydrogen carriers.

1. R&D Collaborations, Technical know-how and Expertise

In 2021, **Landsvirkjun** partnered with **the Port of Rotterdam** and executed a pre-feasibility study on exporting green hydrogen from Iceland to Rotterdam to gain a better understanding of the concept and its feasibility. The pre-feasibility study mapped out the key components of the value chain involved in exporting green hydrogen from Iceland to Rotterdam. The study included a comparison of potential hydrogen carriers, considering various attributes such as energy density, costs, and demand. The findings revealed that by 2030, it could be feasible to export between 2 and 4 TWh/year of green hydrogen, which could contribute significantly to reducing CO_2 emissions by up to 1 million tons/year. In the long term, the potential could be even greater, with the possibility of reducing millions of tons of emissions. The study proposed producing hydrogen through electrolysis, which would then be either liquefied or converted into a carrier for transportation to Rotterdam, where it would be recovered for use at the port or in the hinterland. The results indicate that such a project could be technically feasible, financially attractive and would have a significant contribution to the fight against climate change[160]. The study results are promising for Dutch companies seeking to enter the Icelandic hydrogen market, providing them with potential opportunities for collaboration and investment.

The partnership between Landsvirkjun and the Port of Rotterdam signals a potential opportunity for Dutch companies to enter the Icelandic hydrogen market. If the project is successful, it could create a demand for Dutch companies to provide expertise and technology for hydrogen production and transportation. Additionally, it could open opportunities for partnerships between Icelandic and Dutch companies in the hydrogen industry, potentially leading to new innovations and collaborations. As Iceland continues to prioritize its transition to renewable energy, it could present a promising market for Dutch companies looking to expand their operations in the clean energy sector. The partnership also provides an opportunity wherein the Dutch companies with expertise in the hydrogen industry could provide consultancy and advisory services to Icelandic companies and the government to support the development of a hydrogen industry in Iceland.

During discussions with the experts at Landsvirkjun, it was highlighted that although Iceland has significant potential for the development of a hydrogen industry, the country lacks the necessary skills and expertise in the field of hydrogen production, handling, storage, and safety measures. This presents a significant opportunity for Dutch companies to partner with Icelandic companies, as Dutch companies have a strong track record in logistics, technical know-how of hydrogen technology, and managing industrial parks. With their expertise, Dutch companies could potentially play a key role in developing the necessary infrastructure and knowledge base to support the growth of a hydrogen industry in Iceland.

2. Transportation, Maritime and Aviation

A promising prospect exists for Dutch companies to collaborate with their Icelandic counterparts in the advancement of hydrogen fuel cell vehicles, along with the essential refuelling infrastructure. This has the potential to involve the creation of hydrogen-powered buses, trucks, and ferries. Considering Iceland's remote location and restricted infrastructure, it is possible that Dutch companies can introduce innovative techniques for transporting hydrogen, such as through pipelines or using liquid hydrogen carriers, in which the Dutch have a history of leading.

The shipping industry is a significant contributor to greenhouse gas emissions, and there is increasing interest in using hydrogen as a low-carbon fuel in the sector. Iceland has a significant shipping industry, and Dutch companies

[160] https://www.businesswire.com/news/home/20210622005796/en/Study-Shows-Shipping-Green-Hydrogen-From-Iceland-to-Rotterdam-to-be-Realistic-Before-2030

with expertise in developing hydrogen fuel cells for marine applications could potentially find opportunities to collaborate with Icelandic shipping companies to develop and deploy hydrogen-powered ships.

The aviation industry could be a promising area for collaboration between Icelandic and Dutch companies. Icelandair has already expressed interest in transitioning to hydrogen-powered aircraft, and KLM Royal Dutch Airlines has announced plans to invest in sustainable aviation fuels. The Dutch Government has also set a goal for KLM to use 14% sustainable aviation fuel by 2030[161]. With Iceland's potential for green hydrogen and e-fuels, there is an opportunity for Dutch companies to collaborate with Icelandic counterparts in the production and supply of sustainable aviation fuels, which could benefit both countries in their efforts to reduce carbon emissions in the aviation industry. By combining Iceland's abundant renewable energy with Dutch expertise in sustainable aviation fuel production, a sustainable aviation fuel supply chain could be established, potentially leading to new business opportunities for Dutch companies in Iceland.

Overall, there are several potential opportunities for Dutch companies in the hydrogen value chain of Iceland, particularly in the areas of hydrogen production, infrastructure development, transport, research and development, and consultancy and advisory services. However, it will be important for Dutch companies to navigate the unique challenges and opportunities presented by the Icelandic market and work closely with local partners to develop and deploy effective solutions.

The Dutch Embassy in Norway can offer valuable support to Dutch companies looking to enter the Icelandic and Norwegian hydrogen markets. The Embassy can provide information on the market, including local business culture, regulations, and market opportunities as well as facilitate introductions to local business networks and hydrogen organisations. For further information, please contact osl-ea@minbuza.nl.

[161] https://www.government.nl/latest/news/2020/03/04/minister-van-nieuwenhuizen-imposes-use-of-cleaner-fuel-in-aviation-sector

9 Norway

9.1 Policy landscape

9.1.1 Energy Mix

- Norway has the highest share of renewable energy in TFEC among IEA member countries, with 61% coming from renewables in 2020.
- Most renewable energy in Norway is hydropower, with increasing shares from biofuels and wind.
- However, a short-term market analysis by Statnett suggests that Norway might have a net negative energy balance in 2027 due to a significant expected increase in electricity consumption without a corresponding increase in power production.
- The demand for more network capacity has grown exponentially across Norway due to new industries such as battery factories and data centres, as well as the electrification and decarbonisation of both existing industry and transport.

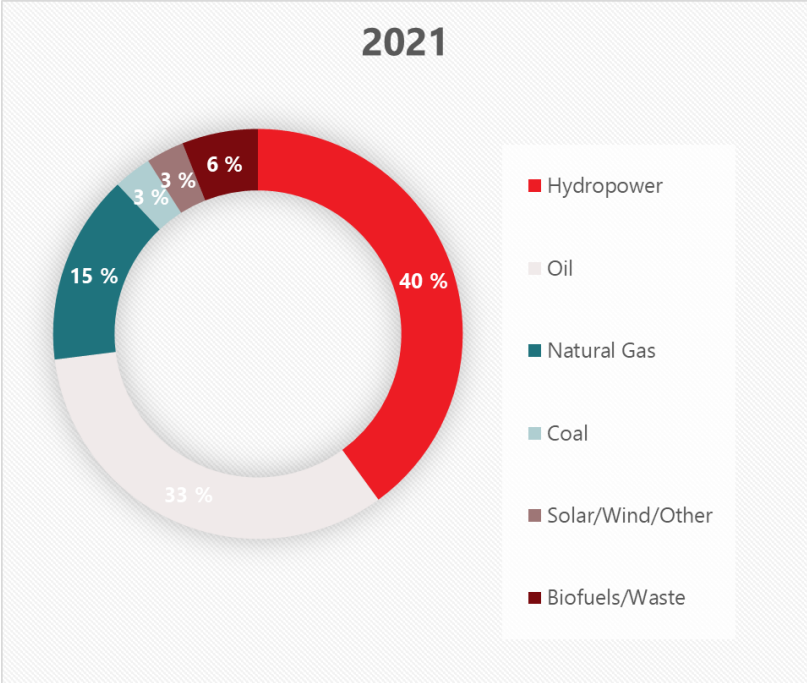


Figure 14 Norway's energy mix

Norway has the highest share of renewable energy in total final energy consumption (TFEC) among IEA member countries. In 2020, 61% of TFEC came from renewables, compared to the IEA average of 13%. Most renewable energy in Norway is hydropower, which covers the largest share (92%) of the electricity generation. Energy shares from liquid biofuels and electricity from wind have been increasing and covered respectively 2,2% and 3,5% of TFEC in 2020. The share of biofuels in transport demand in 2020 (9%) was the third highest among IEA member countries after Sweden and Finland and has increased fourfold since 2009. Norway's high share of renewable electricity and an almost fully renewable heating system mean that **the country's future efforts to increase renewable energy will be focused on more challenging, harder to abate sectors, in particular industry and transport.** Additional electrification in these sectors, including offshore oil and gas platforms, will provide a significant opportunity to further increase Norway's renewable energy share and reduce emissions in line with climate obligations[162]. With a high amount of TFEC coming from renewables, Norway promises huge potential to produce green and blue hydrogen.

[162] Norway 2022: Energy policy Review

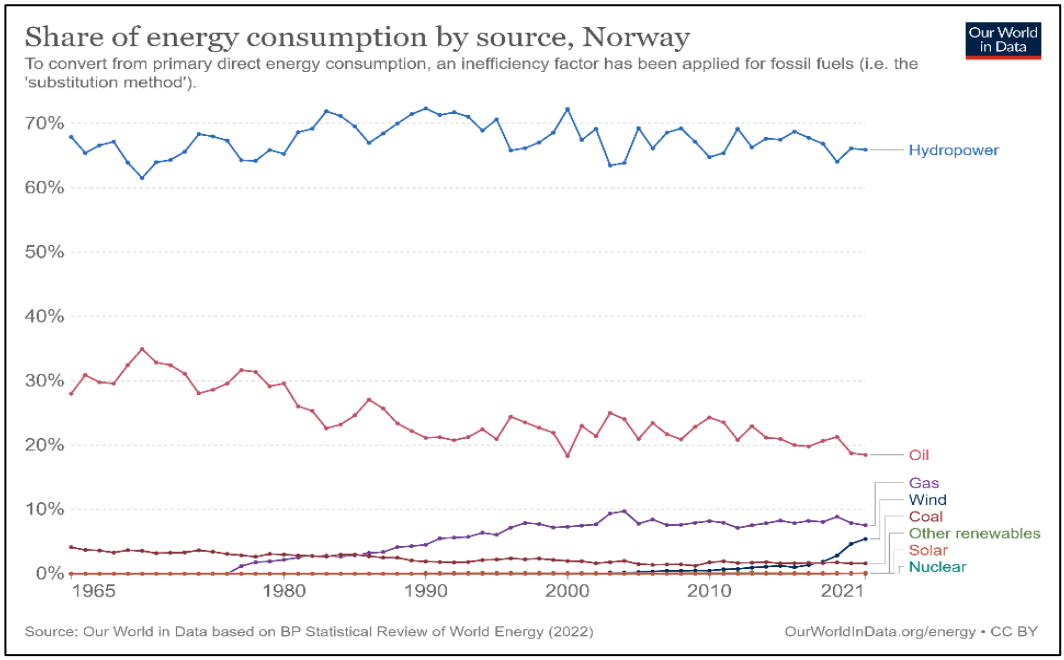


Figure 15 Norway's energy consumption[163]

However, at the same time, **Statnett**, a Norwegian state-owned enterprise responsible for owning, operating, and constructing the stem power grid in Norway, performed a short-term market analysis for 2022-2027 and it shows a significant expected increase in electricity consumption in the coming years, without a corresponding increase in power production. This suggests that **Norway might have a net negative energy balance in 2027**. Statnett expects a significant growth in the demand for electricity in Norway in the coming five-year period, up from around 140 TWh today, to 164 TWh in 2027. It also expects the power demand in Norway to grow by 60% to 220 TWh by 2050 on the back of decarbonization efforts and the establishment of new electricity-intensive industries. Increased energy consumption in battery production, hydrogen production and possible electrification of oil and gas production is perhaps most noteworthy in this regard, but other sectors will also see substantial growth. However, energy consumption in households and in service industries are not expected to grow accordingly. During the coming five-year period, consumption is expected to increase by up to 24 TWh, while there are plans to increase power production by around 6 TWh. This will result in a negative energy balance in southern Norway of 7 TWh, and 2 TWh in Norway as a whole. Statnett CEO, Hilde Tonne, gave her insights into the situation and said, *'The industry of the future needs lots of energy. Now, we see bigger and more tangible plans for establishing new industry and for the electrification of society.* ***This challenges the power grid, but also requires new power generation.*** *We will invest somewhere between 5 million to 8,5 million EUR (60 and 100 billion NOK) in the transmission grid towards 2030. At the same time, we need to speed up the development of new power production.'* [164].

In recent years, the demand for more network capacity has grown exponentially across Norway. As mentioned, this growth comes from new industries such as battery factories and data centres, as well as the electrification and decarbonisation of both existing industry and heavy-duty transport. Demand from industry and society more broadly will require the construction of as much network capacity over the next ten years as the network companies have managed to build over the last one hundred. Yet despite this, large grid projects usually have longer lead times than industrial development projects[165]. Thus, it would be interesting to investigate what measures grid companies and industries can take in the short term to facilitate the energy transition while awaiting grid reinforcement. This will also

[163] https://ourworldindata.org/energy/country/norway
[164] ttps://www.statnett.no/en/about-statnett/news-and-press-releases/news-archive-2022/increased-consumption-results-in-a-negative-norwegian-energy-balance-from-2027/
[165] https://thema.no/en/rapporter/can-industry-be-partially-electrified-without-more-grid-capacity/

impact who gets electricity in Norway and with the **long waiting list of high energy-intensive industries waiting to connect to the grid in Norway, it could potentially impact the development of green hydrogen production.**

9.1.2 Outlook of the Hydrogen Industry

- Norway has strong expertise and experience in hydrogen technologies, with several internationally recognized companies and investments in production facilities, transport solutions, and renewable energy.
- The hydrogen market in Norway has experienced growth in the number of players due to government policies and initiatives, with over 70 members of the Norwegian Hydrogen Forum as of 2022 spanning various sectors of the value chain.
- Norway has made significant progress in implementing its short-term hydrogen plan for 2025 with 96 million EUR (NOK 1,12 billion) in financing for green hydrogen hub projects and hydrogen-powered ships.
- The five hydrogen hub projects in Norway will scale up hydrogen production, reduce costs, and provide a clean alternative fuel for ships while leveraging Norway's well-established maritime sector and network of ports.

In Norway, **Norsk Hydro** have produced and utilized hydrogen for large scale fertilizer production since 1927. Their electrolysis technology is being further developed and supplied by **NEL Hydrogen**. Norsk Hydro, **Statkraft** and **Statoil (now Equinor)**, together with **Raufoss Fuel Systems (now Hexagon Purus)** and Norwegian research institutions, brought hydrogen from the industrial and research domain to the public refuelling arena in the beginning of 2000 through the **HyNor-project**, which was established to demonstrate the readiness of hydrogen as an alternative fuel for passenger cars. Some hydrogen refuelling stations were established through public and private investments[166]. **NEL Hydrogen built the world's largest water electrolysis plant as early as 1940** where hydropower was used to produce green hydrogen for fertiliser production. But an abundance of cheap natural gas in the 1950s soon replaced green hydrogen with grey hydrogen, and this remained the case for many decades. According to Herbert, this may soon change[167].

Norwegian companies, research institutes, and universities have over the last decades developed strong competence and long experience within hydrogen technologies. Norway has several internationally recognised companies that have already capitalised on this advantage to become leaders in the field. **NEL**, for example, is the world's largest manufacturer of electrolysers. **Hexagon Purus** and **Umoe Advanced Composites** are leading suppliers of composite tanks, storage containers and transport solutions for hydrogen. **Statkraft**, Europe's largest producer of renewable energy, has also heavily invested in hydrogen[168]. Other major companies like **Yara** and **Equinor** have also been playing an active part in the hydrogen value chain in Norway by investing in production facilities. Two companies, **Nippon Gases (formerly Praxair)** and **Ineos**, produce and distribute green hydrogen for transport. In addition, there are several projects, plans and studies aiming to establish large-scale production of hydrogen for use as energy carrier[169].

Since 2019, major industry players have been laying the groundwork for the hydrogen value chain in Norway, as mentioned in the preceding paragraph. As a result, the number of actors in the hydrogen market has increased. According to Tor Kristian Haldorsen, Lead Advisor of Government Relations at the **Norwegian Hydrogen Forum**, a non-profit organisation which promotes advantages of hydrogen and ammonia as energy carriers, **the hydrogen**

[166] https://www.hydrogen.no/en#Almost+100+years+of+hydrogen
[167] https://businessnorway.com/articles/meeting-global-demand-for-green-hydrogen
[168] https://businessnorway.com/articles/norway-poised-to-lead-green-hydrogen-market
[169] https://www.sintef.no/en/publications/publication/1794574/

market in Norway has experienced a surge in the number of players since 2019 due to the impact of government policies and initiatives, including the publication of a hydrogen roadmap and related strategies. These measures have provided a clear direction and framework for the development of the hydrogen market, which has spurred the interest of various stakeholders, including investors, companies, and other actors. As per his remarks, the recent political indications have made it viable to explore the hydrogen market in Norway. An excellent example of Norway's positive signal towards hydrogen adoption is the government's ambitious objective to eradicate pollution from fjords, particularly those recognized as UNESCO heritage sites, by 2026. To meet this target, the maritime sector in Norway would need to explore alternatives to traditional fossil fuels and likely turn to hydrogen or its derivatives as a viable and sustainable fuel source. Such policy initiatives have, in turn, helped to create a conducive environment for the growth of the hydrogen market, attracting a surge of investors and industry players eager to take advantage of this opportunity. **As of 2022, the membership of the Norwegian Hydrogen Forum, counted over 70 members spanning Norwegian producers, distributors, industry, universities, research institutes, companies in the transportation sector, consulting firms and other organisations interested in hydrogen.** There are also several entities in other categories, who do not participate in the Hydrogen Forum as well as early users, such as **ASKO, Ruter, Boreal, Norled, Havyard, and TiZir**, who contribute centrally to the promotion and uptake of hydrogen solutions.

Table 15 Some players of Norway's Hydrogen value chain

Large Incumbents	Major Technology Providers	Distributors and Retailers	New Entrants, Spin-offs	Semi-Public companies
Equinor	NEL	Nippon Gases	Hydrogen Mem-tech	Energi Norge AS
Statkraft	Hexagon Composites	AGA Linde	Hynion AS	Varanger Kraft Hydrogen
DNV GL	Ballard Power Systems Norway	Toyota Norway	CMR Prototech	Nasjonalt Vindenergisenter
Shell	Umoe	Hyundai	Cerpotech	Glomfjord Hydrogen
Aker Solutions ASA	Reinertsen New Energy AS	Bilimportørenes Landsforening	Agri-e AS	Sogn og Fjordane Energi AS
Total	New Energy	Ineos	Hystorsys AS	Sunnhordland Kraftlag AS
Yara	FMC Technip	Gasnor	HydrogenPro	TrønderEnergi
Air Liquide Norway AS	ITM Power	Hyundai Motor Norway	ZEG Power AS	
	PowerCell		Hyon	
	Wärtsilä		CoorsTek Membrane Sciences AS	
	Fiskerstrand Verft AS		IFE Hynor	
	ABB		Greenstat	
	Siemens			
	Wilhelmsen			

As the above table shows, a much wider range of actors, across the whole value chain, is engaged now. In 2019, a report by THEMA consulting revealed that there were 77 actors involved in the upstream hydrogen value chain in Norway, with approximately 70% being private businesses, interest organisations, or research institutions. The report further categorized these actors into various sub-sectors, including production, carbon capture and storage (CCS),

compression, transport and distribution, and storage of hydrogen. Of the total number of actors, 33 were involved in production, 7 in CCS, 4 in compression, 18 in transport and distribution, and 15 in storage[170]. While the current number of total players in the hydrogen value chain in Norway is not known, it is reasonable to assume that this number has grown since 2019, given the increasing interest and investment in the country's hydrogen market. The table mentioned above only includes a limited number of players. However, recently, the Norwegian Hydrogen Forum has published a comprehensive list of its members, which comprises numerous additional players (see[171]).

When it comes to set policies, Norway's efforts towards implementing its short-term hydrogen plan for 2025 have resulted in significant progress being made. In June 2022, **Enova SF**, which is a state-run enterprise, announced **EUR 96 million (NOK 1,12 billion) in total financing for several green hydrogen hub projects and hydrogen powered ships.** The Norwegian Government enterprise, which is owned by the Ministry of Climate and Environment, is providing EUR 57,5 million (NOK 669 million) in financial support to five green hydrogen hubs along the Norwegian coast and a further EUR 39 million (NOK 451,3 million) to seven hydrogen and ammonia-powered vessels. According to the CEO of Enova, Nils Kristian Nakstad, the supported green hydrogen hubs will have a combined capacity to supply between 35 to 40 vessels, including the financially backed ships[172]. Table 16 below gives details about the five hydrogen hub projects.

Table 16 Five Hydrogen Hub Projects in Norway[172]

Project (company) name	Location	Financial support	Owners / Stakeholders	End-use	Production start-up	Value chain
Glomfjord Hydrogen AS	Glomfjord, Meløy	EUR 13M (NOK 150M)	Greenstat ASA, Nel ASA, Meløy Energi AS, Troms Kraft AS	Sea and land transport	Q2 2025	Production Transformation End use
Hydrogen hub Rørvik	Rørvik	EUR 11M (NOK 125,7m)	NTE, H2 Marine	A wide range of vessels	2025	Production Transformation End use
Hydrogen hub Central Norway	Hitra Industrial Park and Coastal Harbour, Jøsnøya	EUR 10M (NOK 113m)	TrønderEnergi, Statkraft	Will investigate further opportunities in the hydrogen market; Refuelling	Q3 2025	Production Transformation End Use
HyFuel AS	Florø	EUR 11,5M (NOK 132m)	Fjord Base Holding (FBH), Sogn og Fjordane Energi AS (SFE), Gasnor AS	Hydrogenation of Liquid Organic Hydrogen Carrier (LOHC)	--	Production Transformation End Use
Hydrogen hub Agder	Kristiansand	EUR 13M (NOK 148m)	Everfuel AS, Greenstat ASA, others	Shipping Industry	Q4 2024	Production Transformation

[170] https://www.sintef.no/en/publications/publication/1794574/
[171] nhf-hydrogenguiden2023.pdf
[172] https://renewablesnow.com/news/norways-enova-awards-usd-112m-to-maritime-hydrogen-hub-ship-projects-789342/

The mentioned hydrogen hubs offer several advantages for the development of hydrogen infrastructure and the transition to a low-carbon economy. They will serve as centres to produce hydrogen, which will help to scale up production and reduce costs. **This will make it easier for businesses and consumers to access hydrogen as a clean energy source** since the hubs are strategically located near important transportation corridors, as well as areas with a high concentration of industry and energy production. The location of the five hydrogen hubs in Norway provide several advantages because Norway has a well-established maritime sector and a large fleet of ships that operate in its coastal waters. Hydrogen can be used as a fuel for these ships, providing a clean alternative to fossil fuels and reducing greenhouse gas emissions. More importantly, **the location of the hubs along the Norwegian coastline provides access to a network of ports and shipping lanes,** making it easier to transport hydrogen to other parts of Norway and to other countries in Europe.

The Netherlands is also investing heavily in hydrogen fuel technologies and has set a goal to become a major player in the European hydrogen market. By partnering with Norwegian companies and investing in the Norwegian hydrogen infrastructure, **Dutch businesses can gain access to a reliable and sustainable source of energy, as well as tap into new markets and create new partnerships.** Additionally, as the hydrogen market continues to grow, there may be opportunities for Dutch businesses to export hydrogen technologies and expertise to Norway and other countries.

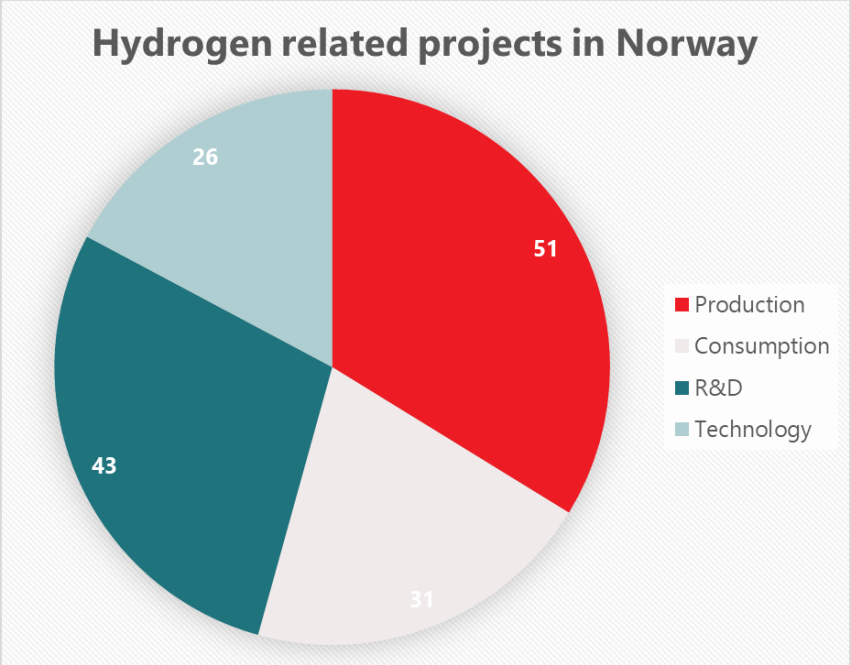


Figure 16 Number of hydrogen related projects in Norway by type

In all, hydrogen has shifted from a predevelopment phase, when relatively immature technologies were explored by a limited circle of incumbents, researchers, and technology providers, to a take-off phase where various technological options coexist, linked to different social networks with new entrants and partly diverging views and visions. Recently, The Norwegian Hydrogen Forum has compiled a comprehensive database of all upcoming and ongoing hydrogen and ammonia projects in Norway, revealing a staggering **126 projects currently in the pipeline**. The identified hydrogen and ammonia projects in Norway have been categorized based on their focus areas, including Production, Consumption, R&D, and Technology. Among the 126 projects, approximately 34% (51) are related to production, with green hydrogen projects comprising the majority. However, it's noteworthy that **blue hydrogen is projected to**

constitute over 50% of the planned production capacity by 2030[173]. This link directs to the entire list of hydrogen and Ammonia projects in Norway, provided by the Norwegian Hydrogen Forum.

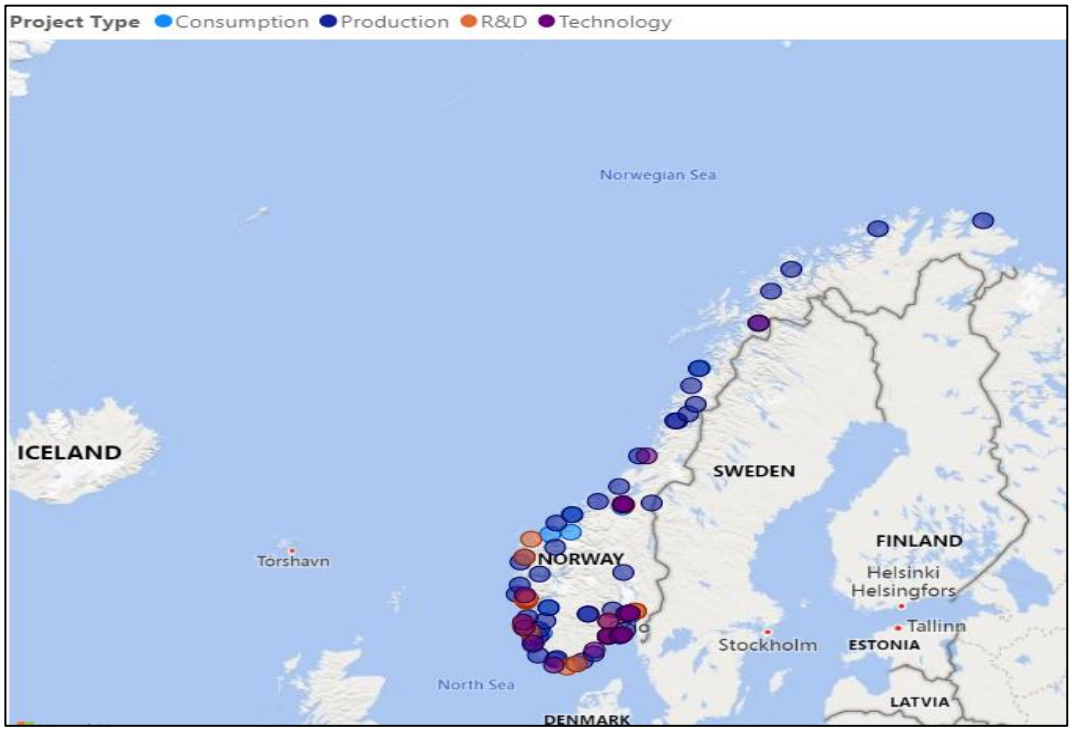


Figure 17 The Norwegian Hydrogen Landscape

9.1.3 Production Methods

- Norway has a history of producing green hydrogen and ammonia for local use, with Norsk Hydro's experience in hydrogen production spanning almost 100 years.
- Currently, Norway is implementing various methods for hydrogen production.
- The government has taken steps to incentivize the production of green hydrogen through electrolysis.
- Blue hydrogen production could also take place in several locations with established gas and CCS infrastructure.

Norway has a history of producing green hydrogen and ammonia for local use. As mentioned in chapter 9.1.2, **Norsk Hydro's** experience with the production of hydrogen stretches back almost 100 years. As early as 1926, the company decided to build a small ammonia factory at Notodden, Norway. Hydrogen played a central role there. Much of the technology in the ammonia factory was American, but Hydro's Norwegian engineers played an active role in developing and improving the process. Among other things, it was decided that production should be based on hydrogen produced by electrolysis of water, which these days is referred to as *'green hydrogen'*. The process was developed in Norway and was very power-intensive, but in return gave completely pure hydrogen. Later, **NEL Hydrogen**, founded as part of Norsk Hydro in 1927, built the world's largest water electrolysis plant as early as 1940 in the town of Rjukan, where hydropower from a local dam was used to produce green hydrogen for fertiliser production. But an abundance of cheap natural gas in mid-20th century soon replaced green hydrogen with grey hydrogen, and this remained the case for many decades. According to **CMS**, an international law firm, in Norway, **225 000 tonnes of hydrogen were produced from natural gas for use in industrial processes in 2020-2021.** The

[173] https://www.tu.no/artikler/her-er-norges-126-hydrogenprosjekter/529272?key=GX2CWJcP

production of hydrogen from natural gas ("grey" hydrogen) has a high emission of CO_2, but the cost of hydrogen produced this way is only a third of the emission-free alternative.

As interest in hydrogen continues to grow in Norway, **the government has taken steps to incentivize the production of green hydrogen through electrolysis.** The Norwegian Government is making it more financially viable for companies to invest in and produce green hydrogen. Also, the cost of connecting to the grid and the regular electricity grid tariff varies across regions. Connecting the facility directly to a power production plant will eliminate these costs, but this will reduce the flexibility of the hydrogen production and require more storage capacity. **The potential for large-scale production of green hydrogen**, at least in the short term, **is limited by the availability of renewable energy sources and costs.** A prevailing perspective is that electrolysis has more potential for decentralized production and in the longer term, when technologies grow more mature, and costs may be brought down. To be profitable, green hydrogen production depends on cheap electricity. Because of the large share of adjustable hydropower, **the Norwegian power system is relatively flexible, leading to more stable prices than in other countries.**

With regards to hydrogen produced through carbon capture and storage (CCS) from natural gas, based on the report "Large scale hydrogen production in Norway"[174], the potential for production of blue hydrogen has been emphasized by several of the consulted stakeholders, as well as at the attended workshops. The finding of the report suggests that there have been ongoing efforts to promote blue hydrogen to the pilot at Tjeldbergodden, Norway. Once a business case develops, **large-scale production of blue hydrogen could take place in several locations with established gas and CCS infrastructure**, such as the ports in **Bergen** and **Ålesund**, or the gas terminals in **Kårstø** or **Melkøya**. The main arguments for hydrogen produced from natural gas relate to costs and volume, in that current methods for grey hydrogen production (without CCS) are profitable and well suited for larger scales. **DNV GL** (2019) finds that in a 10-year perspective, **natural gas reforming with CCS will be cheaper than large-scale electrolysis.** However, they also note that large-scale blue hydrogen production will be limited to certain locations.

In summary, **Norway is currently implementing various methods for hydrogen production**, including grey hydrogen for industrial purposes, blue hydrogen as a cleaner alternative to grey hydrogen, and green hydrogen using renewable energy sources. The country is investing in these different methods to meet its climate goals and reduce its carbon footprint. Alongside investments in blue and grey hydrogen, Norway's focus primarily is on developing economically viable methods to produce green hydrogen.

9.1.4 Trade

- Norway has the potential to become a significant exporter of green hydrogen, with growing momentum in the hydrogen market and investments in hydrogen infrastructure.
- The Netherlands is well-positioned to benefit from Norway's hydrogen exports, given its strong industrial base with a focus on sustainability and innovation.
- Recent collaborations between Norwegian and other European companies in the hydrogen market could lead to potential collaborations in various aspects of the hydrogen value chain in the future
- Norway can quickly build upon its existing renewable energy capacity to create a domestic market for hydrogen technology and services, paving the way for export and global leadership in the field.

Currently, Norway does not have a significant hydrogen trade market, as most of the hydrogen produced in Norway is consumed domestically by the industrial sector. However, as the global demand for hydrogen grows, **there is**

[174] https://www.sintef.no/en/publications/publication/1794574/

potential for Norway to become a significant exporter of hydrogen, especially green hydrogen produced using renewable energy sources.

The Norwegian Government and several private companies are investing heavily in the development of hydrogen infrastructure, such as production facilities, storage solutions, and transportation networks, which will enable the country to participate in the global hydrogen trade market in the future. There has been a growing momentum in the hydrogen market in Norway in the recent times. Beside contextual changes such as climate change concerns and government support, this has to do with technological advancement and commercial success. In 2018, **NEL** signed a mega-order for 448 electrolysers and refuelling equipment with **Nikola**, and a planned expansion of their electrolyser plant at Notodden **will make it the largest in the world. Hexagon** is currently supplying compressed hydrogen tanks for serial production of fuel cell electric vehicles to three of the international car producers, as well as to the maritime market. They recently joined the prestigious Hydrogen Council. The Hydrogen Council is made up of nearly 150 steering members, supporting members and investor group members from across the world. Many major players of the industry, such as **Air Liquide**, **Alstom**, **Airbus**, are a part of the council. According to Hexagons' own estimate, they will invest 35 to 51,5 million EUR (400-600 million NOK) in the next five years. There is also the success with maritime solutions, where especially shipyard **Fiskerstrand** has a central role, and with new membrane technology for natural gas reforming in **Reinertsen New Energy** and **Mem-tech**. The increased engagement by industry giants such as **Equinor**, **Statkraft**, and **Yara**, also generate further activity in the field of hydrogen[170].

Equinor and **RWE** have recently signed a memorandum of understanding (MoU) on developing large scale projects that will contribute to the European energy supply and to the ramp-up of the hydrogen economy in Germany, Norway, and the EU. Among the key areas the two partners agreed upon is also joint development of offshore wind farms to produce renewable hydrogen. Equinor and RWE's collaboration on large-scale hydrogen projects, including the development of offshore wind farms, is contingent on the construction of a hydrogen pipeline between Norway and Germany, which is being assessed by **Gassco**, **Equinor**, and third parties, and will be used for the distribution of both blue and green hydrogen**. If the pipeline is built, Equinor would transport blue hydrogen produced in Norway, which RWE would purchase and use in hydrogen-ready gas plants in Germany.** On this Equinor-RWE collaboration, Anders Opedal, CEO and President of Equinor said ¨*The collaboration has the potential to develop Norway into a key supplier of hydrogen to Germany and Europe. This is a unique opportunity to build a hydrogen industry in Norway where hydrogen also can be used as feedstock to domestic industries*¨. As part of this plan, the partners will jointly explore possibilities for offshore production of renewable hydrogen in Norway, Germany, and countries adjacent to the proposed hydrogen pipeline. Recently, **NEL Hydrogen** received a purchase order from **HyCC** for 40 MW alkaline electrolyser equipment for the H_2eron project in Delfzilj, Netherlands, focusing on emission reduction for the aviation sector. **H_2eron will use electrolysers to produce up to 6 000 tons of green hydrogen per year from renewable power and water.** Nel Hydrogen has previously supplied electrolysers to the PosHydon project in the Netherlands as well, which is a collaboration between **Neptune Energy** and **TNO**. Such collaborations represent **a significant step towards the development of large-scale hydrogen projects in Europe with Norway leading the way.** Projects like these could also lead to potential collaborations between Norway and the Netherlands in various aspects of the hydrogen value chain in the future.

While the market is still immature, the winners would be those who have an existing competitive advantage and the capacity to produce green hydrogen. Ingebjørg Telnes Wilhelmsen, Secretary General of the Norwegian Hydrogen Forum, believes that a burgeoning hydrogen industry can quickly build upon Norway's strongest asset i.e., its existing renewable energy capacity. Norway being a long country, heavy-duty transport and marine vessels require long range, short filling time and large cargo space. Wilhelmsen believes that **by creating a domestic market for**

development and delivery of hydrogen technology and services, Norway can pave the way for export having companies that are global leaders in the field already[175].

9.1.5 Infrastructure

- Norway has been investing in hydrogen fuel for heavy-duty transport and the maritime sector for over a decade, with several hydrogen refuelling stations already operational.
- Everfuel and Vireon AS have launched ambitious plans to establish networks of hydrogen refuelling stations for heavy-duty transport across the Nordic region, with the aim of promoting zero-emission transportation.
- Norwegian Government, technology companies, and shipping operators are collaborating to develop hydrogen hubs for the maritime industry, comprising of various components such as hydrogen production facilities, storage facilities, and refuelling stations.
- Several major players in the maritime industry are involved in developing these hydrogen hubs, including the Norwegian Government, technology companies, and shipping operators.

Hydrogen for transport, specifically heavy-duty transport and the maritime sector, has been on Norway's agenda for a while. It's first hydrogen station was opened in 2006 near Stavanger, the second in Porsgrunn in 2007, and two stations opened in Oslo and Lier in 2009. Hydrogen stations were also planned for Bergen and Lyngdal, but these projects were never carried out.

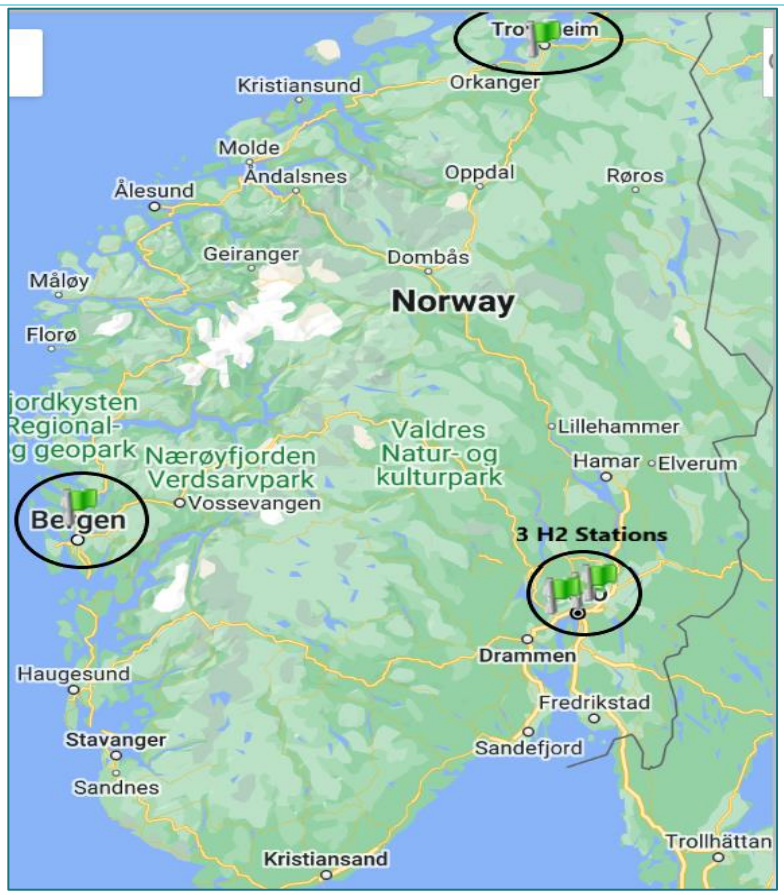
A few years back, a plan to roll out hydrogen stations in southern Norway was unveiled, with the **ambition to have up to 15 zero-emission freight and passenger fuelling points in operation by the end of 2023.** The plan was part of **Everfuels'** Scandinavian green hydrogen refuelling strategy for trucks, buses and cars connecting major traffic corridors in Norway, Sweden, and Denmark. It will initially cover Norway south of Trondheim and connect to H_2 stations in Sweden and Denmark[176]. **Everfuel's Scandinavian green hydrogen refuelling strategy is an ambitious plan to establish a network of hydrogen refuelling stations across the region,** enabling the widespread adoption of hydrogen-powered transportation. The company aims to build a network of stations along the major highways in the region, allowing for long-distance travel without range anxiety. The company has already launched its first refuelling station in Norway in 2020 and plans to expand its network to other Scandinavian countries soon.

Recently, **Norwegian Hydrogen A/S** has launched a new subsidiary, **Vireon AS**, which aims to develop a comprehensive network of hydrogen refuelling stations for heavy-duty transport across the Nordic region. This initiative is part of their ambitious growth strategy to promote the use of hydrogen as an alternative fuel for heavy transport. The CEO of Norwegian Hydrogen A/S is confident that Vireon will help them achieve a breakthrough for hydrogen-powered heavy-duty transport in the Nordics. The subsidiary is also keen to engage in dialogue with transport operators interested in adopting hydrogen as an alternative fuel. The first Vireon refuelling station is expected to open in Norway in 2023, with Norwegian Hydrogen A/S supplying green hydrogen. The company has received grants to build the first refuelling stations in Sweden and Finland, and work to open these as soon as possible. The first station in Denmark will soon be announced, and refuelling stations will in the years to come be built at a much greater pace[177]. This marks a significant step forward in promoting sustainable transportation in the Nordic region.

[175] https://businessnorway.com/articles/norway-poised-to-lead-green-hydrogen-market
[176] https://www.h2stations.org/
[177] https://hydrogen-central.com/norwegian-hydrogen-vireon-become-largest-supplier-hydrogen-heavy-transport-nordics/

Since 2005, **Ludwig Bölkow Systemtechnik (LBST)**, a German company, has provided the most comprehensive information on hydrogen refuelling stations worldwide. According to their data, **there are currently five operational hydrogen stations in Norway,** with several more under construction. The operational hydrogen stations in Norway can be found in the list provided in Table 17.

Table 17 List of Hydrogen filling stations in Norway[176]

Operational Hydrogen filling stations - Norway	
Trondheim multi-purpose station -ASKO Midt-Norge AS	
Bergen Åsane – Everfuel Europe A/S	
Hynion Høvik - Hynion	
Everfuel Oslo station Alna – Everfuel Europe A/S	
Oslo Hvam – Everfuel Europe A/S	

Norway is also at the forefront of developing sustainable solutions for the maritime sector, including the use of hydrogen as a fuel source. The country has had ambitious plans to establish a network of hydrogen hubs for the maritime industry, with the aim of promoting zero-emission shipping. These hydrogen hubs comprise of various components such as hydrogen production facilities, storage facilities, and refuelling stations. These facilities are strategically located along the coast, enabling ships to refuel easily and efficiently. Several major players in the maritime industry are involved in developing these hydrogen hubs, including the Norwegian Government, technology companies, and shipping operators. For example, the Norwegian Government has provided funding for hydrogen-related research and development projects, while shipping operators such as **Wilhelmsen** are investing in the development of hydrogen refuelling infrastructure. A comprehensive overview of five significant hydrogen hubs in Norway and their advantages has been provided in chapter 9.1.2.

9.1.6 Policies

- Norway aims to become carbon-neutral by 2050 and has set a target to reduce greenhouse gas emissions by 90-95% as compared to 1990 levels.
- The Norwegian Government is facilitating infrastructure and funding to enable the development and adoption of new climate solutions and has increased its focus on hydrogen-related research and technology development.
- The government offers several R&D-related support measures for the development of green and blue hydrogen, and electricity used to produce hydrogen through electrolysis is already exempt from the consumer tax on electricity in Norway.
- The government plans to continue work on developing regulations and standards for the use of hydrogen-based systems in new applications, and the handling of hydrogen is governed by various regulations and authorities in Norway.

Norway is aiming to become a carbon-neutral society by 2050. The Norwegian Government has a target for greenhouse gas emissions to be reduced by 90 to 95%, as compared to 1990 levels, by 2050. Under the Paris Agreement, in the nationally determined contribution, the Norwegian Government has submitted a more climate ambitious target of reducing emissions by at least 50% and towards 55% by 2030 as compared to the levels in 1990. To achieve this, **the government, for several years, has been facilitating infrastructure and funding to enable the development and adoption of new climate solutions by the research community and businesses.**

In the post Covid-19 crisis package presented to Parliament in May 2020, **the government announced an increased focus on hydrogen-related research and technology development** as a way of meeting these challenges. This hydrogen strategy is a contribution to the process of developing new low emission technologies and solutions. An increased focus on hydrogen in Norway is in line with the goal of having internationally competitive businesses which develop the technology and solutions addressing tomorrow's challenges[178]. Complying with the following, the Norwegian Government also offers several R&D-related support measures for the development of green and blue hydrogen. The Research Council of Norway (RCN), Innovation Norway and Enova contribute to developing and demonstrating energy-efficient and cost-efficient methods and value chains for the production, transport, storage, and use of clean hydrogen, including through joint calls for proposals in the PILOT-E scheme. The former government also **published a Hydrogen Strategy in June 2020, followed by a white paper in 2021** that assessed the entire energy sector and included a road map for hydrogen. The road map includes signposts for the production and use of hydrogen in the 2025, 2030 and 2050 timeframes, however, the government is reluctant to set a fixed production target and believes it will be up to the industry to determine how much production if feasible. One of the strategy's important points is to develop a coherent value chain where production, distribution and use are developed in parallel.

With the support of the Norwegian Government, **electricity used to produce hydrogen through electrolysis is already exempt from the consumer tax on electricity in Norway.** This helps to reduce the cost level at which hydrogen becomes competitive compared with other energy carriers. In transport, hydrogen vehicles get the same tax breaks and user benefits as battery electric vehicles. Moreover, the Zero Emissions Fund was introduced to accelerate the introduction and growth of zero emissions solutions in the commercial vehicle and vessel market. Through Enova, the government also supports the build-out of early-phase fuelling infrastructure for shipping (Norway, Ministry of Petroleum and Energy and Ministry of Climate and Environment, 2020). The government also plans to continue work on developing regulations and standards for the use of hydrogen-based systems in new

[178] The Norwegian Government's hydrogen strategy

applications. By 2050, the road map expects that hydrogen will be used as a chemical feedstock in industry where economically feasible, as fuel in shipping both in coastal waters and for longer distances, in heavy-duty road transport, and exported to create economic value domestically. In the medium term, by 2030, the road map plans for the creation of hydrogen clusters that are geographically spread and demand-driven to align with access to vessels and vehicles; projects in the industry that can be tied to a market for hydrogen in Europe and the rest of the world; hydrogen solutions as a competitive alternative to fossil fuels; and companies that are tied to the development of a market for hydrogen in Europe through exports. **In the short term, by 2025, the hydrogen roadmap outlines plan for the establishment of five hydrogen hubs for maritime transport,** one or two industrial projects with associated hydrogen production units, and five to ten pilot projects for the development and demonstration of new and cost-efficient hydrogen technologies[179].

In Norway, the production, storage, and transportation of hydrogen are not covered by the Energy Act. However, hydrogen facilities must follow the regulations under the Energy Act. The Norwegian Directorate for Civil Protection (DSB) is responsible for flammable, reactive, pressurized, and explosive substances, including hydrogen. DSB also oversees electrical safety and road transport of dangerous goods, including hydrogen.

The handling of hydrogen is governed by regulations for hazardous substances and dangerous goods. These regulations cover hydrogen bunkering and stationary equipment used to handle hydrogen. Hydrogen transportation must comply with the regulations for the transport of dangerous goods by road. Undertakings storing 5 tonnes or more of hydrogen are also covered by Major Accident Regulations. These regulations are based on directives and are similar to those in other EU/EEA countries. The Regulations for the handling of hazardous substances are national regulations[178].

9.2 Market characteristics

9.2.1 Networks

- A list of some of hydrogen-related forums, clusters, events, and conferences in Norway

As the Norwegian field is well-established throughout the whole value chain with several projects and collaborations, it also has several networks that are working to promote the development and use of hydrogen technology. These organisations are typically made up of a diverse group of stakeholders including government agencies, private companies, and research institutions. There are various hydrogen related events and conferences also that happen on a yearly basis in Norway.

CLUSTERS & ORGANISATIONS

1. **Norwegian Hydrogen Forum (NHF)**

Norwegian Hydrogen Forum (NHF) was founded in 1996 as a non-profit member organisation, which promotes the advantages of hydrogen and ammonia as energy carriers. As of 2022, over 70 members span Norwegian producers, distributors, industry, universities, research institutes, companies in the transportation sector, consulting firms and other organisations are interested in hydrogen.

[179] Norway, Ministry of Petroleum and Energy and Ministry of Climate and Environment, 2020

NHF works actively to disseminate key information in Norway on hydrogen and ammonia research and technology commercialisation, market trends and international policy making. Moreover, NHF organizes conferences, seminars, and workshops, some in collaboration with our Nordic sister-organisations, projects, or other national and international stakeholders.
https://www.hydrogen.no/en

2. Centre for Environment-friendly Energy Research (FME) in Hydrogen

The Norwegian Government has decided that a Centre for Environment-friendly Energy Research (FME) will be established in the field of clean hydrogen and hydrogen-based energy carriers, including ammonia. The FME will be dedicated to work on hydrogen produced from both natural gas and renewable energy to be used in the energy, mobility, and industrial sectors. The centre will coordinate and enhance research efforts and education in this field and support the ambitions set out in the government's hydrogen roadmap.
https://www.forskningsradet.no/en/call-for-proposals/2021/fme-hydrogen/

3. Arena H_2 Cluster

H_2 Cluster brings together the Norwegian hydrogen players to build the new hydrogen value chains. The cluster speeds up development and is a spearhead for sustainable restructuring, value creation and contributes to creating new green jobs nationally and internationally. It has partners such as **Hyon**, **Greenstat**, **DNV**, **Aker Clean Hydrogen**, **Hydrogen mem-tech** and other giants of the industry.
https://h2cluster.com/

4. NCE Maritime CleanTech

NCE Maritime CleanTech is a Norwegian cluster of companies and organisations working to develop sustainable maritime solutions. The cluster includes several companies and organisations working on hydrogen-related projects and initiatives.
https://maritimecleantech.no/

5. Norwegian Energy Partners (NORWEP)

Norwegian Energy Partners is a network of energy companies in Norway that promotes the country's energy expertise and technologies internationally. The organisation includes a hydrogen working group that focuses on promoting the development and deployment of hydrogen technology in Norway and abroad.
https://www.norwep.com/

6. SINTEF

There are various projects that are funded and collaborated by SINTEF. SINTEF partners with companies from all stages of the hydrogen value chain to develop new H_2-based solutions and offer consultation, testing, and validation services. SINTEF provides analysis and cost-efficient solutions for decarbonization and solves technical challenges in relation to hydrogen production, storage and utilization. The HYPER project – Liquified hydrogen production from surplus wind/hydro power and fossil sources in Norway – is one of them. The central technology elements and processes and their interaction will be investigated using SINTEF ER's and NTNU's expertise in cooperation with the industrial partners **Equinor**, **Shell**, **Nel Hydrogen**, **Linde Kryotechnik**, **Kawasaki Heavy Industries**, **Mitsubishi Corporation** and **Gassco**. Additionally, two new research centres have been established in 2022, one in Bergen coordinated by NORCE and one in Trondheim coordinated by SINTEF.
https://www.sintef.no/en/

7. **Arena Pro – Ocean Hyway Cluster**

Ocean Hyway Cluster is Norway's leading network for hydrogen-based solutions for the maritime sector. They are making green waves together with their broad national and international network. The cluster works closely with the industry to exploit the commercial opportunities of new hydrogen technology solutions to make Norway a global leading hydrogen player.
https://www.oceanhywaycluster.no/

9.2.2 Events

Table 18 Hydrogen events in Norway

Event	Date	Location	Website
Nor-Shipping	6.-9.6.2023	Oslo	*https://nor-shipping.com/exhibition/*
The Hydrogen Conference 2023 – Norsk Hydrogenforum	1.6.2023	Oslo	*https://www.hydrogen.no/hydrogenkonferansen*
The Maritime Hydrogen Conference	1.-2.11.2023	Florø	*https://maritimehydrogen.no/*
Maritime Hybrid, Electric, and Hydrogen Fuel Cells Conference	17.-19.10.2023	Bergen	*https://www.rivieramm.com/events/events/maritime-hybrid-electric-and-hydrogen-fuel-cells-conference-2023*

1. **Nor-Shipping**

Nor-Shipping is a maritime trade fair that has been held in Norway biennially since 1965. It is one of the leading international shipping events and an important meeting place and forum for the shipping industry. It remains one of the most pivotal and well-attended events of the marine and offshore calendar.
https://nor-shipping.com/exhibition/

2. **The Hydrogen Conference 2023 – Norsk Hydrogenforum**

The conference is the year's largest meeting place for the hydrogen and ammonia industry. The conference is organized by the Norwegian Hydrogen Forum (NHF), the industry association for hydrogen and ammonia.
https://www.hydrogen.no/hydrogenkonferansen

3. **The Maritime Hydrogen Conference**

The conference brings together world-leading players in the field of maritime hydrogen technology. To ensure further development and future value creation, it is crucial to gather representatives from all corners of the industry: business, R&D, academia, finance, and public enterprises. Through knowledge sharing and working together, the companies contribute to solving technological challenges that will reduce global CO_2 from maritime transport.
https://maritimehydrogen.no/

4. **Norwegian Hydrogen and Fuel Cell Conference**

The Norwegian Hydrogen and Fuel Cell Conference is an annual event that brings together industry leaders, policymakers, and researchers to discuss the latest developments in hydrogen and fuel cell technology.
https://www.nordicinnovation.org/events/2022/hydrogen-and-fuel-cell-conference

5. **Maritime Hybrid, Electric and Hydrogen Fuel Cells Conference**

The Bergen Hydrogen Conference is an annual event focused on hydrogen as a fuel source for transportation. The conference includes presentations and panel discussions from industry leaders, researchers, and policymakers.
https://www.rivieramm.com/events/events/maritime-hybrid-electric-and-hydrogen-fuel-cells-conference-2023

Please contact the Dutch Embassy in Norway for latest updates on hydrogen related events.

9.2.3 SWOT Analysis

Table 19 SWOT Analysis, Norway

STRENGTHS	WEAKNESSES
• Norway's extensive experience across the entire hydrogen value chain, combined with its renewable, flexible, secure, and competitively priced power supply, creates ideal conditions for the production and use of clean hydrogen. • Through the petroleum industry, Norway has robust experience of everything from processing gas to tackling major industrial projects. • Norway's competitive knowledge and technology communities, combined with its well-established maritime industry, positions the country to leverage its experience in developing and implementing high-technology solutions in maritime transport, such as batteries and LNG, to support the growth of the hydrogen industry. • Electricity used to produce hydrogen through electrolysis is currently exempt from the consumer tax on electricity. This helps to reduce the cost level at which hydrogen becomes competitive compared with other energy carriers.	• Hydrogen value in energy-sector is less in Norway than in other European countries. • Technology readiness level and high costs are central barriers to the use of hydrogen. • The cost estimates for the use of hydrogen and ammonia in the Norwegian Government's report Climate Cure 2030 are at the upper end of the cost spectrum (costing more than 130 EUR/tonne of CO_2 (1,500 NOK/tonne of CO_2). • Limited domestic demand for hydrogen, which can limit the scale of the industry.
OPPORTUNITIES	**THREATS**
• A more stringent emissions trading market, combined with the increase in the CO_2 tax announced by the government, will make emission-intensive solutions more expensive. It was announced that the government will increase the flat CO_2 tax by 5 per cent every year for all sectors until 2025. • Production of blue hydrogen requires the capture and storage of CO_2. The Norwegian continental shelf could potentially act as a CO_2 storage. • Potential for exporting green hydrogen to other countries, such as Germany and the Netherlands, to meet their demand for clean energy. • The widespread use of hydrogen depends on cost reductions through technology developments outside of Norway.	• Competition from other countries, such as Saudi Arabia and Chile, that have lower production costs for green hydrogen. • Uncertainty around future hydrogen demand and market adoption. • Norway might have a net negative energy balance in 2027.

9.3 Opportunities for Dutch businesses

9.3.1 Segments providing opportunities

- Sectors that have the possibility to provide opportunities for Dutch businesses to enter the hydrogen market in Norway.

Value creation and emissions reductions are the main drivers for hydrogen development. Almost all hydrogen in Norway today is being used in refineries of petroleum-based products and as a feedstock in chemical industries as a part of the end-product. Currently, the most relevant direct applications for hydrogen in Norway appear to be the maritime sector, heavy goods transport and industrial processes as highlighted by the hydrogen strategy. These are sectors in which there are currently few emissions reduction alternatives, and in which replacing fossil energy sources with renewables, batteries or bioenergy solutions will be challenging[180].

1. Transportation

The transportation sector is particularly interesting in Norway, and especially in the maritime segment. Dutch strengths lie in heavy-duty transportation and this knowledge could provide opportunities in a country like Norway, where the distances are long. Norway is already the leader in battery electric propulsion in short sea traffic. Battery electric and fuel cell propulsion have many similarities, and the next step is zero emission deep sea voyages. As Norway is investing heavily in the development of hydrogen technologies for the maritime industry, Dutch companies could collaborate with Norwegian businesses to develop and manufacture new hydrogen-powered vessels or retrofit existing vessels to run on hydrogen fuel. By tapping into the Norwegian market for hydrogen-powered vessels, Dutch companies could gain access to new markets and expand their reach beyond their home country. This could create new business opportunities and increase revenue streams for Dutch companies. There may be investment opportunities for Dutch companies in this sector as well. This could include investing in the development of new hydrogen refuelling stations, hydrogen storage solutions, or hydrogen production facilities. As the use of hydrogen for ships becomes more widespread in Norway and other Nordic countries, there may be opportunities for Dutch companies to export their hydrogen technologies and expertise. This could help increase the global reach and influence of Dutch companies in the growing hydrogen economy.

2. Maritime Sector

The Norwegian Shipowners Association aims to have a climate-neutral fleet by 2050, which has led to a significant amount of innovation, R&D, and funding being invested in developing hydrogen-based systems. Norway has a well-established network of research institutions and industry players involved in the hydrogen value chain. As a result, many technologies required for developing and implementing hydrogen-based systems can be sourced from various places. This presents an opportunity for Dutch companies, and they can leverage their technical know-how and expertise to collaborate with Norwegian businesses and research institutions. By collaborating with Norwegian institutions and businesses, Dutch companies can gain access to new technologies and knowledge related to the hydrogen value chain. This collaboration can help them to improve their own products and services, increase their competitiveness, and expand their business opportunities in the growing hydrogen market. Norway also has several funding programs and investment opportunities available for businesses and projects focused on hydrogen

[180] https://iea.blob.core.windows.net/assets/de28c6a6-8240-41d9-9082-a5dd65d9f3eb/NORWAY2022.pdf

technology development. Dutch businesses could benefit from these funding and investment opportunities by partnering with Norwegian businesses and applying for joint projects or investment opportunities.

3. Technical know-how and Expertise

Norwegian companies have a significant presence in various parts of the hydrogen value chain related to land transportation, including tanks, logistics, and fuelling systems. Many carriers have already placed orders for hydrogen trucks, indicating a growing demand for hydrogen-based solutions in the transportation sector. However, while the Norwegian Government is investing in the green shift in various industries, it is crucial to note that Norway also relies on input from other countries and markets. As a small and open country, Norway promotes free trade and encourages collaboration with foreign companies to drive innovation and growth[181]. Norway's offshore oil and gas exploration and production industry has been successful due to the involvement of foreign companies. Similarly, in the emerging hydrogen market, there is potential for Dutch businesses to contribute their expertise and technologies to collaborate with Norwegian companies and institutions, further advancing the development and implementation of hydrogen-based solutions in Norway. Dutch strengths in heavy-duty transportation and refuelling systems could be a good selling point for Norway, especially considering the country's long distances. Norwegian companies could benefit from Dutch expertise in developing and implementing heavy-duty transportation solutions, such as buses and trucks, that run on hydrogen fuel. Additionally, Dutch companies that specialize in developing heavy-duty refuelling systems could help establish a robust hydrogen refuelling infrastructure in Norway, which would further support the growth of the hydrogen industry in the country.

4. Electrolyser Industry

Norway has established itself as a leader in the manufacturing of electrolysers, which are critical components in the production of green hydrogen. Electrolysers are used to split water molecules into hydrogen and oxygen using an electrical current. This process, known as electrolysis, produces hydrogen that is considered "green" when the electricity used to power the process is generated from renewable sources. Norwegian companies, such as NEL Hydrogen and Hystar, are among the leading global manufacturers of electrolysers. NEL Hydrogen, for example, is one of the largest electrolyser manufacturers in the world, and it has been operating for over 90 years. Hystar, another Norwegian company, specializes in the design and production of PEM electrolysers for industrial applications. The company's products are used in a variety of industries, including renewable energy, chemical production, and electronics manufacturing. Norwegian companies' expertise in electrolyser manufacturing is partly due to the country's abundant supply of renewable energy. In addition, the country's strong focus on research and development has helped to drive innovation and improve the efficiency and performance of electrolysers.

However, at the moment, the international market volumes for electrolysers are still low. Demand is also held back by the relatively high-cost price of water electrolysis, which is up to four times greater than the cost price of ‘fossil’ or ‘grey’ hydrogen. This offers opportunities for Dutch industry to catch up and to position itself internationally as a developer and supplier of (components for) electrolysers. An important factor in the high-cost price of electrolysis is the fact that the production process is automated to only a limited degree. In the Netherlands in particular, a lot of expertise is available (including from other industrial markets) to improve the production process and to increase the quality and efficiency of electrolysers[182]. Even as per some of the professionals whose interviews we conducted, Norway is known for its strong industrial and technological capabilities, particularly in the areas of energy and maritime sectors. However, in recent years, there has been a growing recognition that the country needs to enhance its competence in areas such as automation, logistics, and digitalization to stay competitive and maintain its

[181] https://www.trade.gov/market-intelligence/norway-hydrogen-projects
[182] https://www.fme.nl/system/files/publicaties/2020-11/FME-TNO-Summary%20report%20electrolyser%20production%20NL.pdf

leadership position in the global economy. The Netherlands, on the other hand, is recognized as a world leader in automation, logistics, and digitalization. This presents an opportunity for the Dutch companies to partner and collaborate with Norwegian electrolyser manufacturers and improve the production process and increase quality and efficiency of electrolysers.

5. **Imports**

Norway's potential to become a major exporter of hydrogen also presents significant opportunities for Dutch industries. The Netherlands is already an importer of natural gas from Norway and has a strong industrial base with a focus on sustainability and innovation, which makes it well-positioned to benefit from the growing hydrogen market. Norway's hydrogen exports could also help the Netherlands achieve its goal of transitioning to a low-carbon economy. The Dutch Government has set ambitious targets to reduce greenhouse gas emissions and increase the share of renewable energy in its energy mix and the use of hydrogen in various industries, such as transportation, energy storage, and heating, could play a key role in achieving these targets.

Overall, collaboration between Norwegian and Dutch businesses could result in mutually beneficial partnerships, as both countries have strengths in different areas of the hydrogen value chain. By leveraging each other's expertise and resources, they could accelerate the growth of the hydrogen industry in both countries and contribute to the development of a sustainable and low-carbon energy future.

9.3.2 Recommendations for market entry

- An overview of recommendations for market entry into the hydrogen-market of Norway.
- List of funding opportunities for non-Norwegian companies in Norway.
- The Dutch Embassy in Norway helps Dutch companies with market entry.

Like other Nordic countries, the key factor for market entry in Norway for green hydrogen related projects, as well as accessing incentives and subsidies, is to identify a local partner. Norwegian companies are highly motivated to collaborate, and it is crucial to find a partner within the country to navigate the local market and culture effectively. Norwegian professionals also emphasize the importance of having a solid understanding of the Norwegian market and the relevant regulations and policies.

Interestingly, Norway and the Netherlands share many similarities in culture, values, and working styles. They also share a know-how from the gas sector, offshore sector, and the maritime sector. This suggests that Dutch companies may find it easy and enjoyable to collaborate with Norwegian partners, creating opportunities for mutually beneficial partnerships and driving innovation in the green hydrogen space. Additionally, Norway has been at the forefront of the development and deployment of hydrogen technologies, making it an attractive market for companies looking to invest in the green hydrogen sector.

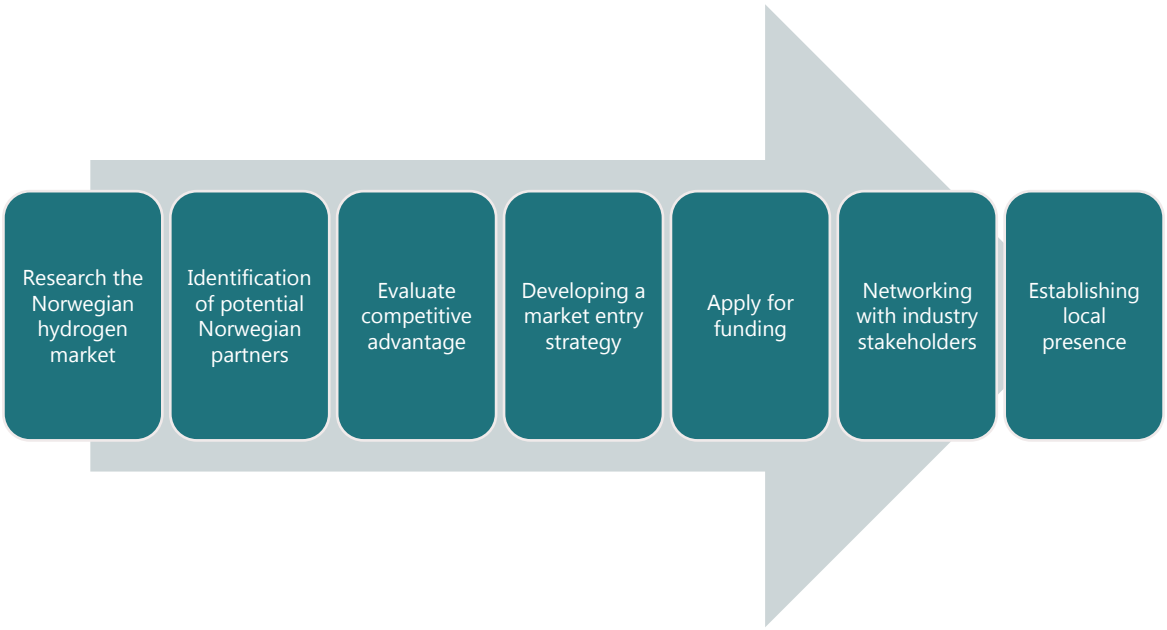


Figure 18 Steps to enter the Norwegian hydrogen market

1. *Research the Norwegian hydrogen market*

Before entering any market, it is essential to research the market thoroughly. You should gain an understanding of the current state of the Norwegian hydrogen market, including the major players, government policies, and regulations.

2. *Identification of potential Norwegian partners*

As mentioned earlier, finding a local partner is crucial to entering the Norwegian hydrogen market. You should identify potential Norwegian partners who can help you navigate the market and provide valuable insights.

3. *Evaluation of your competitive advantage*

You should evaluate your competitive advantage in the Norwegian market. Determine what sets your company apart from the other players in the market and how you can leverage this advantage to succeed in the market.

4. *Developing a market entry strategy*

Based on your research and evaluation, develop a market entry strategy that outlines your approach to entering the Norwegian hydrogen market. Your strategy should consider factors such as market size, target customers, pricing strategy, and distribution channels.

5. *Applying for funding*

There are several Norwegian and European funding programs that support hydrogen-related projects as specified in detail below. Apply for funding that aligns with your business strategy and supports your market entry plans.

6. *Network with industry stakeholders*

Attend industry events, conferences, and exhibitions to network with industry stakeholders and potential partners. You can also participate in hydrogen-related forums and engage with industry experts to gain insights and expand your network. Events, conferences, funding opportunities and hydrogen-related forums in Norway have been included in the list below.

7. *Establishing local presence*
   Establishing a local presence in Norway, such as a representative office or a subsidiary, can help you build credibility and demonstrate your commitment to the Norwegian market.

The Dutch Embassy in Norway can offer valuable support to Dutch companies looking to enter the Norwegian hydrogen market. The Embassy can provide information on the Norwegian market, including local business culture, regulations, and market opportunities as well as facilitate introductions to local business networks and hydrogen organisations. In addition, the Embassy hosts events and seminars on various topics related to doing business in Norway, such as market entry, regulations, and investment opportunities. For further information, please contact osl-ea@minbuza.nl.

To successfully enter a new market, companies must research funding opportunities, events, and industry forums that can provide them with valuable information and networking opportunities. By leveraging these funding opportunities and participating in industry events and forums, non-Norwegian companies can gain valuable insights into the Norwegian hydrogen market and establish key contacts that can help them succeed in the market. In Norway, there are several options available to non-Norwegian companies looking to enter the hydrogen market. They are:

1. **PILOT-E**

A Norwegian scheme that provides funding for research, development and demonstration for Hydrogen production and utilization. A Non-Norwegian company can receive funding from PILOT-E, but to be eligible for funding the company must have a Norwegian company or research organisation as the main applicant. The project also must have a clear link to Norway, such as a Norwegian market or a Norwegian pilot project. The aim of the scheme is to promote the development of new technologies in Norway and to support the commercialization of these technologies in the Norwegian market.

2. **ENOVA SF**

Enova SF is a Norwegian Government-owned company that provides funding and other support for projects that promote the development and use of renewable energy and energy efficiency, including hydrogen-related projects. Non-Norwegian companies can apply for ENOVA funding if they are registered in Norway and have a Norwegian organisation number. International companies with significant presence in Norway can receive funding from it. The funding is provided in the form of grants and loans and can be used to cover costs associated with research, development, and demonstration projects, as well as the commercialization of new technologies.

3. **INNOVATION NORWAY**

This is a government agency that provides funding and support to companies looking to invest in Norway. They have several funding schemes available for hydrogen-related projects, including the Green platform program, which provides funding to companies developing innovative solutions for a greener future.

4. **RESEARCH COUNCIL OF NORWAY**

The research council of Norway offers funding for research and development projects related to hydrogen technology. Non-Norwegian companies can apply for this funding if they are collaborating with Norwegian research partners.

5. **EUROPEAN UNION (EU) FUNDING**

Norway is a member of the European Economic Area (EEA) and participates in various EU funding programs. Non-Norwegian companies can apply for EU funding for hydrogen-related projects in Norway if they meet the eligibility criteria for the specific funding program. For e.g., **Horizon Europe.** Norway and Iceland became the first countries to

be associated to Horizon Europe in September 2021, with an effect from the start of the Programme. Norway sees association as a gateway to an excellent international cooperation in science, research, and innovation, focusing on common priorities: the twin green and digital transitions, public health and Europe's competitiveness in the global landscape. Joint efforts will aim to address environmental problems in the Arctic, develop hydrogen and carbon capture technologies, boost data-driven innovation, and more.

6. TAX INCENTIVES

Norway offers tax incentives for companies investing in hydrogen technology, including tax deductions for research and development costs and accelerated depreciation for assets related to hydrogen production.

10 Sweden

10.1 Policy landscape

10.1.1 Energy Mix

- Sweden is well positioned to be a strong country in the development of hydrogen.
- By 2045, Sweden targets to reach net zero greenhouse gases emissions and thereafter negative emissions, by strengthening existing industry and creating new opportunities.
- Sweden has a large and increasing share of renewable electricity production available.
- Sweden has a stable electricity grid which is available all year-round.
- Sweden is divided into 4, SE1-SE4, electricity areas. Impact on the electricity price differ between the areas.

Sweden has successfully surpassed its target to reduce emissions by 17% from 2005 levels by a significant margin, well ahead of the 2020 deadline. Sweden is currently the leader of all EU member states in renewable energy usage, with renewable sources accounting for 62,6% of its energy mix in 2021[183]. This is a notable increase from the 53,9% recorded in 2015, which had already surpassed the 2020 target of 49%.

In line with its commitment to show international climate leadership, Sweden has set itself a target of achieving net-zero emissions of greenhouse gases by 2045, with the goal of achieving negative emissions thereafter. To support this transition, the Swedish Government introduced the "Industrial Leap" initiative in 2018[184]. The Swedish Energy Agency is working closely with various organisations to tackle the main challenges involved in this transition, which are:

- Cooperation between technology, organisations, and society.
- Energy systems in relation to other societal objectives.
- Energy and climate transitions as a global challenge.

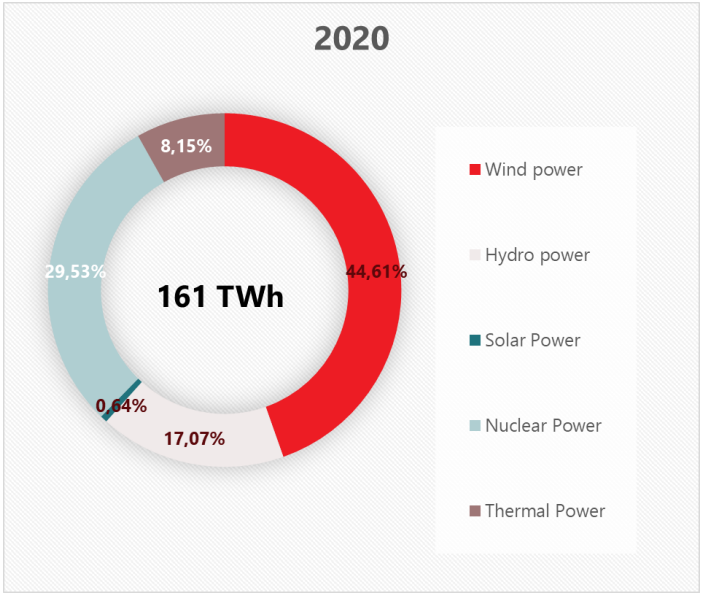


Figure 19 Swedish electricity production, 2020[185]

[183] https://ec.europa.eu/eurostat/statistics-explained/images/b/b1/Share_of_energy_from_renewable_sources,_2021_%28%25_of_gross_final_energy_consumption%29.png
[184] https://www.energimyndigheten.se/en/innovations-r--d/energy-systems-in-society/
[185] Electricity supply, district heating and supply of natural gas 2020. Final statistics. Swedish Energy Agency. Available: Statistiska meddelanden-El-, gas- och fjärrvärmeförsörjningen 2020. Slutliga uppgifter (scb.se)

Renewable energy sources and nuclear power are the primary contributors to Sweden's energy mix, both of which are domestically produced. The country's renewable energy portfolio is comprised of hydro, wind, solar, and biofuels. Though the energy mic within Sweden is well established, they do import certain fuels, such as nuclear, biofuels, and fossil fuels, including oil and natural gas. To illustrate this, Figure 19 displays Sweden's energy production, which totals 161 TWh/year. Though over the last 40 years, the demand to Sweden's energy system has remained relatively constant, averaging between 350 to 400 TWh/year. Nonetheless, **the use of wind power has experienced a significant increase over the past decade.** Figures 20 and 21 depict the evolution of Sweden's final energy consumption from 1970, showcasing the contribution of different energy carriers and sectors over time. Of note, the industrial sector accounts for almost one-third of the total energy use and greenhouse gas emissions, in addition to being a significant consumer of electricity and heat. The importance of a secure energy supply has become increasingly relevant for Sweden and other countries due to recent events, such as the restrictions on fuel supply during the pandemic, the significant increase in energy prices as of the second half of 2021, and the ongoing conflict between Russia and Ukraine, which has disrupted the supply of natural gas to Europe[186].

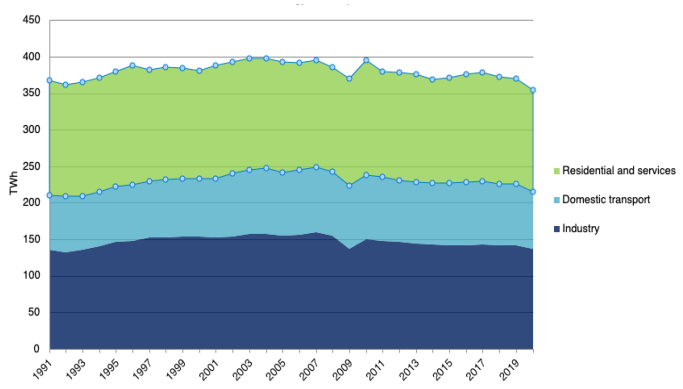


Figure 20 Swedish total final energy use, by sector.

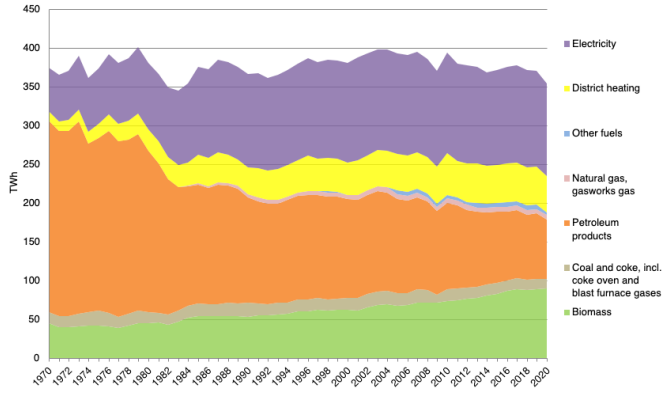


Figure 21 Swedish total final energy use by energy carrier.

As wind and solar power sources make up a greater proportion of the energy mix, there has been an increase in decentralized and variable generation within Sweden's electricity system. This has created new demands for grid flexibility in order to maintain a balance between energy generation and consumption. Moreover, the electricity grid itself requires improvements, as consumers now have the ability to produce their own electricity, resulting in power flows that move in both directions[187]. As the country's renewable energy sector continues to grow, **Nordion Energi**, Swedish national gas TSO has experienced a significant increase in the total transmission volume of local renewable electricity generation. In 2021, approximately 41% of the total transmission volume (compared to 34% in 2020) came from fossil-free combined heat and power (CHP), wind, hydro, and solar sources[188].

Since 1996, the electricity trade in Sweden has been deregulated, and the country is now part of the wider European electricity market. This means that Swedish customers have the ability to choose from approximately 120 electricity suppliers when purchasing their energy. However, electricity distribution remains under the control of a monopoly network. The operations of this network are regulated by the **Swedish Energy Markets Inspectorate** (EI). To facilitate energy distribution, **Sweden has been divided into four distinct electricity areas** since November 2011 (Figure 20).

[186] Energy in Sweden 2022 With energy balance for year 1970-2020, ET 2023:01, ISBN (pdf) 978-91-7993-103-2
[187] https:// www.svk.se/utveckling-av-kraftsystemet/transmissionsnatet/transmissionsnatsprojekt/
[188] https://www.nordionenergi.se/download/18.3e831922180945f84b3790cb/1652870899021/Nordion_Energi_sustainability-report_2021_EN.pdf

This electricity grid is interconnected, allowing for electricity to flow across national borders, albeit with some limitations due to the capacity of the electricity cables.

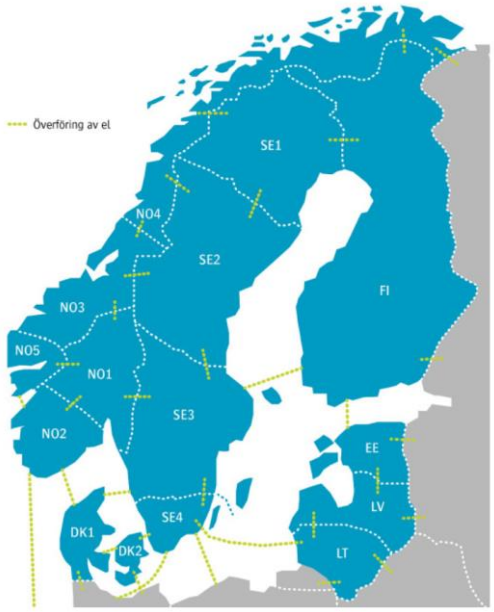


Figure 20 The 4 electricity areas in Sweden, SE1-SE4[189]

This interconnectedness has an impact on the electricity price between the various electricity areas[190]. In the northern section of Sweden, the lower cost of electricity has made it highly profitable to undertake large-scale hydrogen projects. This cost advantage has facilitated the development of green hydrogen technologies, hydrogen infrastructure, and production capabilities in the region. The Swedish Energy Market Inspectorate is cooperating (within NordREG, Nordic Energy Regulators[191]) with Finland, Norway, Denmark, and Iceland on matters that concern the Nordic energy markets.

Sweden's energy policies prioritize technology-neutral measures and market mechanisms to reduce emissions in a cost-effective manner. As a pioneer in environmental policy, Sweden introduced a CO_2 tax on fossil fuels as early as 1991, making it one of the first countries to do so. Carbon taxation has proven to be an effective means of driving decarbonization, and Sweden's example demonstrates that it is possible to combine high environmental taxes with sustained economic growth. The implementation of carbon taxation in Sweden has been a significant step towards decarbonization, and a model for other countries to follow.

[189] Sources: Energimarknadsinspektionen. Ren energi inom EU Ett genomförande av fem rättsakter (in Swedish). Available: www.ei.se

[190] Sources: Energy in Sweden 2022 With energy balance for year 1970-2020 (ET 2023-01)

[191] NordREG (nordicenergyregulators.org)

10.1.2 Outlook of the hydrogen industry

- Sweden needs to continue putting in a lot of effort if it is to maintain its the lead position in the sustainable transition.
- Green hydrogen production can be profitable due to Sweden's electricity prices, particularly in the northern region.
- The Swedish Government has proposed that there should not be a requirement for directly connected renewable electricity production to hydrogen production facilities, all carbon-free electricity should be able to be used.
- In 2017, Sweden's Parliament, announced a climate policy framework with a climate act for Sweden.
- The Swedish Energy Agency has been assigned to coordinate hydrogen-related initiatives, identify, and address any barriers, and integrate hydrogen into the energy system in compliance with EU directives.

In March 2023, the Swedish Government tasked the Swedish Energy Agency to lead the coordination of hydrogen initiatives in Sweden. The agency's role is to identify and address barriers to the integration of hydrogen into the energy system, in accordance with EU directives. The guiding principles outlined in the agency's previous report, Proposal for Sweden's National Strategy for Hydrogen, Electro Fuels, and Ammonia[192], will serve as the basis for the assignment. **The Swedes view hydrogen as one of the key technologies required to achieve climate neutrality.** Though, the government does not believe that renewable electricity production should be directly connected to hydrogen production facilities but rather recommends that all carbon-free electricity from the grid be utilized. The Commission should concentrate on sectors where cheaper alternatives are lacking and the unique properties of hydrogen are beneficial, such as emission-free steel production, which could benefit from industrial clusters around electrification and hydrogen[193].

Hydrogen can serve as a raw material, fuel, or energy carrier with potential applications in the industrial, transport, and energy sectors. While Sweden has largely decarbonized its electricity and heat supply, the main challenge is to reduce emissions in the transport sector. In 2017, Sweden's Parliament passed a climate policy framework with a climate act, an important milestone in the country's history. This framework implements the Paris Agreement in Sweden. The framework contains, three parts[194]:

1. **Ambitious climate goals**
   - By 2045, Sweden's target is to achieve net-zero greenhouse gas emissions.
   - By 2030, emissions from domestic transport will be reduced by at least 70 percent compared to 2010.

   These goals also reflect Sweden's aim to show international climate leadership, and to show that Sweden undertakes to achieve emission reductions that far exceed the requirements under the EU Effort Sharing Regulation.

2. **A Climate act**
   - Government's climate policy must be based on the climate goals, and it is required to present a climate report every year in its budget bill.
   - Every fourth year, the government is required to draw up a climate policy action plan to describe how the climate goals are to be achieved.

[192] https://www.bing.com/search?q=ER 2021%3A34 – Förslag till Sveriges nationella strategi för vätgas ...&form=IPRV10
[193] https://www.regeringen.se/faktapromemoria/2020/08/201920fpm61/
[194] Sweden's climate policy framework - Government.se

- Climate policy goals and budget policy goals must work together.

3. **A Climate policy**
   - This refers to an independent and interdisciplinary body that monitors the alignment of the government's overall policy with the climate goals established by the Parliament and the government. It also evaluates whether the relevant policy areas contribute to or hinder the potential to achieve these climate goals.

The Swedish Climate Policy Council is an independent and interdisciplinary expert body responsible for assessing the degree to which the government's policies are consistent with the objective of achieving no net greenhouse gas emissions by 2045.

Making significant progress in the climate transition presents various challenges that can lead to conflicts and synergies with other goals or interests, which may become more evident and complex. To illustrate this, the Climate Policy Council conducted a detailed analysis of the large-scale industrial organisations involved in the climate transition in Upper Norrland, revealing that expansive changes require a societal transformation and pose several challenges. These challenges include the inadequacy of established planning processes and forms of cooperation to manage the pace of the industry's transition, which applies to different political levels, stakeholders, and actors on various levels (national, regional, and local) [195]. The challenges relating to working methods and processes encompass, but are not limited to, permitting processes of various types.

Green hydrogen is expected to play a crucial role in Sweden's future energy supply, facilitating the decarbonization of heavy industries and transportation. In 2021, Sweden's greenhouse gas emissions totalled 47,9 million tonnes, with a national goal of achieving net-zero emissions by 2045. Figure 21 highlights the current emissions breakdown, with industry and transportation being the primary sources. To achieve this ambitious target, hydrogen and biogas are expected to be instrumental, particularly in northern Sweden where demand for hydrogen is high due to the iron and steel production industry.[196] The Swedish steel industry is assumed to switch away from coal to hydrogen and electricity, following a PtX pathway, highlighting the efficient use of electricity.

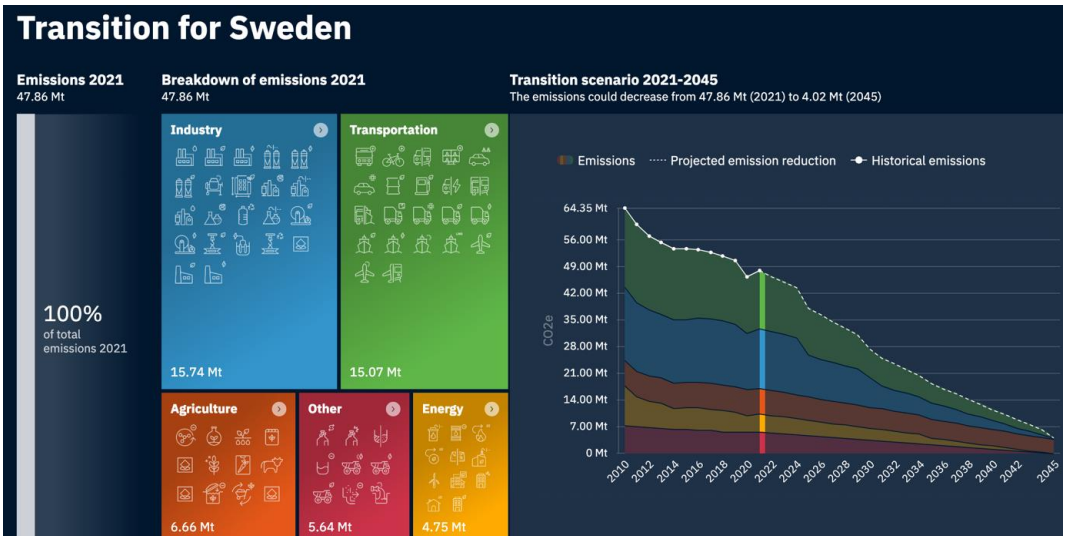


Figure 21 Panorama - an interactive and web-based tool illustrating paths for Swedish transition[197]

[195] https://www.klimatpolitiskaradet.se/en/report-2023/
[196] https://energiforsk.se/program/vatgasens-roll-i-energi-och-klimatomstallningen/rapporter/the-role-of-gas-and-gas-infrastructure-in-swedish-decarbonisation-pathways-2021-788/
[197] https://www.klimatpolitiskaradet.se/en/panorama-2/ (Direct link to the map - https://app.climateview.global/public/board/48023530-bb99-4a82-a00e-c9e7aad71f5d)

The government-initiated platform, **Fossilfritt Sverige** (Fossil free Sweden), **has created a hydrogen strategy that focuses on new industrial initiatives to foster innovations, create jobs, and develop export products.** The strategy has been developed by actors across the hydrogen value chain, including large companies such as **Adesso Bio Products AB, Alfa Laval, Fortum Sverige, LKAB, Scania CV AB, Siemens Energy AB, SSAB, St1 Sverige AB, Uniper Sverige, Vattenfall,** and **Volvo Group Truck Technology.** According to the strategy, today's hydrogen projects could reduce direct emissions by 7,1 million tonnes of carbon dioxide annually by 2045, equivalent to 14 percent of Sweden's national emissions. When including the emission reductions from the customers using the products, the total emission reductions will amount to over 30 percent, with additional reductions from customers in other countries.[198] Figure 22 provides an overview of the main hydrogen players in Sweden, along with their potential for emission reductions.

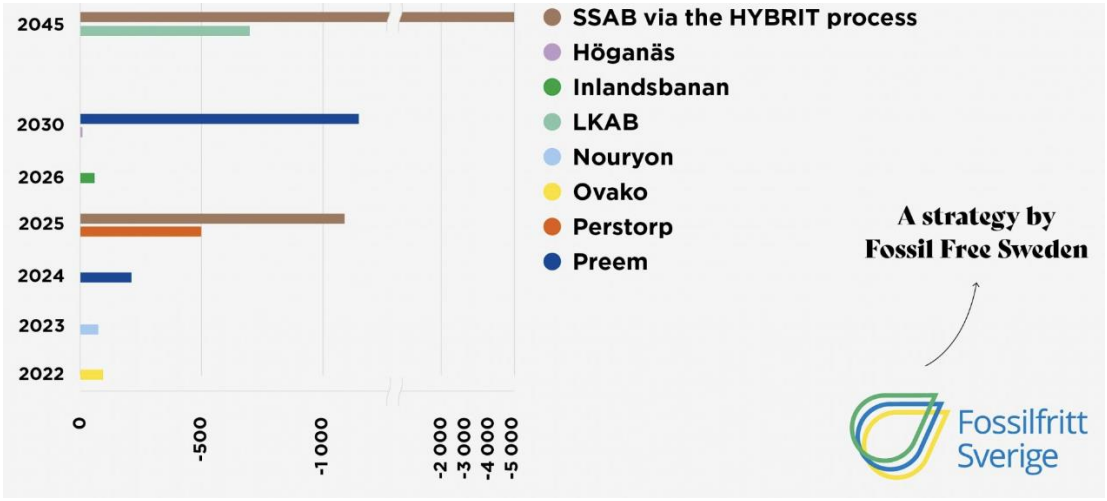


Figure 22 Potential direct emission reduction from announced hydrogen projects in kton CO_2/year[199]

SSAB

SSAB is a leading Nordic steel company with a focus on high-strength and sustainable steel products, operating in over 50 countries. SSAB's products are used in a variety of applications, including automotive, construction, mining, and energy. The company has been actively involved in developing sustainable steel production technologies, such as the **HYBRIT (Hydrogen Breakthrough Ironmaking Technology)** initiative, which aims to replace fossil fuels with hydrogen in the steelmaking process.[200].

Höganäs

Höganäs specializes in the production of metal powders and powder metallurgy solutions. The company is a world-leading supplier of iron and metal powders used in a wide range of industries, including automotive, aerospace, electronics, and healthcare. Höganäs has a joint venture together with SSAB and LKAB which aims to replace coking coal with hydrogen in the iron and steelmaking process. As part of this initiative, Höganäs has been exploring the use of hydrogen as a reducing agent in iron ore processing, which could significantly reduce GHG emissions.

Inlandsbanan

Inlandsbanan is the state-owned railway line in Sweden that runs from Gällivare to Mora investigating the potential for hydrogen both as a fuel and for distribution. These experiments have already been demonstrated by Alstom and passenger train Coradia iLint on the Inlandsbanan.

[198] https://fossilfrittsverige.se/wp-content/uploads/2021/01/Hydrogen_strategy_for-_fossil_free_competitiveness_ENG.pdf
[199] https://fossilfrittsverige.se/en/start-english/strategies/hydrogen/
[200] WP3-report-Energy-efficiency-and-conservation-1.pdf (nordicenergy.org)

LKAB

LKAB (Luossavaara-Kiirunavaara AB) is a Swedish mining company specializing in the production of high-grade iron ore products. The company is one of the world's largest suppliers of iron ore pellets with customers in over 50 countries. LKAB is actively participating in the HYBRIT project, with the aim to use hydrogen instead of coal in the iron ore reduction process. The company is currently working on a project to produce sponge iron using hydrogen gas, which would reduce emissions from customers outside Sweden by 30 million tonnes[201].

Nouryon

Nouryon is a chemicals company that produces a wide range of products used in personal care, agriculture, energy, and more. The company is currently exploring opportunities for green hydrogen in electro fuels, together with RISE, forestry group Södra and packaging materials company BillerudKorsnäs.

Ovako

Ovako is a manufacturer of high-quality engineering steel. The company specializes in the production of clean steel, which is made using recycled scrap and electric arc furnace technology, resulting in reduced carbon footprint. The company, in partnership with Volvo Group, Hitachi Energy, H2 Green Steel, Nel Hydrogen, and Vattenfall, is working on developing a fossil-free hydrogen value chain to produce steel. The project aims to build a fossil-free hydrogen plant in northern Sweden for steelmaking process and cell-powered heavy-duty vehicles.

Perstorp

Perstorp is a specialty chemicals company that produces a wide range of chemicals used in various industries such as coatings, adhesives, plastics, and agriculture. The company is part of the "Project Air" initiative, which aims to develop sustainable processes for producing methanol using carbon capture and utilization (CCU) technology. Perstorp is working with energy companies Fortum and Uniper on this project.

Preem

Preem is the largest fuel company in Sweden, refining and selling gasoline, diesel, heating oil and renewable fuels. In collaboration with Vattenfall, the companies are investigating the large-scale production of fossil-free hydrogen in Lysekilv to be used in large scale refineries in the production of biofuels. Preem is also working with St1 to increase biofuel production using fossil-free hydrogen.

Sweden is a key player in the emerging hydrogen market, with several major industrial projects across the country, covering all parts of the value chain, from production to storage to end-use. Table 20 highlights some of the largest and most significant projects currently underway.

[201] https://fossilfrittsverige.se/en/start-english/strategies/hydrogen/

Table 20 Major hydrogen projects in Sweden

Project (company) name	Location	Owners / Stakeholders	End-use	Production start-up	Value chain
HYBRIT Sweden	Lulelå, Gällivare	SSAB, LKAB Vattenfall	Fossil-free steel	2026	End-use
H2Green Steel ("H2GS")	Boden	Altor, AMF, BILSTEIN GROUP, EIT InnoEnergy, Exor, FAM, GIC, HITACHI, IMAS Foundation, Kingspan, KINNEVIK, KOBELCO, MARCEGAGLIA, BMW, SCANIA, SCHAEFFLER, SMSgroup, Swedbank, VARGAS HOLDING	Green steel production	2025	End-use
Baltic Sea Hydrogen Collector (BHC)	Baltic Sea, Sweden, Finland, Germany	Gasgrid Finland, Nordion Energi, OX2, Copenhagen Infrastructure Partners	Sea and land transport	2030	Transportation
HyTrucks	Gothenburg	Scania, Volvo	Fuel cell trucks	2025	Transportation
Hydrogen Hub Karlstad	Karlstadt	Everfuel, Karlstad Energi	Green hydrogen	1st phase: 20MW by 2025 2nd phase: 120MW	Production
Lysekil refinery	Gothenburg and Lysekil	Vattenfall, Preem	e-fuels	2030	Production, tansformation
BotnialänkenH2	Luleå	Uniper, ABB, Port of Luleå	Green hydrogen & storage	--	Production, Storaging

The majority of the 31 announced projects are concentrated in the electricity areas of SE3 and SE4, located in the southern region of Sweden. A comprehensive overview of the distribution of these projects is provided in Figure 23. For companies interested in exploring the opportunities presented by the Swedish hydrogen market, we highly recommend consulting the constantly updated list of hydrogen projects on the Swedish Energy magazine 'Tidningen Energi' website. This will provide valuable insights into the goals and partners of these projects, enabling companies to make informed decisions about how best to enter and succeed in this dynamic and rapidly evolving market. The interactive map is available at: Här är alla svenska vätgasprojekt (energi.se)

Below, on Figure 23, the geolocations of the announced hydrogen projects can be seen. As shown on the map, the projects are more focused on Southern Sweden.

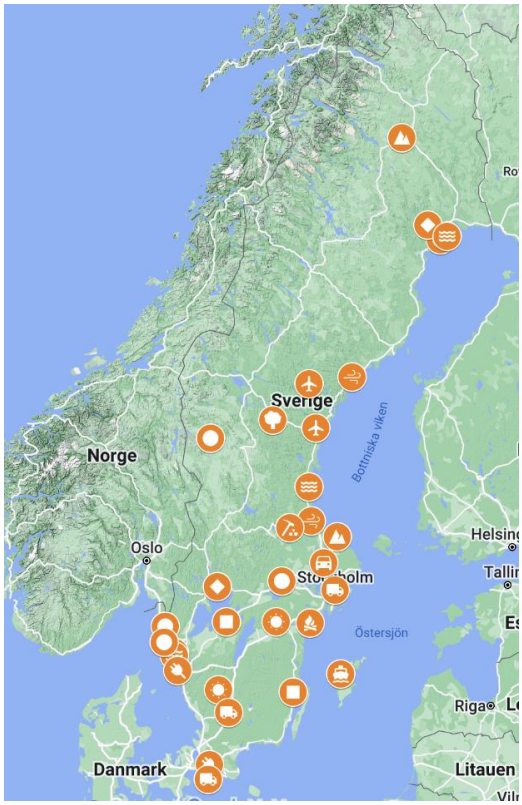


Figure 23 Swedish Hydrogen projects[202]

10.1.3 Production Methods

- The chemical and refinery industry in Sweden is responsible for most of the hydrogen production.
- Almost all hydrogen produced is consumed near the production site.
- Only a very small fraction, around 1 percent, is used directly, primarily as vehicle fuel or in metallurgical industries.

Sweden, along with other Nordic countries, is well-positioned to meet a significant portion of Europe's domestic green hydrogen production target, with over 100 GW of offshore wind in early phase development. While Sweden has made significant progress in its sustainable transition, more action is needed to maintain its leading position. Integration between production systems and energy generation is necessary, and flexible energy transmission and storage capabilities will be critical.

The production and use of hydrogen in Sweden, illustrated in Figure 24 and Figure 25 below, **amounts to nearly 6 TWh/year and 180 000 tonnes of hydrogen per year.**

[202] https://www.energi.se/artiklar/2022/november-2022/har-ar-alla-svenska-vatgasprojekt/

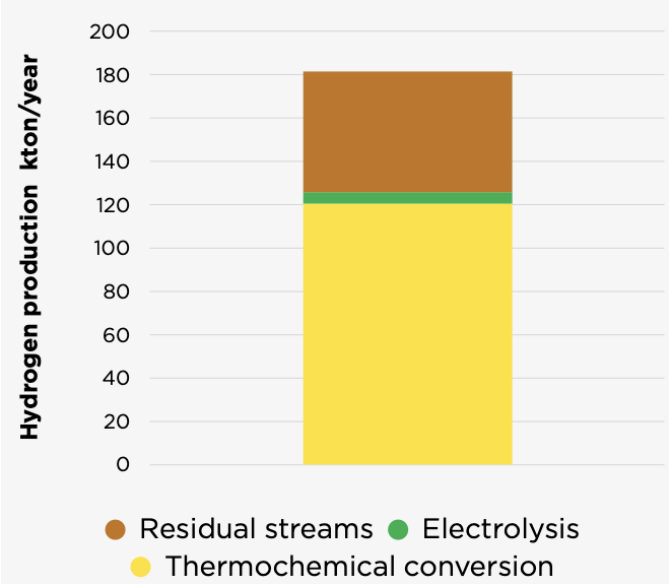


Figure 24 Total produced hydrogen used in Sweden today and the distribution of different production technologies[203]

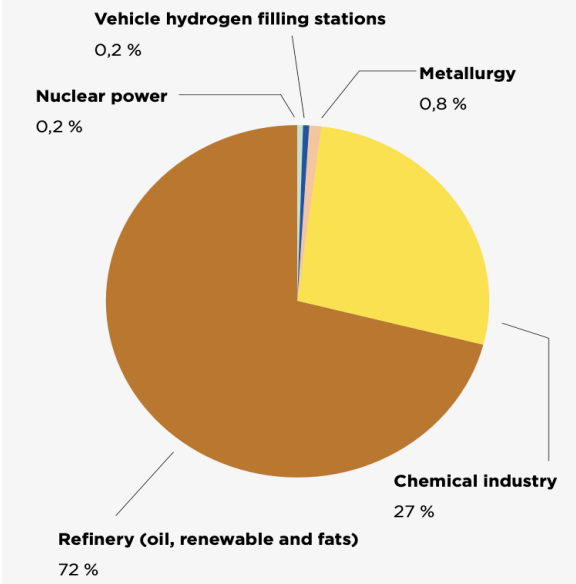


Figure 25 Use and production of hydrogen in Sweden

From 2020, leading hydrogen company in Sweden was **Preemraff**. **Preemraffs** annual hydrogen production capacity amounted some about 65 000 metric tons (Lysekil production plant) and additional 15 000 metric tons in Gothenburg and Göteborg Plant. The production volume of hydrogen by company (in metric tons) is illustrated below.

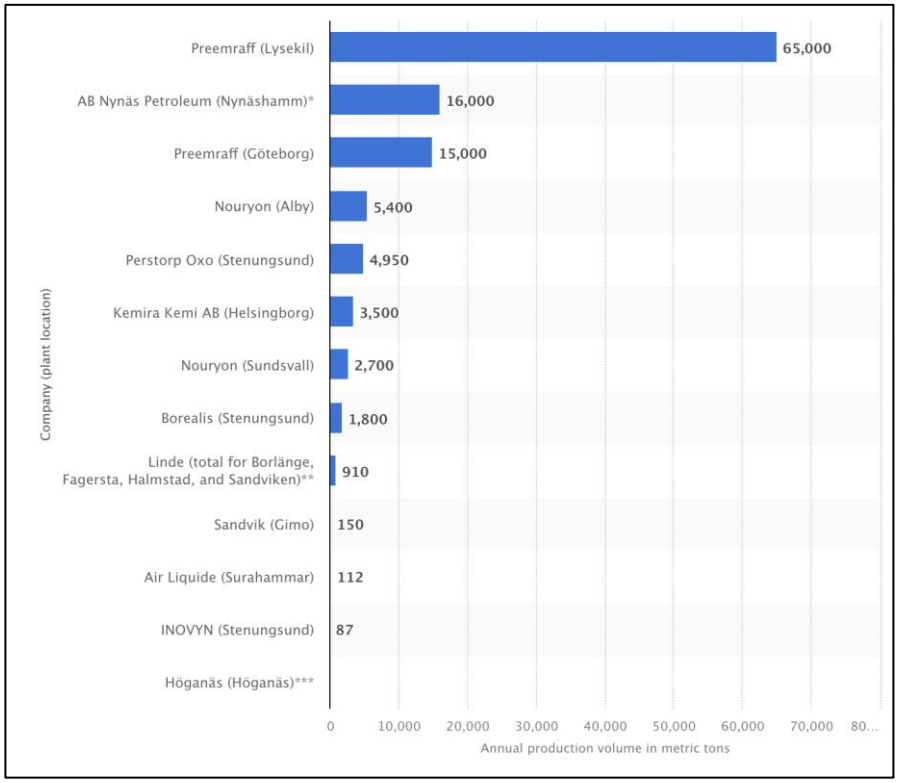


Figure 26 Swedish hydrogen production volume by company in 2020 (in metric tons)[204]

[203] 2023 Fossilfree Sweden Hydrogen strategy
[204] Sweden: hydrogen production by company | Statista

However, the majority of this hydrogen is currently produced from fossil fuels, with 67 percent of the hydrogen produced using thermochemical conversion of natural gas[203]. This method is known as steam methane reforming (SMR) and involves reacting natural gas with steam to produce hydrogen gas and carbon dioxide as a by-product. The carbon dioxide is usually captured and stored to reduce greenhouse gas emissions. The remaining hydrogen production in Sweden comes from industrial residual streams, which are waste or by-products from various industrial processes. These industrial residual streams can include sources such as biogas from the wastewater treatment process or syngas from the production of iron and steel. The use of industrial residual streams for hydrogen production is a way to reduce waste and increase the efficiency of industrial processes. **Only a small percentage (less than 3 percent) of the hydrogen produced in Sweden comes from electrolysis**[203].

There is, however, **a significant potential for the production and use of hydrogen in countries surrounding the Baltic Sea**, as well as for developing offshore wind and hydrogen production. The Baltic Sea region has excellent conditions for producing onshore and offshore wind energy. With strategic investments in infrastructure, renewable energy, and hydrogen production, up to 55% of the clean hydrogen target defined in the REPowerEU Plan can be produced in the region, simultaneously supporting innovative decarbonization projects within each country and helping the EU to meet its overall goals. The Marienborg Declaration recognized the potential for offshore wind in the Baltic Sea region to reach at least 19,6 GW by 2030, with the potential for up to 93 GW of offshore wind power in the Baltic Sea.

To reach its goal of becoming carbon neutral by 2045, Sweden is working to increase the use of renewable energy sources for hydrogen production, including electrolysis. This could help to reduce the country's reliance on fossil fuels and promote the use of cleaner hydrogen production methods.

10.1.4 Trade

The fossil free strategy highlights hydrogen as an important tool for achieving the climate goals but also as a focus for new industrial initiatives to create innovations, jobs, and export products.

Sweden has **ambitious plans to become a leading player in the global hydrogen market**, driven by its strong industrial demand for hydrogen. While the country's focus is on refining and strengthening their own industrial products domestically to create jobs and promote innovations within the country[205], there are also opportunities to develop the export of its industrial products such as hydrogen-powered industrial turbines, aircraft engines, heavy vehicles (**Volvo Truck**), fossil-free iron, steel, and methanol[206]. As Sweden's industrial sector has a significant appetite for hydrogen, which is expected to drive demand for the foreseeable future, **the country aims to ensure the security of its hydrogen supply with limited plans for hydrogen exportation at present.** This focus on meeting its own hydrogen demand may limit opportunities for hydrogen exportation but also ensures Sweden's continued leadership in the global hydrogen economy[207].

Sweden's hydrogen trade scenarios are looking promising as the demand for hydrogen is increasing in Northern Sweden. With the increase in demand, hydrogen supply capacity is forecasted to rise to 9,7GW_{H2} by 2045, which is equivalent to 13GW electricity. This supply capacity is mainly from electrolyser capacity, with minimal additional SMR capacity. By 2025 to 2030, green hydrogen becomes cost competitive. **About 40% of all new electrolyser capacity will be installed in SE2**, which serves as a hydrogen production hub for demand in SE1 in the north and SE3 in the south. SE2 has a surplus of electricity supply capacity, some of which is used to produce hydrogen. While SE1 and

[205] https://fossilfrittsverige.se/wp-content/uploads/2021/01/Hydrogen_strategy_for-_fossil_free_competitiveness_ENG.pdf
[206] https://www.diva-portal.org/smash/get/diva2:1571446/FULLTEXT01.pdf
[207] https://www.both2nia.com/en/news/hydrogen-changes-sweden

SE3 have the most hydrogen demand, SE4 also has a portion of demand, which is initially supplied via domestic hydrogen from electrolysers. However, the availability of low-cost green hydrogen from the future European hydrogen network triggers the development of an interconnection from Denmark, leading to hydrogen imports partially supplying hydrogen demand in SE4.[208]

10.1.5 Infrastructure

- Sweden, unlike other European countries, lacks natural gas networks that can be converted to pure hydrogen networks.
- Natural gas infrastructure is very limited in place, only some in the south of Sweden, with the possibility to transform them into hydrogen pipelines.
- Nordion Energi is participating together with over 20 other gas infrastructure companies with European Hydrogen Backbone project.
- The transition offers opportunities for businesses to invest in and develop necessary infrastructure and technologies for green hydrogen production.

1. Hydrogen Clusters

Sweden's strategic location in Northern Europe provides vast potential for the development of hydrogen infrastructure, spanning over 450 000 square kilometres and bordered by Finland to the east and Norway to the west. Its extensive coastline stretches over 3 200 kilometres on the east, and the Baltic Sea lies to its west. Cross-sectoral local and regional hydrogen clusters can be established in areas where existing industries use or will use hydrogen, as well as near ports and railways, to maximize this potential and pave the way towards the creation of a "Hydrogen Valley". In Sweden, **cluster development for hydrogen is already under discussion in various places**, including on the west coast from Gothenburg via Stenungssund to Lysekil and in Gävleborg and Dalarna. Based on the various initiatives and larger projects that are now underway in Sweden, it is also reasonable to expect future cluster development in Norrbotten and Skåne. There are also other examples of regions in Sweden where hydrogen development through local and regional clusters is now being discussed[209].

As hydrogen is expected to play an increasingly critical role in Sweden's transition to sustainable industries and transportation, the country needs to create an entirely new infrastructure to facilitate the integration of hydrogen into its economy. This could represent one of the most significant infrastructure investments Sweden has ever made. According to the Pathway Study, Sweden's electricity demand will nearly double by 2045, rising from 130 TWh at present to 241-253 TWh per year. To meet this demand, approximately 50-65 TWh will be required to produce enough hydrogen, which can only be achieved with the establishment of a robust hydrogen infrastructure[210]. The development of hydrogen infrastructure through industrial clusters in Sweden can be complemented in some parts of the country through ongoing initiatives such as Inlandsbanan, which can constitute freight corridors for the transport of hydrogen over long distances.

[208] https://energiforsk.se/media/29966/the-role-of-gas-and-gas-infrastructure-in-swedish-decarbonisation-pathways-energiforskrapport-2021-788.pdf
[209] https://fossilfrittsverige.se/en/start-english/strategies/hydrogen/
[210] https://www.nordionenergi.se/download/18.3e831922180945f84b3790cb/1652870899021/Nordion_Energi_sustainability-report_2021_EN.pdf

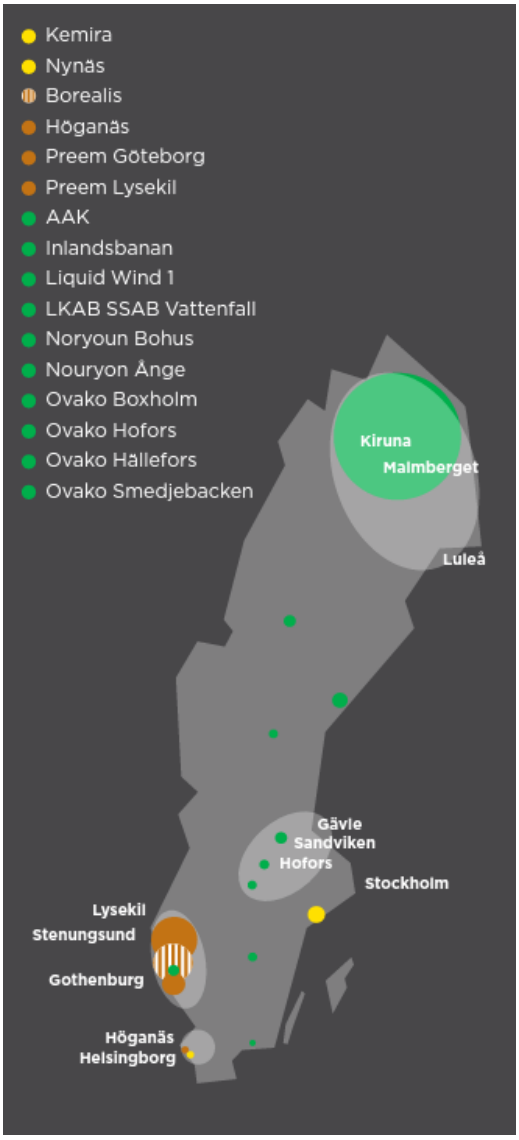


Figure 27 Examples of potential hydrogen clusters in Sweden[205]

2. Bothnian Bay

Sweden's hydrogen plans are already taking shape across the country, from Trelleborg in the south to the **HYBRIT project** at Malmberget in the north. Several large-scale initiatives are currently being implemented, while others are in the planning stage. As part of these plans, the Swedish and Finnish TSOs are collaborating **to build a 1 000 km hydrogen pipeline in the Bothnian Bay region by 2030.** The **Gasgrid Finland's** and **Swedegas'** joint venture will oversee the pipeline's construction, which will be about 350 km long onshore. In addition to this pipeline, Gasgrid Finland and Swedish energy supplier **Nordion Energi** are also working together to establish a hydrogen route connection between the two countries, exploring opportunities for cooperation in hydrogen infrastructure and market development in the Bothnian Bay regions.

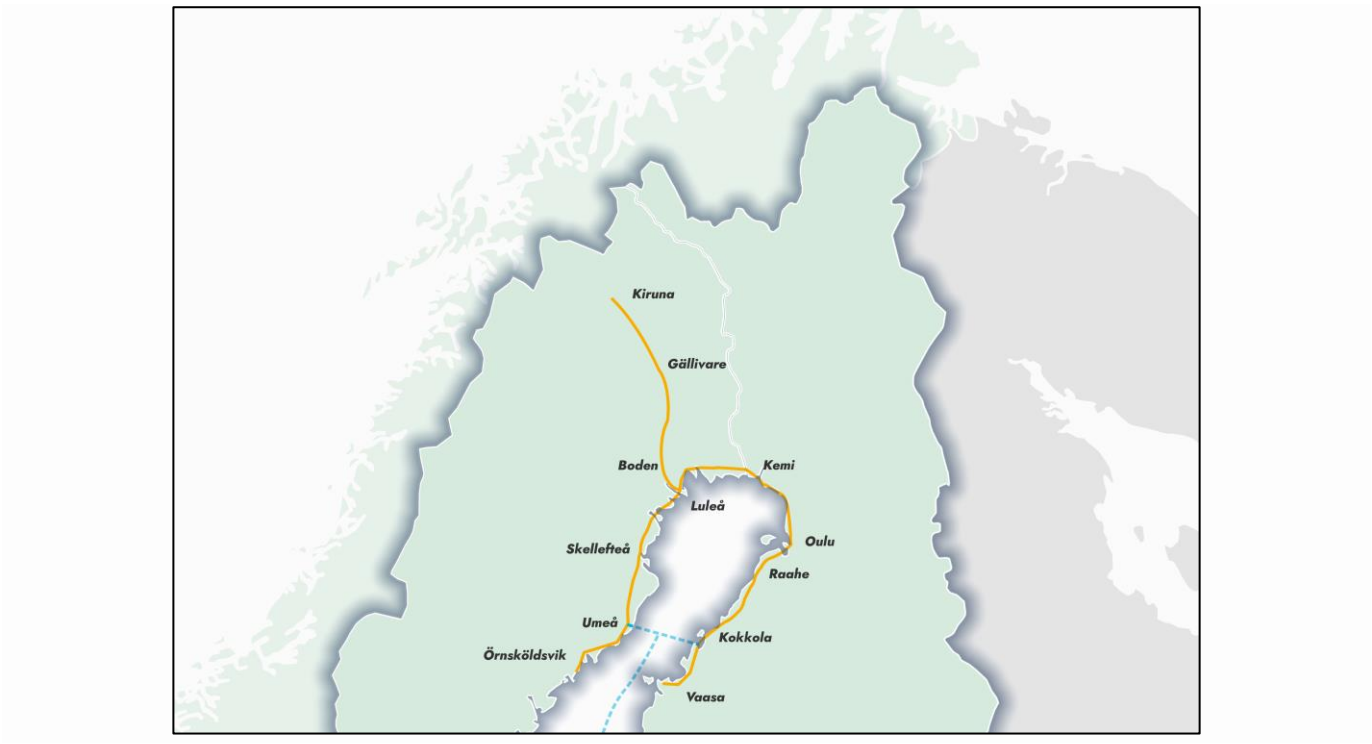


Figure 28 Bothnian Bay[211]

3. Southern Sweden

Building and maintaining infrastructure is a capital-intensive and long-term business, requiring significant investment. In Sweden, **Nordion Energi**, a leading energy and infrastructure company, operates and invests to meet the high demands of the country's infrastructure. However, unlike many other countries, **Sweden does not have a natural gas network that can be converted to a pure hydrogen network.** Instead, the plan is to gradually convert the natural gas grid on the west coast into a pure biogas network.

Currently, the operational infrastructure for hydrogen is limited in Sweden. Some local grids supply hydrogen, mostly in and around Göteborg, serving the petrochemical and refinery industries such as:

- Stenungsund cluster
- Höganäs industries
- Sandvik Materials
- Kemira in Helsingborg

However, these operations represent only a small fraction of the potential hydrogen demand in the country. Thus, a significant expansion of the hydrogen infrastructure is needed to support the growth of hydrogen usage in Sweden, requiring substantial investment and cooperation among various actors in the industry.

Nordion Energi consist of **Swedegas** and **Weum** that build an infrastructure and climate-neutral distribution of gas. For the industry and with flexibility and storage capacities in combination of sustainable energy and transport system the role of gas can be changed. The group also included **Falbygdens Energi**, see yellow lines in Figure 29 below.

211 https://www.epressi.com/tiedotteet/energia/gasgrid-finland-and-nordion-energi-launch-the-nordic-hydrogen-route-the-first-large-scale-cross-border-hydrogen-network-in-europe.html

Figure 29 Nordion Energi and infrastructure for distribution of gas[212]

Note: Nordion Energi was formed in 2020 by merging the operations of Swedegas AB and Weum Gas AB. Swedegas is a TSO (Transmission System Operator) for the southwest Swedish gas grid and sells transmission, storage and system balancing services. The gas grid transports energy to distributors and directly connected customers. Weum operates Sweden's largest gas distribution network, which is connected to the gas grid. Falbygdens Energi was acquired in January 2021, with electricity network operations in Falköping and the surrounding area.[213]

10.2 Market characteristics

10.2.1 Networks

- This section provides a list of some of hydrogen-related forums, clusters, and organisations in Sweden.

The Swedish landscape of networks is rich and well-established throughout the entire value chain. There are several clusters and programs facilitating networking, knowledge transfer, and initiation of new projects and cross-sectoral partnerships to promote the development and use of hydrogen technology. These organisations typically consist of a diverse group of stakeholders, including government agencies, private companies, research institutions, and universities. Funding and programs are further discussed later in chapter 10.3.2.1.

[212] NORDIONENERGI-ENGLISH - NORDIONENERGI
[213] https://www.nordionenergi.se/download/18.3e831922180945f84b3790cb/1652870899021/Nordion_Energi_sustainability-report_2021_EN.pdf

CLUSTERS & ORGANISATIONS

1. Fossil Free Sweden

The national initiative to make Sweden the first fossil-free welfare nation in the world was launched by the Swedish Government in 2015, as part of efforts to accelerate the transition to a more sustainable future. The initiative, called Fossil Free Sweden, is led by an office headed by a national coordinator. Its goal is to build a strong industrial sector and create more jobs and export opportunities by transitioning away from fossil fuels. Members include companies, industries, municipalities, and regions, all working together towards this goal. As part of the initiative, 22 different industries have developed their own roadmaps outlining how they plan to become competitive while transitioning to a fossil-free or climate-neutral economy. These roadmaps have been presented to the Swedish Government and form the basis of ongoing work by Fossil Free Sweden and the industries involved. In 2021, a follow-up report was published to track progress and implementation, which included a total of 54 policy proposals for the transition, as well as four strategies.

- Strategies for a sustainable battery value chain
- Hydrogen strategy
- Bio-strategy
- Finance strategy

Fossil Free Sweden's website can be found from the link below:
https://fossilfrittsverige.se/en/start-english/

2. Both$_2$nia

Both$_2$nia is a cross-border network of different actors in the field of hydrogen and fuel cells, that aims to promote the deployment of this technology in the Bothnia region of Finland and Sweden. The network is also presented in chapter 7.2.1.

3. RISE

RISE is Sweden's research institute and innovation partner. In international cooperation with companies, academia, and the public sector, they contribute to a competitive business life and a sustainable society. The Swedish Hydrogen Development Center, SHDC, at RISE is a test bed project started in 2018 funded by **Vinnova**. RISE conducts research and development in the field of hydrogen production, storage, and use. They work on developing new materials and technologies for hydrogen storage and transport, as well as on improving the efficiency of hydrogen production methods. RISE's hydrogen development center can be further examined at:
https://www.ri.se/en/what-we-do/projects/swedish-hydrogen-development-center

4. Business Sweden

Jointly owned by the Swedish state and the Swedish business sector, Business Sweden was set up to bridge Swedish companies to be globally with sales and international businesses. Several reports and knowledge sharing are available via their website. Founded on 1 January 2013 through a merger of the Swedish Trade Council (Exportrådet) and Invest Sweden. Business Sweden can be contacted trough their website:
https://www.business-sweden.com/

5. Energiforsk

Energiforsk initiates, coordinates, conducts research and analysis in the field of energy, and disseminates knowledge to contribute to a robust and sustainable energy system. Energiforsk is politically neutral and strives for objectivity. They are a non-profit limited liability company owned by the industry organisation Energiföretagen Sverige and Energigas Sverige, the state-owned enterprise Svenska kraftnät, and the gas and energy company Nordion

Energi. Their investment in hydrogen is a broad research programme which includes a neutral dialogue platform between industry, academia, and politics – a place where different sectors can gather to conduct unbiased research and discuss hydrogen and electrofuels. Energiforsk's website is: https://energiforsk.se/

6. Centre for Hydrogen Energy Systems Sweden - CH2ESS

Is a research and knowledge initiative at Luleå University of Technology with a focus on hydrogen use in industrial processes and energy systems, in close collaboration with Swedish industry. Also, they develop research and training so that they match the needs for hydrogen competence. MOCC – Hydrogen for sustainable solutions is an on-line education and course which is free to use. To sign-up follow below link. MOOC Hydrogen for sustainable solutions: What is hydrogen and why is it important? - Luleå University of Technology (ltu.se).

CH2ESS' website is linked below:

https://www.ltu.se/centres/CH2ESS?l=en

7. Climate Smart Process Industry (Climate-leading process industry)

In this project the aim is to develop a climate-leading and competitive process industry within the Green chemistry in order to also meet the increased sustainability and environmental requirements in the competition and requirements that also require efficiency and more flexible processes. It is a 10-year initiative that started 2018 with the coordination from Johanneberg Science Park AB situated in Göteborg, at the west coast of Sweden. Funding is from Vinnova.

https://www.vinnova.se/en/p/climate-smart-process-industry/

8. Stenungsund Cluster

Stenungsund is a municipality located on the west coast of Sweden. The Stenungsund area is interesting from an industrial symbiosis point of view due to the energy, feedstock, and knowledge exchanges among the five large chemical companies, the local utility companies, and the municipality. Key Actors and main resource exchanges are:

- **Borealis**: In Stenungsund Borealis have four plants, one cracker plant where ethylene is produced and three polyethylene plants. Some of the ethylene produced is sold to the other chemical industries. Borealis also produce the by-product fuel gas which provides the other industries with fuel. Waste heat from Borealis is send to the local district heating network which provides the municipality of Stenungsund with heat.
- **INEOS ChlorVinyls Sweden**: In Stenungsund PVC, lye and hydrochloride acid is being produced. INEOS also produce hydrogen, and the excess is sold to Borealis.
- **Akzo Nobel**: Akzo Nobel is the world's largest paint company and in Stenungsund the company manufacturs amines and surface substances.
- **Perstorp**: Perstorp in Stenungsund produces specialty chemicals that can be used in for example specialty glass and water-based colors. This facility also hosts Scandinavia's largest plant for production of the biofuel rape seed methyl ester (RME), a type of bio diesel used as fuel for vehicles. Perstorp also delivers their waste heat to the district heating network, providing the municipality with heat.
- AGA Gas: This facility produces oxygen, carbon dioxide, argon, and nitrogen gas from ambient air. The gases are used in the food industry, metal works and others.

https://www.greenclustercy.org/stenungsund-industrial-symbiosis.html

9. Höganäs industries

Höganäs is the world leader on the market for iron and metal powders with a yearly capacity of 500 000 tons. Together with customers, they develop solutions for automotive components, brazing, electrical motors, and additive manufacturing. The company was founded in 1797 and is owned by **Lindéngruppen** and Wallenberg owned **FAM**. They can be contacted via: https://www.hoganas.com/en/search/?q=hydrogen

10. Sandvik Materials
Sandvik is a global, high-tech engineering group providing solutions that enhance productivity, profitability and sustainability for the manufacturing, mining, and infrastructure industries. Their products and services enhance productivity, profitability, and sustainability in, for example, the manufacturing, mining and infrastructure industries.
https://www.home.sandvik/en/

11. Kemira in Helsingborg
Kemira is a global leader in sustainable chemical solutions for water intensive industries. We provide best suited products and expertise to improve our customers' product quality, process, and resource efficiency. Our focus is on pulp & paper, water treatment and energy industry.
https://www.kemira.com/

10.2.2 Events

The sections above outline different projects (chapter 10.1.2), cluster and organisations (6.2.1chapter 10.2.1) within Sweden with links to access the most up-to-date information on hydrogen related events. In addition, **to keep track and be updated on the Swedish events please contact the Embassy of the Netherlands for an updated list.** There are also many smaller events that happen in Sweden and to keep track on those, contact sto-ea@minbuza.nl.

10.2.3 SWOT Analysis

Table 21 SWOT Analysis, Sweden[214]

STRENGTHS	WEAKNESSES
• Industry clusters, small and large companies, financing R&D. • Strong innovation environment and established partnership (industry, academia**,** and the institute sector). • Neutral dialog forum between industry, research**,** and policy. • Relatively stable electricity grid. • Development of fossil-free steel, sustainable chemicals such as methanol, hydrogen powered gas turbines/hydrogen powered heavy vehicles and aircraft engines, system components for electrolysers and fuel cells and complete fuel cell systems. • Low costs for renewable electricity production, green hydrogen compete with natural gas.	• Infrastructure, lack of expanded distribution network. • Permits, process for expansion of production and network lengthy and complicated. • Many hydrogen initiatives and clusters, lack of a "common" view. • Limited electricity capacity and power • Beside industry, experience of hydrogen production and use is unexperienced. • Hydrogen value chains are often local which is complicated due to storage capacity in hydropower and lack of distribution.
OPPORTUNITIES	**THREATS**
• Cost-effective for industries through sector coupling, local/ regional hydrogen clusters. • Ambitious plans to establish Hydrogen Valleys, cross-sectoral local/ regional clusters with major industries, infrastructure (ports, railways). • Potential to develop utilization at ports and for shipping. • Nordic Hydrogen Route – infrastructure/ pipe for fossil free industry. • Industry clusters, small and large companies, financing R&D. • Universities tight and linked to industry (Luleå, Göteborg). • Need for hydrogen storage and distribution to develop the hydrogen market. • Reduced costs in the future for electrolysers.	• Clear regulations and instruments are lacking. • Poor availability of both hydrogen storage and distribution for industrial and transport sector. • Permits, for new build and extension, both land and sea-based wind power too slow. • Investment costs (initially) are high. • Lack of common view on future hydrogen regulations and/ or guidance to major energy stakeholder for long-term planning. • Lack of educated and skilled personnel (academia, operation, maintenance). • Low technology maturity (such a processes). • Tariff development for power systems. • Security and safety for hydrogen can be a barrier when upscaling production. • For transport sector is a lack of connection between el/gas-grid, necessary with more co-planning.

10.3 Opportunities for Dutch businesses

10.3.1 Segments providing opportunities

- The demand in infrastructure, electrolyser components, and research knowledge provide opportunities for Dutch companies in the Swedish hydrogen economy.
- Dutch knowledge on gas and pipeline technology as well as new distribution alternatives can be beneficial for Sweden.
- Dutch electrolyser producers and electrolyser component manufacturers have opportunities in Sweden.
- Sweden aims to understand new market needs and extensive research knowledge in the Netherlands could help creating new business models for hydrogen.

[214] Hydrogen_strategy_for-_fossil_free_competitiveness_ENG.pdf (fossilfrittsverige.se)

Sweden has several strengths in the hydrogen industry that Dutch companies can benefit from. These **import opportunities include abundant renewable energy sources, strong government support with ambitious targets, advanced research and development, a strong automotive industry, and a well-established infrastructure with experience in fuel-cell production.** With its ambitious hydrogen strategy, Sweden provides great export potential and collaboration opportunities for Dutch companies, specifically in logistics and technological knowhow. Similarly, the increased use of electricity for electrolysers opens potential for increased investments in wind power, exports, and new jobs. Besides Sweden's own strengths, foreign investments are needed to create a fully operating hydrogen economy. The country provides great collaboration opportunities for Dutch companies specifically in infrastructure, electrolyser components, and research knowledge.

1. **Infrastructure**

While Sweden has significant strengths in the field of hydrogen technology, with existing studies on both regional and national levels, there is always a need for ongoing research and development to continue advancing the technology and creating synergies with the different sectors of the hydrogen value chain. There is a need for more research on the integration of hydrogen technologies into existing energy systems and infrastructure, as well as on the optimization of hydrogen production, storage, and transport. More specifically, Sweden can benefit from the Dutch knowledge on gas and pipeline technology knowledge. Sweden has a relatively limited network of gas pipelines, as the country has historically relied on other energy sources and currently has pipelines only in the South of Sweden. This could provide an opportunity for Dutch pipeline knowhow as the ongoing Swedish projects will need solutions for gas infrastructure. Notably, Dutch companies could provide new distribution options as larger volumes of hydrogen require cheaper alternatives in liquid form and develop the regional clusters of gas demand. Sweden's participation in the TEN-T network necessitates the development of significant refuelling station infrastructure. This presents an opportunity for Dutch companies with strengths in logistics, particularly in the northern part of Sweden.

2. **Electrolyser components**

Although there are currently no electrolyser production capabilities in Sweden, it is seen as the preferred method for hydrogen production due to its increased efficiency. Electrolyser production is expected to increase in the coming years as it can strengthen Sweden's security of supply as well as work as an enabler for the hydrogen economy. Thus, similarly to Denmark and Finland, Sweden is in dire need of electrolyser components. As the country is experiencing growing demand for hydrogen, electrolyser components and electrolysers itself are planned to be imported in the country. This provides opportunities for Dutch electrolyser producers and electrolyser component manufacturers.

3. **Research, development, and innovation**

Finally, Sweden could benefit from the Dutch research knowledge. The country is specifically aiming to understand new market needs and how to manage the existing hydrogen production methods. This could be in forms of bilateral collaboration, by creating new business models and exploring market needs. Collaboration and knowledge exchange could be highly beneficial in fuel cell development, leveraging Sweden's existing expertise in the field. The country has already conducted national and regional studies on hydrogen valleys, but there is a need for additional input from Dutch companies to further develop and optimize the technology. Collaborating with Swedish research institutes and universities could open new business models and provide insights into emerging market needs.

Sweden has established a Hydrogen Valley, a cluster of companies and research institutions along with universities that also collaborate on hydrogen technologies and the development of the hydrogen economy. For the Dutch

companies there are possibilities to create and build their knowledge of hydrogen technologies to the Hydrogen Valley and benefit from the already existing network and knowledge of the Swedish hydrogen industry.

10.3.2 Recommendations for market entry

- Recommended to contact local actors, the Dutch Embassy in Sweden, clusters, and organisations

To enter the hydrogen market in Sweden, it is crucial to conduct thorough market research and prioritize sustainability in the production and use of hydrogen. Partnering with stakeholders and building a strong supply chain will help navigate the complex regulatory environment and ensure a reliable and cost-effective supply chain. Staying up to date on regulations and investing in education and outreach initiatives will also help promote the adoption of hydrogen technologies. With Sweden's goal of becoming carbon neutral by 2045, the hydrogen market in Sweden presents exciting opportunities for companies to contribute to a sustainable future while achieving commercial success. In addition to these recommendations, there are other steps you can take to help you succeed in the hydrogen market in Sweden. It is essential to contact local actors, contact the Embassy to gain further knowledge on the political and economic situation and any potential legal or regulatory issues, and connecting with clusters and organisations.

Contact the local actors.
Sweden has a strong tradition of collaboration and equality in business, and companies should be prepared to work closely with partners and employees to achieve success. The egalitarian culture also makes the decision-making process more democratic, which is important to keep in mind.

Contact the Embassy.
The Dutch Embassy in Sweden can offer valuable support to Dutch companies looking to enter the Swedish hydrogen market. The Embassy can provide information on the Swedish market, including local business culture, regulations, and market opportunities as well as facilitate introductions to local business networks and hydrogen organisations. In addition, the Embassy hosts events and seminars on various topics related to doing business in Sweden, such as market entry, regulations, and investment opportunities. For further information, please contact sto-ea@minbuza.nl.

Contact the clusters and organisations.
Sweden has a well-established policy on ETRDI (Energy technology research, development, and innovation) and a long history of international collaboration in this field. Given the relatively close correlation between the net spending on energy RD&D and patent applications from 1995 to 2012, the stimulation of ETRDI is considered to have had a positive impact in the recent past. In addition, the significant level of private sector co-funding is an accomplishment.

The Swedish Energy Markets Inspectorate (Ei)[215] is an authority which is commissioned to strive for well-functioning energy markets those including, for example, working actively in a consultative role with legislation work at EU level. But also, for international work also receiving foreign guests and providing information about the Swedish electricity and gas markets, as well as explaining the duties of the Agency.

[215] Ei in English - Energimarknadsinspektionen

10.3.2.1 Available Incentives and Subsidies

Sweden offers a number of incentives and subsidies that make it an attractive landscape for hydrogen development. With a strong history of industrial development projects for new value chains to include research partners and several Swedish universities and research institutes. There are several Swedish initiatives funded, such as **Swedish Hydrogen development Centre** (test bed project), the initiative **Climate Smart Process industry**[216] with support from different research funding agencies and the Swedish Energy Agency. The vision of this (Climate Smart Process Industry) 10-year initiative is that aid in the transition from a fossil-dependent industrial region to a region where the industry is a world leader in the production of chemicals, materials and fuels based on renewable and recycled raw materials.

In March 2017, the parliament adopted the ERIP (Energy Research and Innovation Programme), formed around five major challenges. ERIP is by far the main source of public funding for ETRDI. Compared to other IEA countries, Sweden is close to the median when it comes to public spending on energy research and innovation per GDP. The IEA commends the Swedish ETRDI policy, as it contributes to the country's overarching climate and energy targets and creates economic opportunities and export potential.

The Swedish Energy Agency's ERIP (Energy Research, Innovation, and Policy) program plays a crucial role in providing substantial public funding for Energy Technology Research, Development, and Innovation (ETRDI). In 2017, the program had a budget of approximately EUR 129 million (SEK 1.48 billion), which is expected to gradually increase to around EUR 139 million (SEK 1.6 billion) by 2020. Remarkably, the funding allocated by the SEA ERIP is comparable to the level of co-funding contributed by the private sector for this program. Within the allocated funds, energy efficiency received the largest share at 45% in 2017, followed by renewable energy at 16% and cross-cutting technologies at 12%. It is important to note that the distribution of funds across different areas of energy Research, Development, and Demonstration (RD&D) can vary from year to year, reflecting the evolving priorities and dynamics of the energy sector. This sustained commitment by the Swedish Energy Agency through the ERIP program signifies a significant investment in advancing ETRDI, fostering innovation, and driving the energy transition towards a more sustainable future.[217]

Funding for cross-cutting research, however, has increased in recent years, as integration between sectors is becoming more important. A case in point is smart grid research, which often integrates electricity, heat, transport, and industry sectors.[217]

Additionally, there is funding for organisations with concepts for avoiding energy-related emissions to aid in the goals set in Sweden's policies. Since the Paris agreement was signed in 2015, several Swedish policy measures which enable start-ups to create new clean energy technology market. The approaches from the government, today, deviates from former and traditional funding models as there are new and specific barriers needed to be tackled[218].

1. **The Swedish Energy Agency**

With an overall responsibility for the energy transition in Sweden, the Swedish Energy Agency is equipped with a range of tools. It's support for research and innovation helps to achieve both the energy and climate policy goals of the national energy agreement and the economic, environmental and research policy goals. It is also a prerequisite for building knowledge and competence and for developing new solutions to reach the system changes that can

[216] https://klimatledande.johannebergsciencepark.com/sv
[217] IEA, IEA Energy Technology RD&D 2018 (database), www.iea.org/statistics/. And Energy Policies of IEA Countries - Sweden 2019 Review
[218]https://iea.blob.core.windows.net/assets/c0efd465-a914-4fe6-b3cf-cbbf96a9d8c6/Howgovernmentssupportcleanenergystart-ups.pdf

accelerate the transition. The grants can also be designed to guide innovators' technologies to higher TRLs (maturity) with co-operation along with potential customers.

In 2018, the Swedish Government introduced **Industriklivet** a subsidy for research and innovation projects with potential to support challenges such as:

- Reducing greenhouse gas emissions from industrial processes, or
- Achieving permanent negative greenhouse gas emissions

The Swedish Energy Agency also provides subsidies for investments. In addition, the Swedish Energy Agency shall coordinate and plan the application process **of a second Important Project of Common European Interest (IPCEI)** to support research and innovation. The project is called IPCEI Hy2Use and it is further explained in chapter 5.5. The IPCEU will involve in total, 39 projects from 29 companies. Included from Sweden is HYBRIT and for selection for the second process [219], is Regional Hubs and their Links (RHATL). The assignment will continue until 2027 [220].

2. **Swedish Research Council**

The Swedish Research Council is Sweden's largest governmental research funding body and supports research of the highest quality within all scientific fields. They pay out almost EUR 709 million (SEK 8 billion) per year to support Swedish research and fund research infrastructure, both in Sweden and abroad. Research infrastructures are advanced tools that researchers may need to carry out their research. Examples include databases, research facilities, biobanks, and large-scale computational tools.

3. **Vinnova Swedish Innovation Agency**

Vinnova is Sweden's innovation agency. Vinnova provides funding for research and innovation projects, coordinates strategic initiatives, collaborates with actors across all sectors, and highlights inspiring solutions and ideas. They aim to promote sustainable growth by supporting innovative projects and solutions that address societal challenges and contribute to the development of new products, services, and processes. Vinnova also works to build a strong innovation ecosystem in Sweden by promoting collaboration between businesses, academia, and government agencies. They support projects at different stages of development, from early research to commercialization, and encourage the development of new technologies and business models that can help to drive the transition towards a more sustainable society.

4. **Swedish Environmental Protection Agency (SEPA)**

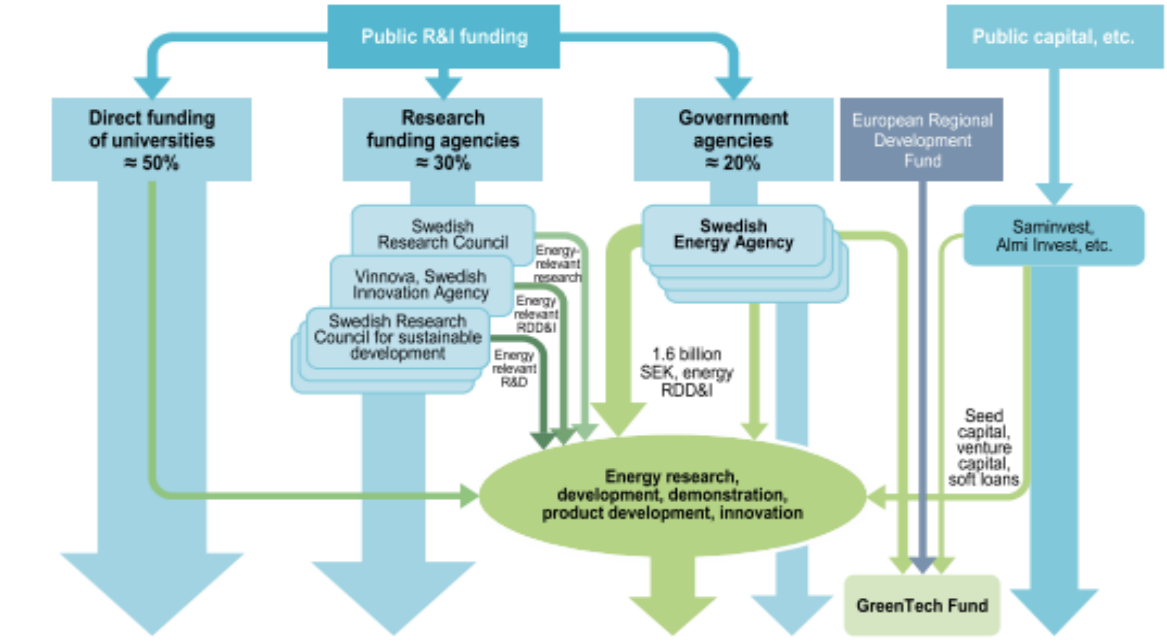
SEPA is the public agency in Sweden that is responsible for environmental issues. The Agency carries out assignments on behalf of the Swedish Government relating to the environment in Sweden, the EU and internationally. In 2015, the Swedish Government introduced Climate Leap (Klimatklivet), a subsidy programme to support local and regional infrastructure investments that reduce GHG emissions. The programme is administered by SEPA, which supports projects with the largest emissions reductions per invested SEK. The programme is thus intended to be technology neutral. On average, climate Leap provides 44% of the project cost.

[219] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5676
[220] https://www.energimyndigheten.se/49fd4c/globalassets/forskning--innovation/omraden-for-forskning-affarsutveckling-och-kommersialisering/internationella-forskningsinsatser/uppdragstext---n2020_03065-original-dnr-2020-025560.pdf

5. FFI, Strategic Vehicle Research and Innovation

FFI is a collaboration between the state (Vinnova, the Swedish Transport Administration and the Swedish Energy Agency) and the automotive industry (Scania CV AB, AB Volvo, Volvo Car Group and FKG - Fordonskomponentgruppen). Cooperation is important. By FFI has knowledge built up at industry, universities, university colleges and research institutes, and solutions developed within the collaboration have been implemented and accepted by both users and society.

In addition to these mechanisms there are university fundings, European Regional Development Fund, Public Capital and investments in Sweden. In Figure 30below are different Research and Funding initiatives presented both on a national and European level.



Note: RDD&I = research, development, demonstration and innovation.
Source: IEA, based on information from the Swedish Ministry of the Environment and Energy.

Figure 30 Public R&I funding in Sweden[221]

[221] IEA, based information from the Swedish Ministry of the Environment and Energy

11 Results & Conclusions

11.1 Discussion

This chapter presents a comprehensive overview of the findings and conclusions derived from the market study. The research drew upon a wide range of sources, including publicly available information, databases, articles, studies, and reports spanning the period from 2020 to 2023. Additionally, interviews were conducted with industry professionals involved in the hydrogen economy across the Nordic countries and the Netherlands.

The analysis presented in this report highlights the tremendous investment potential within the green hydrogen sector in the Nordic countries. The transition towards a hydrogen-based economy, coupled with the projected surplus production of hydrogen in the region, creates a remarkable opportunity for collaboration between the Netherlands and the Nordics. Moreover, the Nordic countries have demonstrated a clear willingness to cooperate with Dutch companies in advancing the necessary infrastructure and technologies for green hydrogen production. Notably, Finland has taken a pioneering stance by aiming to achieve carbon neutrality by 2035, positioning it as a frontrunner in the pursuit of a sustainable future with the other Nordic countries following ambitious goals.

While the hydrogen economy is still in its nascent stages in all Nordic countries, there is a growing interest in green hydrogen and Sweden, Finland, Denmark, and Iceland have all set concrete goals for green hydrogen production. Furthermore, the Nordic countries offer a stable investment environment, characterized by abundant and affordable renewable energy resources that can be effectively harnessed for green hydrogen production. Although hydrogen pipelines are not presently available for transportation, several international pipeline projects are scheduled to commence operations by 2030.

Based on our comprehensive analysis of the green hydrogen industry in the Nordics, as well as the strengths possessed by Dutch enterprises in this domain, we strongly recommend that Dutch SMEs explore opportunities within the Nordic countries. The Nordics present a highly lucrative prospect for collaboration with Dutch companies, driven by increased investments in the region and the demand for infrastructure and technology development. Leveraging the strategic location of the Netherlands, its innovative technology and its robust hydrogen infrastructure, Dutch businesses possess a competitive edge to successfully partner with the Nordics. Engaging in collaborative ventures within the green hydrogen economy will enable Dutch companies to capitalize on growth opportunities while contributing to the carbon neutrality objectives of the Nordic region.

11.2 Research questions and answers

The following chapter summarises the key takeaways for the five research questions:

1. *What parts of the hydrogen value chain in the Nordics as a region and in Denmark, Finland, Iceland, Norway, and Sweden provide opportunities for Dutch companies and organisations?*

Most of the Nordic countries share similar characteristics in their hydrogen value chain development and possess **common strengths**, particularly in the **generation of renewable electricity for electrolysis processes.** However, one consistent challenge across the Nordic region is the shortage of skilled labour in the hydrogen industry. Moreover, certain parts of the hydrogen value chain in each country open areas where Dutch entities can contribute their expertise and technologies to foster collaboration and drive the region's energy transition. These key findings are summarized in Table 22.

In Denmark, collaboration is required to address the construction of new pipelines and repurposing of existing gas infrastructure. Additionally, there is a limited number of off takers for Danish green hydrogen within the country. When scaling up production, Danish companies are in need of making storage solutions and pipelines more efficient.

The Finnish value chain currently lacks large-scale electrolyser production capacity, a critical component for expanding hydrogen production. Furthermore, Finland requires additional expertise in hydrogen infrastructure and supply of hydrogen, specifically in storage solutions, efficiency, and pipelines. Despite the challenges, Finland's commitment to developing a hydrogen economy creates opportunities for Dutch companies proficient in hydrogen production, storage, and infrastructure to collaborate and contribute to Finland's energy transition.

In the **Norwegian value chain**, the transportation sector, particularly in maritime applications, presents notable opportunities. Dutch companies specializing in heavy-duty transportation possess relevant expertise that can be applied in Norway, where long distances are a factor. Considering Norway's strength in manufacturing electrolysers, exporting components for electrolysers also emerges as a viable opportunity for Dutch companies.

The Icelandic value chain offers Dutch companies' opportunities in infrastructure development, the maritime and aviation sectors, sustainable aviation fuels, research and development, as well as consultancy and advisory services. Expanding into these areas aligns with Iceland's hydrogen objectives.

The Swedish hydrogen value chain presents promising prospects for export and collaboration with Dutch companies. The demand for logistics, hydrogen infrastructure development in Sweden, electrolyser components, and research knowledge all create avenues for Dutch firms to participate in the Swedish hydrogen economy.

Table 22 Export potential for Dutch companies

Country	*Export potential for Dutch companies*
Denmark	Knowledge of hydrogen valleys, repurposing existing gas grid, building new gas pipelines, components for electrolysers, e-methanol / e-fuels, storage solutions.
Finland	Knowledge of hydrogen valleys, components for electrolysers, refuelling stations, pipeline technology, storage, knowledge sharing.
Norway	Heavy-duty transportation, components for electrolysers, maritime sector.
Iceland	Transportation, sustainable aviation fuels, maritime sector, hydrogen production.
Sweden	Logistics and technological know-how.

2. *How can Dutch technology and innovative solutions contribute to the transition towards hydrogen solutions in the Nordics?*

Denmark, a prominent player in offshore wind projects, can leverage the Netherlands' leadership in offshore wind production to bolster its own capacity. Dutch expertise in this field can assist Denmark in expanding its offshore wind infrastructure, which can then power electrolysis plants for green hydrogen production. Additionally, Danish companies require components for electrolysers, a demand that Dutch companies can fulfil. The Netherlands' knowledge of infrastructure and energy storage also presents significant possibilities for Dutch firms to contribute to Denmark's hydrogen solutions.

Similar to Denmark, **Finland** requires electrolyser components for scaling up hydrogen production. The Netherlands' expertise in hydrogen infrastructure can aid Finland in addressing emerging infrastructure challenges. Dutch expertise in offshore wind and port development creates collaboration opportunities along the hydrogen value chain.

Furthermore, Finnish SME projects in need of funding can benefit from collaboration with innovative Dutch companies. The Dutch knowledge of hydrogen hubs and valleys can also prove valuable in Finland's hydrogen development efforts.

In **Norway**, Dutch technologies and innovative solutions can play a pivotal role in the hydrogen transition by sharing their expertise in hydrogen infrastructure. The Netherlands is widely recognized as a leader in this field, making their knowledge highly valuable to support Norway's hydrogen ambitions.

Given **Iceland**'s remote location, the aviation sector holds significant importance, and the country aims to reduce emissions in this sector. Dutch technology and collaboration with Icelandic companies, particularly in manufacturing Sustainable Aviation Fuels, can contribute to Iceland's transition towards hydrogen solutions. The commitment of KLM Royal Dutch Airlines to reduce emissions by utilizing Sustainable Aviation Fuels aligns with this opportunity.

Sweden can benefit from Dutch expertise in gas and pipeline technology. Like Denmark and Finland, Sweden faces a pressing need for electrolyser components. Although there is currently no electrolyser production in Sweden, it is considered the preferred method for hydrogen production in the future.

3. What are the hydrogen export opportunities from the Nordics to the Netherlands?

It is highly probable that the **Nordic region will emerge as a net exporter of hydrogen and its derivatives in the future. The Netherlands,** on the other hand, is expected to produce only around 30% of the hydrogen it will consume, highlighting significant export opportunities from the Nordics to the Netherlands. The key findings are summarised in Table 23. **Denmark, Norway, and Finland** are all expected to create substantial excess green hydrogen due to their favourable geolocations and the capacity to produce large amounts of renewable energy. **Finland,** aiming to contribute approximately 10% of the EU's targets, and **Denmark,** with significantly higher production compared to its consumption, demonstrate the potential as key hydrogen exporters. Norway, with abundant renewable energy sources, existing infrastructure for natural gas transportation and storage, and close proximity to the Netherlands, also holds significant potential for hydrogen exports. While **Iceland** possesses abundant renewable energy sources, particularly hydro and geothermal power, which could enable hydrogen exports to the Netherlands, it remains uncertain whether Iceland will actively pursue this opportunity and commit to hydrogen exports. **Sweden** showcases potential for exporting fossil-free steel and provides opportunities for collaboration in understanding market needs and developing business models in the hydrogen industry.

Table 23 Export opportunities from Nordics to the Netherlands.

Country	*Export opportunities to the Netherlands*
Denmark	Green hydrogen products (especially PtX), skilled workforce, knowledge on hydrogen, electrolysers.
Finland	Green hydrogen products, skilled workforce, knowledge on hydrogen, knowledge on applying AI to industrial processes.
Norway	Electrolysers, green and blue hydrogen.
Iceland	Excess renewable energy that is produced and maybe green hydrogen in future.
Sweden	Knowledge on hydrogen, end-products from green hydrogen (i.e. fossil-free steel).

4. *Who are the main partners for global cooperation in the Nordics?*

In Denmark, it is worth noting that the majority of projects announced involve consortiums of well-established companies like **A.P. Moller Maersk**, **SAS**, and **CIP**. However, there is still ample opportunity for Dutch SMEs to collaborate with these large companies. The advantage of collaboration between two similar countries is recognized not only by industry stakeholders but also by the respective governments. It is expected that start-up companies will also enter the market through partnerships with universities and research institutes. To engage with Danish companies, it is advisable to join networks such as Hydrogen Denmark (Brintbranchen) or reach out to State of Green. Further details about these networks are provided in in chapter 6.2.1.

In Finland, while there are SMEs driving large-scale production projects, big companies are also actively involved in the hydrogen field. **Ren-Gas**, **P2X Solutions**, **Hycamite** and **Solar Food** are notable SMEs making significant contributions to hydrogen initiatives. Additionally, well-established companies such as **Neste**, **Wärtsilä**, **Fortum**, and **UPM-Kymmene** are also driving hydrogen innovations in Finland. Similar to Denmark, the most effective way to connect with companies in Finland is through clusters and networks, such as the Hydrogen Cluster Finland and BotH2nia, which are introduced in chapter 7.2.1. Notably, in 2023, a collaboration between Finnish **Convion Oy** and Dutch **Shell** was announced, highlighting the potential for collaboration between the two countries.[222]

In Norway, companies like **NEL Hydrogen** and **Hystar** are renowned for their expertise in electrolysers. There has been significant cooperation between these companies and other European partners in recent times. The **Norwegian Hydrogen Forum** serves as a prominent platform for hydrogen-related discussions in Norway and boasts over 70 members, including major companies such as **Equinor** and **Hyundai Motors**.

Presently, **Iceland** does not exhibit significant hydrogen activity; however, **Icelandic New Energy Ltd. (INE)** promotes the use of hydrogen fuel in the country. INE has established a vision for the role of hydrogen in Iceland's energy transition until 2030, with plans to incorporate new technological developments. This vision serves as a foundational document toward a comprehensive roadmap for hydrogen in Iceland until 2050. To gather more information about the hydrogen market in Iceland and establish a network, Dutch companies can connect with Icelandic New Energy.

In **Sweden**, noteworthy ongoing projects involve joint ventures between large industrial companies like **SSAB**, **LKAB**, and **Höganäs**. To establish contact with Swedish companies, Business Sweden and research initiatives such as the Centre for Hydrogen Energy Systems Sweden (CH2ESS) are valuable resources. For further information about relevant events, the Dutch Embassy in Sweden provides additional guidance.

Moreover, the Dutch Embassies in each of the Nordic countries offer valuable advice to Dutch companies on market entry strategies, facilitating their engagement with the local markets.

5. *Which challenges/risks are to be foreseen within the joint Nordics hydrogen market and the different countries?*

The development of the joint Nordic hydrogen market presents significant opportunities for investment and growth; however, it also entails various challenges and risks. While all Nordic countries, with the exception of Iceland, have formulated concrete hydrogen strategies, the regulatory and legal framework pertaining to hydrogen in these nations is still nascent. In contrast, the Netherlands has a strong and diverse industrial sector with identified importance of green hydrogen early on and has published a hydrogen strategy earlier than any of the Nordic countries, **giving**

[222] https://convion.fi/convion-and-shell-form-partnership-to-commercialise-solid-oxide-electrolysers-soec/#more-675

Dutch companies a head start in the industry. Although the Nordics have announced several projects for infrastructure development, there exists a risk that **the pace of hydrogen infrastructure development might lag behind**. Notably, delays in the permitting process for pipeline construction could potentially compromise the integrity of the Nordic hydrogen network and infrastructure, leading to a decrease in investment inflows. Moreover, certain European countries, such as the Netherlands, have already established robust footholds in the hydrogen industry, granting them a competitive advantage over their Nordic counterparts. Consequently, the Nordic region necessitates unequivocal regulations and laws to provide guidance for the development of crucial infrastructure components, including production facilities, storage systems, and transportation networks.

Furthermore, the presence of **inconsistent industry standards** within the Nordic countries can pose barriers to entry and impede the overall growth in the hydrogen market. Thus, it becomes crucial to prioritise the harmonisation of regulatory frameworks across the region to ensure a seamless and conducive operating environment.
The competitiveness of green hydrogen production is intricately linked to the pricing dynamics of fossil fuel-based alternatives. To foster the adoption of green hydrogen, it may be necessary to implement measures such as taxation to drive up the cost of fossil fuel-based alternatives, making green hydrogen more economically attractive. The development of a well-functioning supply chain for green hydrogen is also a critical factor, as companies may encounter challenges in bringing hydrogen-related products to market effectively.

Moreover, the realization of future investments in the green hydrogen sector may face significant obstacles if **fossil fuel-based alternatives remain considerably cheaper**. To ensure the long-term viability of the green hydrogen industry in the Nordics, a strategic approach supported by the government is necessary. This approach should include subsidies and pricing mechanisms that incentivise the adoption of green hydrogen, offsetting the cost disparity between green hydrogen and its fossil-based counterparts.

Lastly, it is crucial to acknowledge that the Nordic hydrogen industry faces competition not only from fossil-based alternatives but also from other low-carbon technologies such as battery storage and electric vehicles. The market dynamics of these alternative technologies pose additional challenges and considerations for the hydrogen industry to navigate successfully.

In summary, harmonizing regulatory frameworks, addressing pricing disparities, developing a robust supply chain, implementing strategic government support, and effectively competing with alternative low-carbon technologies are all crucial factors that need to be considered for the sustained growth and success of the Nordic hydrogen industry.

Table 24 Hydrogen in the Nordics summarised.

	Denmark	Finland	Norway	Iceland	Sweden
Roadmap & strategy	Strategy published in 2022 focusing strongly on Power-to-X production.	Hydrogen strategy part of Finland´s climate and energy strategy 2022. Roadmap in 2020. Hydrogen Cluster Finland creating an industrial strategy for hydrogen, expected to be publish in 2023. Resolution on hydrogen by the government published in 2023.	Strategy published in June 2021 focusing hydrogen roadmap for the country, setting short-, medium-, and long-term goals.	Hydrogen Strategy and Roadmap in the works.	Swedish Energy Agency's proposals for a national strategy for hydrogen and electrofuels[223]. Decarbonation Pathways Roadmap published in 2021 (energiforsk). Energigas Sverige, Svensk vindenergi, Fossilfritt Sverige
Value chain weakness	Infrastructure as refuelling stations and pipelines. Low off-take readiness and utilization. Skilled work force lacking. Equipment for electrolysers needed.	Infrastructure as refuelling stations, pipelines and storage. Research on technical safety items such as storage, leakages, pipelines. Electrolyser scaling. Skilled work force lacking.	Need of stepping up the infrastructural setup if it aims to be a net exporter, limited domestic demand.	Infrastructure, refuelling stations and pipelines. Low off-take readiness and utilization.	Infrastructure as refuelling stations, pipelines and storage, electrolyser scaling, limited domestic demand
Value chain strength	R&D & Innovation. Both: Hydrogen and energy production	Knowledge regarding industry transformation. Renewable energy production. Electricity grid.	Technology providers, renewable energy production, highly skilled workforce and expertise in the field of hydrogen, strong political commitment	Renewable energy production	Strong political commitment, strong industrial base, renewable energy sources
Regulation	Stable, long-term regulation. Newly established government willing to fulfil commitments made by the previous government. Regulation still	Stable, long-term regulation. Regulation still lacking for the industry really to flourish. Low possibility for negative impacts towards H_2.	The regulations in the hydrogen industry in Norway are still evolving. The production of hydrogen is regulated under the pollution	The regulations in the hydrogen industry in Iceland are still evolving.	The regulations in the hydrogen industry in Sweden are still evolving.

[223] Statens energimyndighet (2021), ER 2021:34, ISSN 1403-1892, pages 41.

	lacking for the industry really to flourish. Low possibility for negative impacts. Possibility to have straight connection between wind-mills and electrolysers without connecting wind-mills to the grid.		control act and the industrial emissions directive. The transportation of hydrogen in Norway is regulated under the road traffic act and the transport of dangerous goods act. There are certain tax incentives provided by the Norwegian Government for the use of hydrogen in certain applications such as transportation.		
Funding opportunities	Hydrogen tender currently ongoing, possibilities to get national funding as well as EU-wide funding. National funding pool relatively large. More information listed in chapter 6.3.2.1	Funding opportunities through different national instruments, Business Finland main national funder. A solar power funding program in 2023. More opportunities can be found in chapter 7.3.2.1	There are several opportunities for funding non-Norwegian companies as referred to in 9.3.2	No funding opportunities currently	There are several opportunities for funding as referred to in 10.3.2.1.
Alignment with the EUs goals	Carbon neutrality goals align with the EU's. Possibilities to produce up to 7GW of green hydrogen and its derivatives.	Possibilities to produce more than 10% of the EU´s goal of 10Mt by 2030. Carbon neutrality goal 2035 more ambitious than the EU's.	Support the installation of at least 6 GW of renewable hydrogen electrolysers in the EU, and production of up to 1 million tonnes of renewable hydrogen by 2024. Support the installation of at least 40 GW of renewable hydrogen electrolysers and production of up to 10 million tonnes of renewable hydrogen by 2030.	Plans to be carbon neutral by 2040, Hydrogen to play a key role.	Plans to be carbon neutral by 2045, Hydrogen to play a key role. The Swedish Energy Agency has proposed a total electrolyser capacity of 5 GW by 2030 and 15 GW by 2045

Focus	Purely on green hydrogen, focus on Power-to-X	Focus on producing green hydrogen.	Focus on producing green hydrogen	Focus on removing emissions in the transportation sector mainly shipping and aviation using green hydrogen	Focus on producing green hydrogen via electrolysis
Trade	Willingness to buy CO_2, aims to export hydrogen. Late-stage discussions with Germany to transport hydrogen / trade hydrogen to CO_2.	Industry believes the country can produce more than 10% of the hydrogen produced in Europe, hydrogen can be exported. Still discussions whether Finland wants to export pure hydrogen or something with more value added.	With the already existing natural gas pipelines, Norway aims to be a net exporter of green and blue hydrogen to other parts of Europe	Currently, no plans to export hydrogen	Aims to be a net exporter of green hydrogen in the future

12 Appendices

12.1 Appendix A – Interviewees

Country	Name	Position
Denmark	Kim Schultz	Special Advisor in Invest at Denmark under Danish Ministry of Foreign Affairs
	Maja Østergaard	Senior Project Manager at State of Green
	Eleonore Fenne	Chief of Press & Communication in Hydrogen Denmark
Finland	Markku Kivistö	Head of Industry, Cleantech at Business Finland
Iceland	Haraldur Hallgrimsson	Director of Business Development, Landsvirkjun
	Jón Björn Skúlason	General Manager, Icelandic New Energy Ltd
Netherlands	Han Feenstra	Program Manager Hydrogen of the Ministry of Economic Affairs and Climate Policy
	Jörg Gigler	Managing Director New Gas at Energy Innovation NL
	Jeroen van Gils	International Consultant Hydrogen & Sustainability at the Netherlands Energy Agency (RVO)
	Mark Schmets	Team lead chemical industry and innovation of the Ministry of Economic Affairs and Climate Policy
	Paul Vonk	Business Development Coordinator Germany & Nordics at the Netherlands Energy Agency (RVO)
Norway	Alexander Jongenburger	Business Development Manager, Equinor
	Tor Kristian Haldorsen	Lead Advisor Government Relations, Norwegian Hydrogen Forum
Sweden	John Sandstedt	Research and Development, Kista, at Research Institutes of Sweden
	Cecilia Wallmark	Director of hydrogen initiative, Luleå University of Technology
	Magnus Sjöö	CEO, PS Energi
	Bertil Wahlund	Programme director, Energiforsk
	Mox Murugan	Business Development Director, Hydrogen, Nordion Energi AB

12.2 Appendix B – Events & Conferences in the Nordics

Country	Event name	Date
Denmark	WindEurope	25.4.-27.4. (Annually)
	Made in Denmark	3.5.2023 (Annually)
	Hydrogen & P2X 2023	14.6.-15.6.2023 (Annually)
	ICHBET 2023: 17. International Conference on Hydrogen-Based Energy Technologies	10.7. – 11.7.2023
Finland	Energy Week	20.3.-24.3.2023 (Annually)
	SuomiAreena – Vetyaareena (Only in Finnish)	26.6.-29.6.2023
	Teknologia 23	7.11.-9.11.2023 (Annually)
	Slush	30.11.-1.12. (Annually)
Norway	Nor-Shipping	6.6.-9.6.2023
	The Hydrogen Conference 2023 – Norsk Hydrogenforum	1.6.2023
	Maritime Hybrid, Electric, and Hydrogen Fuel Cells Conference	17.10.-19.10.2023
	The Maritime Hydrogen Conference	1.11-2.11.2023
Sweden	Refer to contacts with the Dutch Embassy for event inquiries.	