The Nordic Hydrogen Industry Report

- What are the synergies and commitment of the Nordic hydrogen ecosystems for a joint trade and invest promotion?

Report financed by the Swedish Energy Agency, Innovation Norway, Business Finland
Conducted by Business Sweden during October 2022 to January 2023 | Delivered in February 2023

Swedish Energy Agency
BUSINESS FINLAND
Innovasjon Norge
BUSINESS SWEDEN

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    1. Nordic Market Overview
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        2. The Nordic Hydrogen Value Chain
        3. The Nordic Key Projects
    2. Nordic Potential and Need
    3. Potential key markets for the Nordics
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This report serves to map out synergies and complements of the Nordic hydrogen ecosystem and identify potential areas for Nordic collaboration

Background

- In the global context of the green transition, increased energy demand and geopolitics decisively impacting supply chains the demand for stable hydrogen business partners has increased immensely
- The Nordics offer preferable preconditions for the hydrogen industry offering green energy supply, underground storage opportunities, tradition of hydrogen and off-takers such as steel and maritime industry.
  - Investments in hydrogen are done within the Nordics on national, industry and R&D levels, where European and global partnerships are highly relevant and important to grasp business opportunities
- The industry study is initiated by the Finnish, Norwegian and Swedish TPOs and the Swedish Energy Agency
  - The Trade Promotion organisations Business Sweden, Business Finland and Innovation Norway are working to strengthen the economies of each individual country. Since 2021 the three organisations are jointly strengthening Nordic business on carefully selected key industries.
  - The Swedish Energy Agency is Sweden's largest public funder and facilitator of Swedish sustaintech companies. In November 2021 the Swedish Energy Agency presented a national strategy for fossil free hydrogen, electrofuels and ammonia.
- During September 2022 the four organisations agreed to evaluate a potential Nordic collaboration to support the active industry players within the Nordic hydrogen ecosystems

Objective of the report

- The objective of the report is to:
  - Map companies, organisations and institutions in the Nordic markets - Finland, Sweden, Norway, Denmark and Iceland
  - Evaluate synergies, complements and commitment of the Nordic hydrogen ecosystems
  - Conclude on recommendations to initiate collaboration and joint Trade & Invest promotion

Prerequisites of the report

- The report is based on
  - In-depth interviews with ~35 representatives from leading players within all parts of the value chain in Sweden, Finland and Norway – concluded December 2022
  - Market and desktop research for developments on global, European and Nordic markets until end of January 2023
  - Each initiating organisation’s insight into industry actors’ priorities and needs
- Audience and application
  - The report targets collaboration partners to the Nordic industry with limited or specialised knowledge of the hydrogen economy.
  - The report is to be used for discussions with and within the hydrogen ecosystem in the Nordics as well as serve as a foundation for further exploration of joint Nordic trade and invest promotion within select areas
- Limitations
  - The report objective does not include an in-depth analysis of feasibility of the hydrogen economy based on expected electricity supply in each market
  - The report objective does not include in depth analysis of size of potential for each country in terms of employment, turnover or trade nor analysis of the competence gap
  - The value chain used is derived from DNV’s Hydrogen Forecast to 2050. Given hydrogen’s versatility, its value chains can be analysed more detail depending on specific steps, such as conversion and use

The key questions evaluate the feasibility of a joint Nordic trade and invest promotion of hydrogen

Project key questions

1. **Synergies and complements within the Nordics for hydrogen enabled low carbon society**
   a. What is the market overview and outlook ahead in the Nordic countries?
      - What is the development of the sector?
      - What is stated by the industry to be its potential?
      - What are the preconditions to reach this potential?
      - What are the ecosystem needs per step of the value chain to realise its potential?

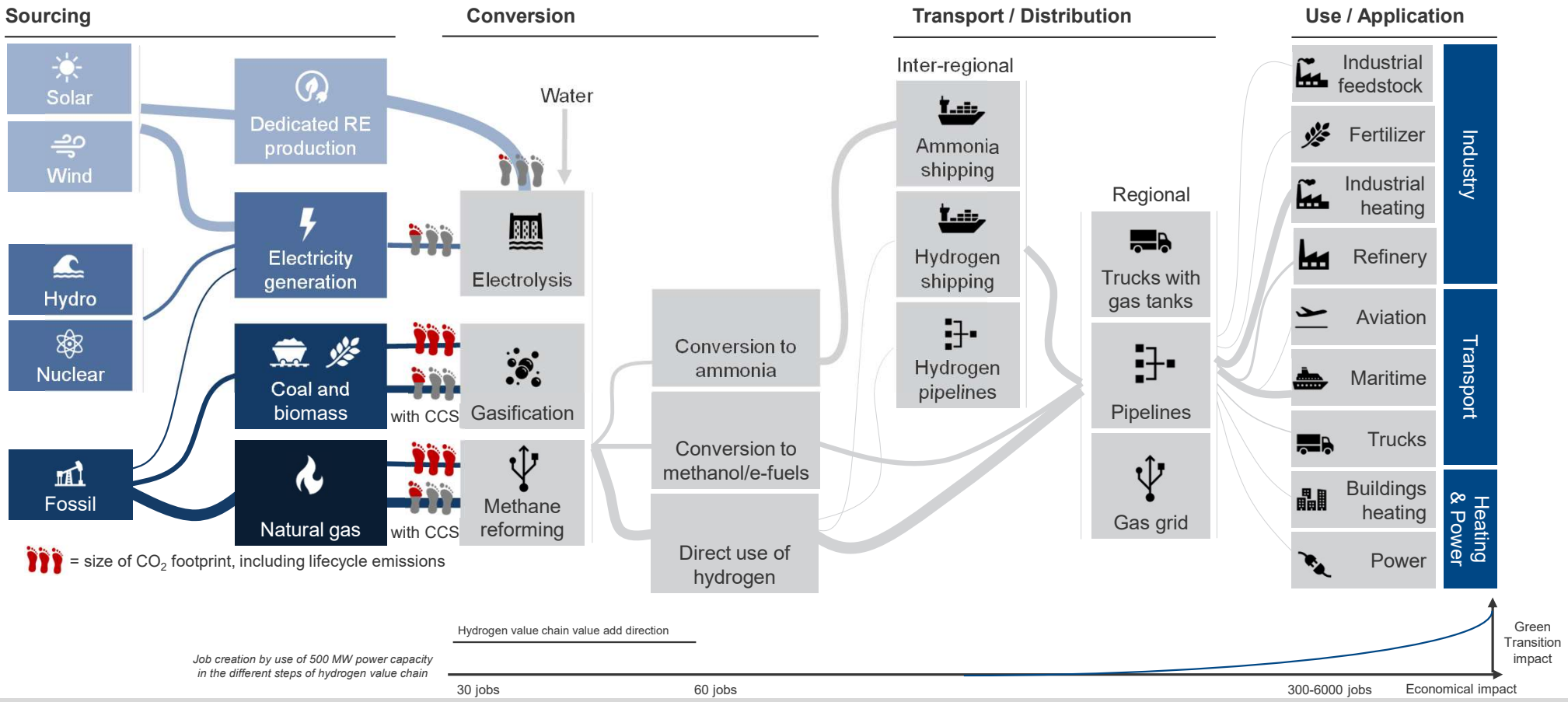
   b. What are the national ambitions and industry maturity per country?
   c. Who are key actors within each step of the value chain of the five countries?
   d. What are key national projects as well as Nordic cross –country collaboration?
2. **Synergies and complements for export market collaboration**
   a. What impact and potential is posed by the EU?
      - What is the market overview, outlook and drivers?
      - Which are the significant strategies for the European hydrogen industry?
      - What EU policy (directives and regulations) will impact the EU and Nordic markets?
      - What are key financing schemes and budget impacting Nordic business opportunities?
      - What are key infrastructure plans?

   b. Which are the key prioritized markets for export and innovation?
      - What are the focus markets key strengths and match with the Nordics?
3. **Synergies and complements for "invest in" for industry development**
   a. What type of investments are needed within the Nordics to strengthen development towards a "hydrogen enabled low carbon society"?
   b. Which are the prioritized country of origin of foreign direct investments globally for the Nordic countries?

4. **What are the potential and recommendation for a Nordic collaboration for trade and invest promotion?**
   a. What are the overall synergies and complements between the countries?
   b. What is the Nordic joint trade and invest offer?
   c. How strong is the ecosystem commitment towards a Nordic collaboration? What are potential actions on a strategic, tactical & operational level?

Note: All five Nordics countries will be covered in the report, however deep-dive is made for Finland, Norway and Sweden, while Denmark and Iceland is covered from less detailed

A schematic model of the Hydrogen Value Chain is applied for the analysis of the Nordics hydrogen ecosystem highlighting societal and economic value addition



The low carbon value chain is intertwined, spans over and makes use of major natural resources, and impacts all parts of industry, transport, power system and housing

Source: Hydrogen value chain DNV Hydrogen Forecast 2022 to 2050, Report analysis

Combined with secondary research, interviews with key stakeholders across the Nordics formed the conclusions and suggested next steps of this study

+35 interviewees from Sweden, Finland and Norway, and select Nordic/European actors

Select companies and organisations interviewed prefer to remain anonymous

- The interviews were conducted throughout November-December 2022
- The specific information from the individual interviews is confidential
- Business Sweden takes full responsibility for the compilation of the information from the interviews
- Although confidential, individual opinions are from the interviewees and not from Business Sweden
- Business Sweden, Business Finland, Innovation Norway, and the Swedish Energy Agency would like to express our gratitude to all interviewees for dialogue and support throughout the work with this report

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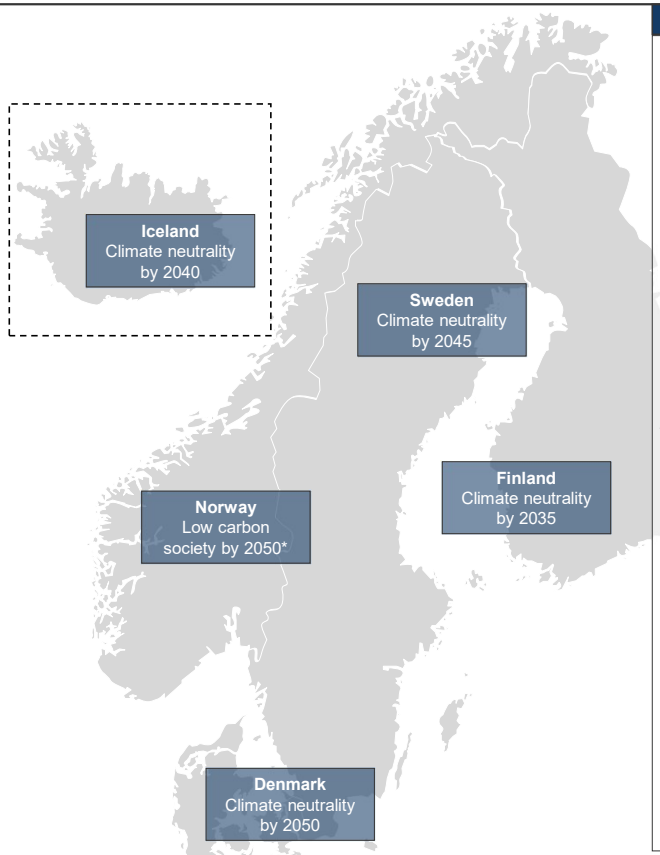
The story of the Nordics builds on leadership sustainability and complementary industrial and energy legacy

A joint point of departure

- The Nordic markets have a joint point of departure as global climate leaders
  - Hydrogen is identified to play a key roll in the Nordic markets green transition
  - The Nordics have access to fossil free cost efficient energy
  - Rank at the top of innovation and collaboration leaders in the world
- In parallel, the Nordics offer a complementary aspects such as
  - Access to natural resources such as natural gas, forest and farmland
  - Industrial legacy – all key industries in need of decarbonisation where clean hydrogen can be key
  - Gas legacy, such as pipeline infrastructure
- Together, the Nordics offer favourable preconditions throughout the value chain, from sourcing of green energy supply, conversion initiatives for clean hydrogen, and potential offtakers such as steel and maritime



The Nordic prerequisites					
Clean hydrogen identified to play key roll in the green transition	✓	✓	✓	✓	✓
Access to fossil free cost efficient energy	✓	✓	✓	✓	✓
Natural gas legacy	✓	✓		✓	
Natural resources	✓	✓	✓	✓	✓
Industrial heritage					
Steel industry	✓		✓		
Maritime	✓	✓		✓	✓
Refinery	✓	✓	✓		
Pulp and Paper	✓		✓		
Fertiliser		✓		✓	
EU member state	✓		✓	✓	✓
Atlantic / Baltic sea access	✓	✓	✓	✓	✓

The Nordic offer in hard-to-abate industries provides an opportunity for climate impact both in the extended home market, in Europe and globally

Source: Report analysis; EHB.eu; government.is; FN.no; Global Innovation Index 2022 * Climate emissions reduced by 90-95% compared to 1990

Key indicators show that hydrogen will play major role in green transition and has large business potential

Snapshot of the Nordic hydrogen economy indicators
Select key figures

Nordic electricity generation expected to increase steeply by

~45%

TWh or more by 2050*

- Access to **renewables is a key aspect to the increased rollout of green hydrogen**, which is favoured by all countries
- Increased investments **in wind power**, especially offshore, drive the increase
- **Fossil fuel expected to decrease** to ~5% by 2050

> *"We have the potential to be a global top 5 player in the hydrogen field"*
>
> [Finnish organisation]

Total estimated electrolysis

150

GW by 2030

- With a growing demand for green hydrogen, **continued rollout of electrolysers are necessary**
- **Electrolysers** could become **bottlenecks** for green hydrogen rollout, which puts the **Nordics** in a **favourable position as the region** holds **electrolyser manufacturers** including **sub suppliers**

Recovery & Resilience & REPowerEU earmarks

~14 BEUR

towards accelerating hydrogen

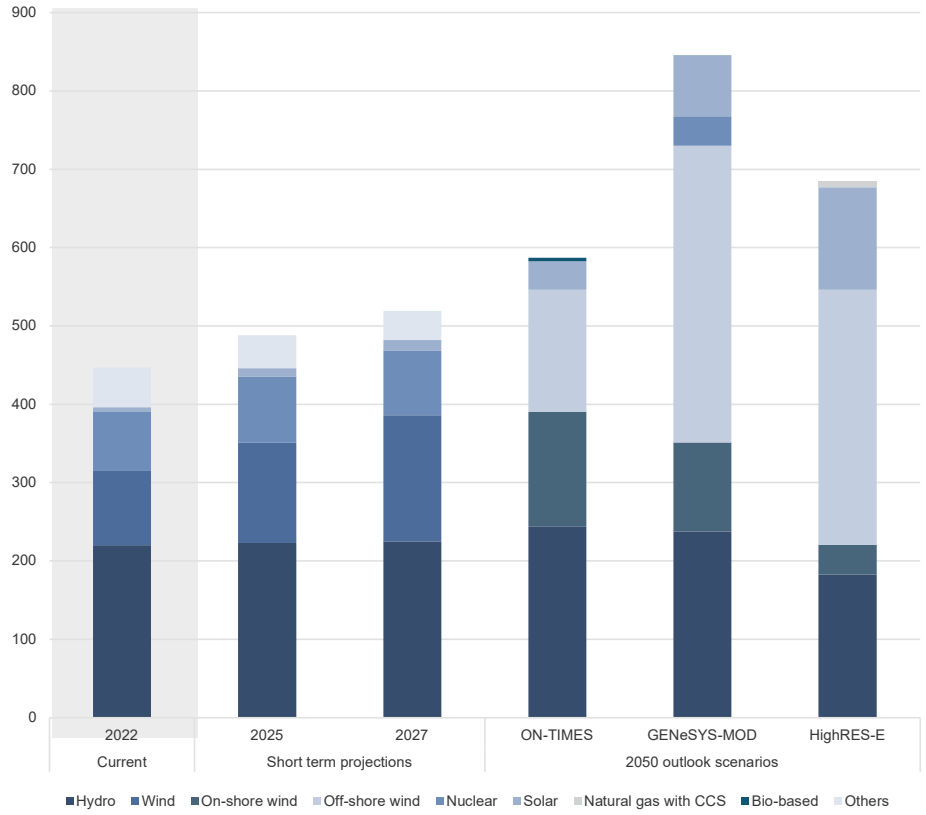
- The funds** support **development of hydrogen enabled project implementation in industry, transport and power system sectors** as well as **R&D&I and competence development** efforts and within the EU
- Funds support EU target of **20 Mt renewable hydrogen by 2030**, whereof 50% imported
- **Sizable investments in the Nordics' closest market** indicates the size of **market potential**
- **IPCEI projects** are included in the REPowerEU funds, which Finland, Sweden, Norway and Denmark have been rewarded and is **considered one key tool for scale by the industry**

The hydrogen economy has the potential to become a key enabler for growth and for climate impact in the Nordics and abroad

Source: Report analysis; McKinsey; Nordic Energy Research, Hydrogen Europe, SP Global; * Compared to 2020. Depends on different scenarios
** Comprises REPowerEU hydrogen funds and Recovery and Resilience funds per national strategies of EU member states.

The Nordic electricity mix will keep growing steadily, driven by on and offshore wind and nuclear capacities and catering towards electrification and Power-to-X

Electricity generation mix projections in the Nordics 2022 – 2050, by source and model (in TWh)



Electrification will be the short-term and Power-to-X long-term driver for scale-up of electricity generation in the Nordics

The Power generation across the Nordics is heterogenous but to largest extent Fossil free

- The overall volume of electricity produced in the Nordics is expected to **grow steadily in the coming 5 years**
- In 2050, the final volume of Nordic power generation will be largely **dependent on the level of deployed Power-to-X capacities**, as well as **source prioritisation**

The Nordic region as a whole is expected to focus primarily on implementing new offshore wind capacities in the long run

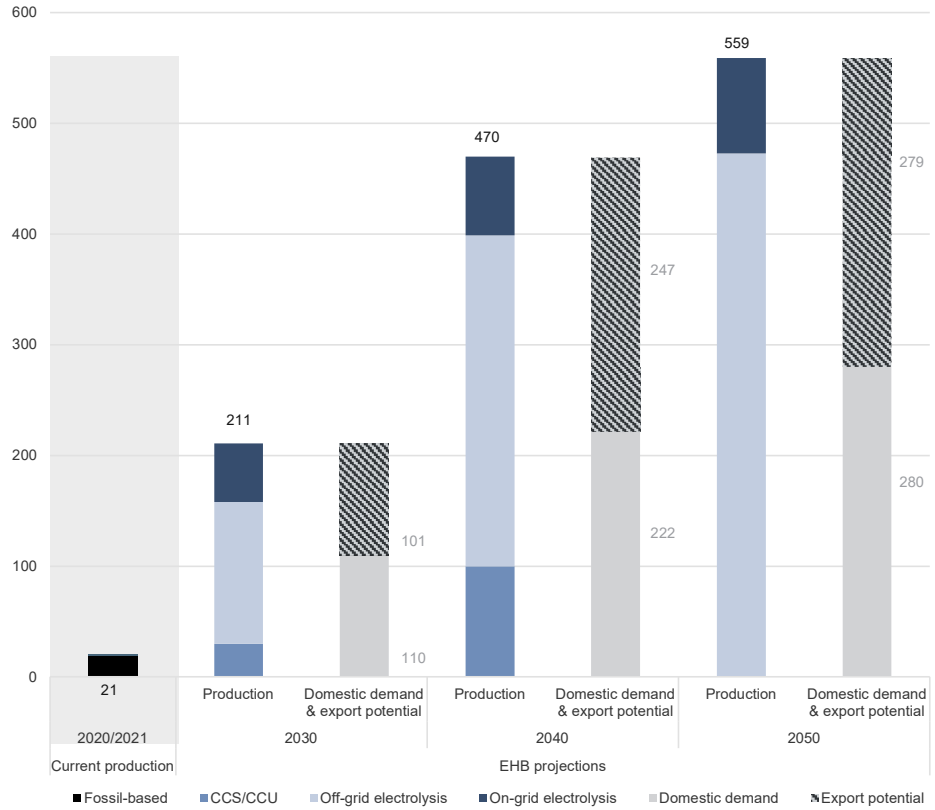
- **Hydropower is and will be the stable backbone** of the Nordic electricity generation mix, with mainly Norway a large contributor to this source
- **Wind will likely be the sector with most developments** both on the short- and long-term horizon, especially when it comes to the **offshore capacities**
- Outlooks regarding the **nuclear power capacities are highly uncertain**, as projections can take a sudden turn with every change of political opinion

A clear vision from Nordic governments on how to stimulate the market to build all required electricity generation is needed

Source: Nordic Energy Research report August 2022: NEOFinalreportWP2-1.pdf; Statnett's Short-Term Market Analysis for the period 2022 - 2027 (KMA): kortsiktig-markedsanalyse-kma-2022-2027---nokkeltall.xlsx
Note: ON-TIMES and HIGHRES are full nuclear phase out scenarios

The Nordics needs to act now to take position in the global clean hydrogen market and make a standpoint of what will be the Nordic scope of business

Current and projected hydrogen supply, demand and export potential by source
(in TWh, without Iceland)



Nordic hydrogen production is expected to significantly grow in scale and be fully decarbonised in the future

The Nordics offer both blue and green clean hydrogen

- The **current** Nordic hydrogen production is almost **entirely fossil-based**
- In **European Hydrogen Backbone**'s projections, the future Nordic hydrogen production will be **primarily covered by off-grid electrolysis**
- Norway is expected to be the only contributor of hydrogen produced from natural gas with carbon capture

The demand for hydrogen in the Nordics will be driven by steel and e-fuel sectors

- Up to 2030, most of the Nordic hydrogen demand is driven by the **industrial sector in Sweden** – primarily related to the adoption of hydrogen **in the steel sector**
- From 2040 to 2050, most new hydrogen demand is **for e-fuels production**, with especially **demand in Finland and Denmark** contributing an increasing share

The Nordic region's share of export will depend on strategic choices and industrial leadership in developing hydrogen derivates production and application sectors for off-take within the region

- Demand in each of the Nordic countries is expected to be **lower than their production** in any given year but development of large light-house projects will influence this heavily
- The EHB sees the **Nordics as an important supplier of hydrogen to Europe**, especially to large demand hubs in Germany and Poland
- Due to their predisposition to **produce renewable hydrogen for a competitive cost**, the Nordics are seen as well positioned in the current supply-demand negotiations
  - Until issues with permitting will be fully resolved on the EU level, **negotiations for future supply deals are being held already now** on the country and TSO level

Access to clean, cost efficient hydrogen and biogen carbon generate good prerequisites to make the Nordics for self reliance and take a leading position globally

Source: European Hydrogen Backbone – Five hydrogen supply corridors for Europe in 2030 (May 2022): EHB-Supply-corridor-presentation-Full-version.pdf

Besides direct electrification hydrogen is one of the key enablers for decarbonisation, resilience and economic growth for the Nordics

The role of hydrogen in the Nordics

Contribution to CO2 reduction & Climate neutrality	Resilience	Contribution to GDP, job creation and export potential	A new field of Nordic collab and global export and investments
➢ As indirect electrification of hard-to-abate sectors, transport, steel and chemical industry being some of the most polluting ones, **hydrogen is a key enabler for decarbonisation** ➢ Hydrogen and its Power-to-X derivates has the **potential to be a key route for carbon neutrality** for the Nordics by 2045	➢ The Nordics has the feasibility to **become self sufficient** for fossil free electricity, climate neutral hydrogen and carbon being the components to produce any Power-to-X fuel and feedstock ➢ This is the springboard not only for **autonomy on the road to climate neutrality**, but also creating independence from the geopolitics of global oil and gas markets	➢ A Nordic hydrogen strategy to be optimised towards **reaching high in the hydrogen value chain** (e.g. value add from clean hydrogen, to low carbon steel, to a low carbon bus) ➢ A Nordic hydrogen economy is an important part of the future to **secure green GDP and growth** in job creation	➢ Potential to create a Nordic **clean hydrogen enabled market** and **innovation hub** ➢ Nordic base industry to market a low carbon premium beyond commodities and **building a new line of trade of enabling technologies** – based on R&D&I collaboration and scale implementation ➢ Investments needed in value creating areas as technology and application **complementing the Nordic current offer**

> ***As part of the green transition, hydrogen is the new green industry. Transition can be enabled in several industries.***
>
> [Norwegian organisation]

> ***Hydrogen used in a system optimised way will merit to expand energy production in order to produce Power-to-X derivates***
>
> [Swedish company]

> ***Nordic collaboration is something that we need to build. With the opportunities and discussions we have with Nordic companies there is no reason for why we should not work within the Nordics***
>
> [Finnish company]

The industry suggests that Nordic export and investment strategy should aim at value addition within Nordics, climate neutrality and resilience

Source: Report interviews and analysis

Nordic market overview | Policy

- Hydrogen is considered a key enabler for decarbonisation of heavy emitting industries such as transport, process industry and refineries across the Nordics
- In light of the geopolitical situation, hydrogen has become increasingly important component for energy security
- EUs Fit-for-55 regulation will be a major regulations steering the Nordic market. The hydrogen value chain will further be impacted by the EU Green Deal Industrial Plan and US Inflation Reduction Act
- Industry demand on policy development varies depending on core industries in the market - e.g. maritime industry in Norway, steel and refineries in Sweden and Finland
- In order to enable the hydrogen ambitions in the long run, electricity demand generated from renewable energy sources will increase and will need to be secured
- Ongoing domestic discussions on domestic use and value add vs. export of hydrogen

Nordics see hydrogen is key for decarbonisation and depend heavily on EU and market policy development

Synergies of Nordic ambitions

- Strong **long term focus on hydrogen** and building the hydrogen
  - All Nordic countries have largely formalized strategies and visions for the domestic hydrogen economy
- **EU directives and standards**, such as the Fit-for-55 and REPowerEU scheme, will have **significant impact** in the Nordic region
- The US Inflation Reduction Act has generated a shift in the playing field, i.e. the US becoming more attractive for investments and business opportunities

Complements of Nordic offer

- Nordic governments are establishing **individual agreements with key markets globally**, jointly contributing to the Nordic hydrogen brand

Industry need to realise hydrogen potential

- As one key USP for Nordic hydrogen production, it is pertinent to keep **a fast and ambitious pace for renewable and fossil free energy investments**
  - A priority basis for what projects are awarded electricity. Optimize strategy towards green transformation, job-creation and self reliance
- An urge for **predictive and fast permitting processes** for hydrogen projects
- **Request for EU investment incentives**, e.g. carbon contracts, that avoids micromanagement
  - The industry needs a joint voice on policy, including state aid objectives
- Incentives towards **investments in electrolysis** would reduce risk and increase speed of scaling up the industry

Potential of collaboration within the Nordics

- A **pan-Nordic strategy** for a Nordic hydrogen economy with
  - Aim at high value creation
  - Strategy for use of biogenic coal to achieve a self reliant fuel and chemical industry
  - Cross sectorial use of bi-products heat and oxygen and grid balancing
- Keep a **joint Nordic voice** in EU for policy development
- Policy-related **promotion activities**, such as:
  - Outline a Nordic investment case benchmark with state aid supported investments in EU and US
  - Identify joint Nordic promotion towards international standards to create low carbon premium segments

Nordic market overview | Funding

- National and to a certain extent derived EU funds available to fund hydrogen related developments
- Expressed need for more funding sources for commercial scale showcase project – pan-Nordic as well as EU level
- Subsidy schemes such as the IRA and state aids practice and regulation across Europe partly considered to leave Nordics in disadvantage

Domestic funding schemes available however cross-Nordic possibilities could be extended

Synergies of Nordic ambitions

- **Increased funding** in hydrogen-related projects across markets
- Key strategic projects largely **supported via public funds**
- **IPCEI** rolled out in all markets besides Iceland but on varying scale

Complements of Nordic offer

- **Geographic project expansion** in several value chains focuses on Nordic area would be supported by **replication of the funding mechanisms**
- Certain parts of the value chain such as infrastructure are developed on the principle of additionality and requires **common due diigence and funding opportunities on the regional level**, rather than on the country and or pan-European level

Industry need to realise hydrogen potential

- **Request for joint Nordic funding schemes for regional projects** – perceived lack thereof between the main Nordic funding agencies. Extended the scope of the existing platforms such as the Nordic Energy Research could be one feasible way.
- Call for **increased cross border collaboration, information sharing and co-creation** between the funding agencies in the instances where join funding schemes are limited by the National agendas
- Lift the Nordic hydrogen case to **enable more EU finance schemes**
- **EU-wide production incentives** – to match the Inflation Reduction Act

Potential of collaboration within the Nordics

- **Increase visibility of Nordic potential projects** in order to attract more investments from EU and private foreign actors
- **Increase Nordic collaboration opportunities** by joining funding sources to enable pan-Nordic lighthouse projects
- Institutionalise and package **the concept of the 'projects of the common Nordic interest',** which will enable increase of public and private funding

European infra planned – domestic and cross-Nordic connection hold highest value add in midterm horizon

Nordic market overview | Infrastructure

- All Nordic countries besides Iceland connected to the European Hydrogen Backbone (EHB) through the North-Sea and the Nordic-Baltic corridor
- Domestic projects in planning in all infrastructure types, soonest to be deployed are refueling networks
- Several infrastructure collaborations initiated in the Nordics, e.g.
  - Shipping and pipe-lines as part of EHB
  - STRING Hydrogen Network (hydrogen refueling)

Synergies of Nordic ambitions

- **Integrated, on-site hydrogen production** is largely considered the most efficient in the short/medium term from a cost and supply security perspective
- **Regional refueling infrastructure** and maturing business case for the Nordic shipping and port infrastructure for hydrogen production and processing are in development

Complements of Nordic offer

- **Varying degree of gas legacy** – i.e. Sweden and Finland low compared to e.g. Norway and Denmark opportunity to pool experiences and competence
- Based on announced directives, **different EHB routes for Sweden and Finland (incl. the Baltics) and for Norway and Denmark**

Industry need to realise hydrogen potential

- Substantial **public and private fundings needed** to build out hydrogen pipelines
  - Domestic and cross Nordic pipelines will speed up and enable larger hydrogen related industrial projects
- Ensure **synergies and integration to avoid overlapping infrastructure**, utilise existing for transportation and e-fuels while awaiting pipeline
- **Clarity in business model and regulations** related to hydrogen transport and storage
- **Supporting infrastructure** to hydrogen production, e.g. power grid capacity

Potential of collaboration within the Nordics

- **Optimise hydrogen infrastructure investments pan-Nordic** partly based on converting existing assets
- **Prioritise what to build first to promote value add** within Nordic and to mitigate risks with lack of legacy piping
  - System thinking considering power networks needed
- **Increased collaboration with existing hydrogen hubs** – often initiated and driven by local and national authorities together with private actors
  - Visibility for the Nordic hydrogen valleys could be created in the Clean Energy Ministerial/Mission Innovation and similar platforms

Nordic market overview | R&D

- Nordics hold key research centers and clusters across all parts of the horizontal and vertical value chain
- Developing and education of competence and attracting the right competencies is considered to be a future risk as in many other sectors
- The interest and focus on hydrogen value chain areas as technology such as electrolysers, CCS/CCU, fuel cells and Power-to-X applications is recognized

Strong research community but need for more competence development and commercial testing

Synergies of Nordic ambitions

- **Strong R&D community** across the Nordics with key universities involved in research and feasibility studies as well as several cluster formations
- **Research** largely conducted **across the full hydrogen value chain**
- **Valuable R&D collaboration in the vertical supply chain** in the Nordics (electrolysers, fuel cells, CCU & CCUS, storage of CO2)
- Research projects to **improve security for ammonia and hydrogen**

Complements of Nordic offer

- Opportunity to **align R&D focus in the region horizontally** along the value chain to where each country have legacy and industrial focus
- **Competence availability and best practice of education and training** of competence are found in different Nordic markets

Industry need to realise hydrogen potential

- The complex field of **Power-to-X need long term strategy** and R&D investments
- **Competence and skills build up** – one of largest limiting factors
- **More targeted funds** to end-use/application segment
  - Enable lighthouse projects and showcase examples of how to scale

Potential of collaboration within the Nordics

- **Further socioeconomic studies on the optimal role for hydrogen** as basis for Nordic hydrogen strategy
- **Industry interest in joint pilot and lighthouse projects** to make Nordics a testbed for hydrogen application
- **Academia and institutes are developing new solutions** around the whole hydrogen value chain with upcoming startup companies that are spinoffs from this development
  - Intensified Nordic R&D&I collaboration to set the basis to build Nordic leading offer of low carbon products (such as steel, SAF) and core technology (such as. electrolysers, CCS/CCU, fuel cells)
- **Joint initiative on hydrogen competence development** and attraction of **talent**

Nordic market overview | Ind. leadership

- Industrial leadership is seen in the first-in-the-world lighthouse projects putting the Nordics on the global hydrogen map
- Besides the legacy industrial actors, fast growing capital backed scale-ups bring new business and growth models benefitting the hydrogen value chain development
- Hydrogen is receiving a lot of attention, but it is still a minor segment for many traditional industry companies
- High number companies are actively engaged in hydrogen value chain both nationally and internationally
- Nordic collaboration approach especially valuable in the complex hydrogen value chain where partnership models required to pair required competence

The Nordics can become a testbed for lighthouse projects within the hydrogen value chain

Synergies of Nordic ambitions

- **Vertical integration happening along the value chain**, with joint Nordic approach this can be managed efficiently and not cause competition issues
  - *Forward*: Energy utility owns conversion, mining company produced green iron sponge
  - *Backward*: Industrial actor owns conversion asset
- Projects investments **decisions often happen before full financing and/or signed offtake**, a risk investors are willing to take

Complements of Nordic offer

- The Nordics have **experience of partnership and pilot creation amongst companies from all markets** – considered the extended home market
- **Complementary industrial and energy profiles** and **competence** based on industrial legacy and natural resources

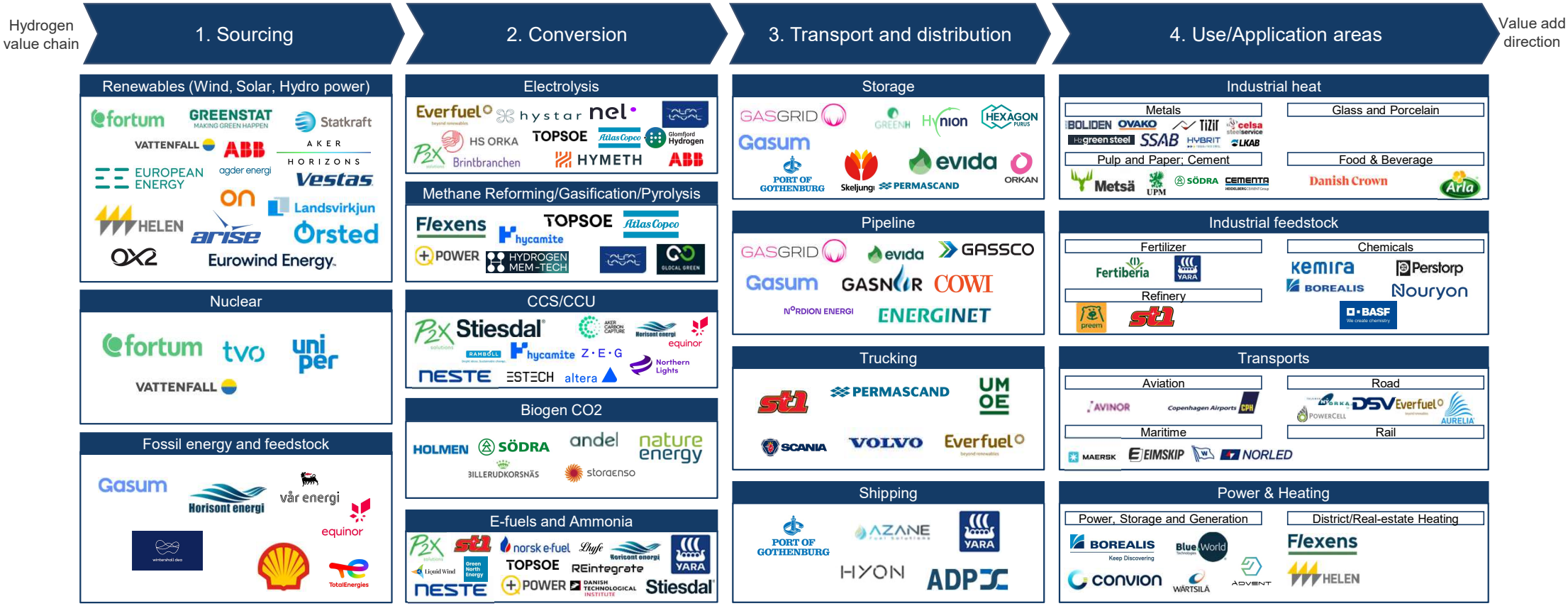
Industry need to realise hydrogen potential

- **Securing cornerstones**: competence, continued cheap green electricity, lowering investment risks
- **Faster scaling** from R&D-step to commercial scale
- To be part of the global hydrogen race **the time is now**, hence the Nordics needs to increase speed and visibility

Potential of collaboration within the Nordics

- Continue to **develop first of a kind lighthouse projects** for commercial testing
- Build **business models that harvest the additional cost** compared to standard commodities
- **Develop Nordic unique low carbon material** (low carbon iron, recycled/virgin steel, chemicals, plastics, fertiliser etc.) and **fuels for export**
  - Experience shows that available low carbon product drive great demand from new unexpected sectors
- **Start with sectors where low carbon material has small cost impact but large value addition** and with few value chain steps from product to end customer

Together the Nordics form an offer throughout the value chain for global growth through export and an attractive invest in offer

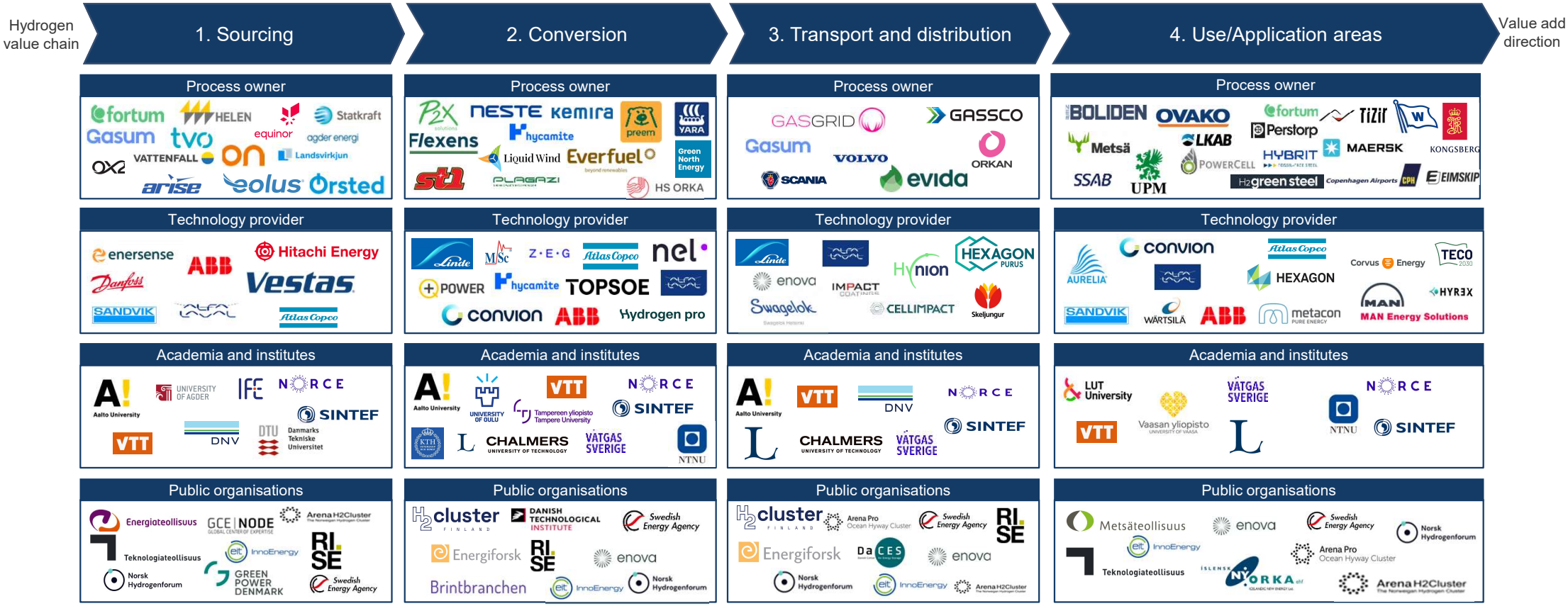


Through collaborative innovation and first-in-the-world lighthouse projects the Nordics has the potential to establish leadership in the hydrogen value chain

Source: Report analysis; Company websites

Note: The overview is illustrative and not exhaustive

The Nordics multiple-helix offer throughout the value chain created a basis for innovation through collaboration, global growth and attractive invest-in offer



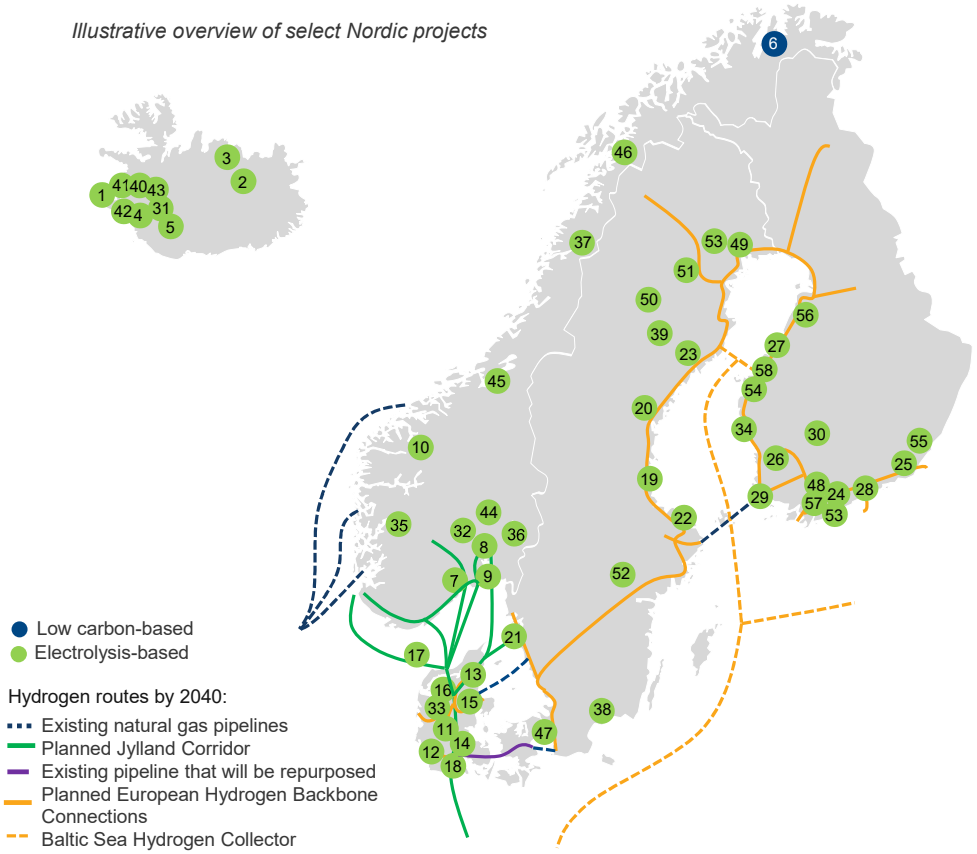
The extensive Nordic clean hydrogen value chain shows opportunity for both enabling technology and lowcarbon based products exports

Source: Report analysis; Company websites

Note: The overview is illustrative and not exhaustive

The Nordics display first-of-a-kind clean hydrogen-enabled projects within industrial feedstock, heating and different modes of transports

Illustrative overview of select Nordic projects



Sourcing	*Conversion*	*Transport and distribution*	*Use/Application areas**
1. Reykjanes power plant | IC 2. Koldís | IC 3. PCC BakkiSilicon plant | IC 4. Hellisheidi | IC 5. Ljósifoss | IC 6. Barents Blue | NO 7. Green Ammonia Porsgrunn | NO 8. HyStar | NO 9. Nel Herøya | NO 10. Hellesylt Hydrogen | NO 11. Topsoe electrolyser man. plant | DK 12. Høst | DK 13. Green CCU Hub | DK 14. HySynergy | DK 15. Green Hydrogen Hub | DK 16. GreenHyScale | DK 17. BrintØ project | DK 18. The port of Aabenraa | DK 19. SoutH2port | SE 20. Flagship ONE | SE 21. St1 Gothenburg | SE 22. Forsmark E-fuel | SE 23. SkyFuelH2 | SE 24. Vantaan Energia | FI 25. St1 | FI 26. Power-to-X Solutions | FI 27. Flexens | FI 28. Neste | FI 29. Green North2 Energy | FI 30. Nordic Ren-Gas | FI 53. Helen | FI 54. EPV | FI	31. Nordic Ren-Gas | IC 32. Deep Purple Pilot | NO 33. ClusterNorthH2 | DK 34. Koppö Energy | FI 48. Vetyverkko | FI 55. Ovako | FI 58. Hycamite and ABB | FI	**Industrial heat** 35. TiZir | NO 36. Hydro Havrand and H2 Green Steel | NO 37. Mo hydrogen hub | NO 49. Hybrit | SE 50. H2GS | SE 51. LKAB | SE 52. Ovako | SE 53. SSAB Luleå | SE 56. SSAB Raahe | FI 57. Blastr | FI **Industrial feedstock** 38. Project Air | SE 39. Fertibieria | SE 51. LKAB | SE **Transports** 40. H2ME-2 | IC 41. ECTOS | IC 42. Fuel stations Reykjavik & Reykjanesbaer | IC 43. E-fuels for shipping | IC 44. HySeas | NO 45. H2Nor | NO 46. HyEkoTank | NO 47. Green Fuels for Denmark | DK

The increasing activity in hydrogen related projects should be showcased and presented as key parts of the Nordic offering and know-how

Source: Report analysis; Company websites

Note: The overview is illustrative and not exhaustive. Highlighted projects are presumed to be mature, e.g. under construction at the time of the report (January 2023), an extension of existing operations, and/or have reached FID * No projects identified under Power and Heating

Renewables considered one of key value propositions for the Nordics – future rollout crucial for clean hydrogen development

Joint Export promotion potential

Nordic collab potential

Potential

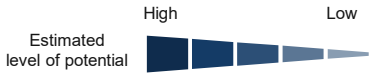
- Nordics has a unique position to become a green powered region as the electricity mix is already virtually fossil free (and to a large part renewable) and the theoretical possibility for expansion of fossil free electricity production is considered high
  - **Onshore-wind** energy production possibilities are immense with large areas of unhabituated land
  - **Offshore wind** farms are being developed in the North Sea and in planning stage in the the Baltic Sea
  - **Solar** power projects are needed and only started to become more important, both small- and large-scale projects needed
  - Additional **nuclear** is foreseen in Finland's and Sweden's energy mix
  - Norway is a global supplier of natural gas that combined with CCS is a low-carbon feedstock
- Value chain vertical – the Nordics could offer **green value chain** for wind and solar equipment and projects

Joint Invest Promotion potential

Nordic collab potential

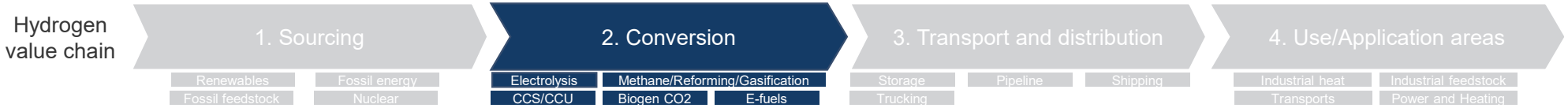
Needs

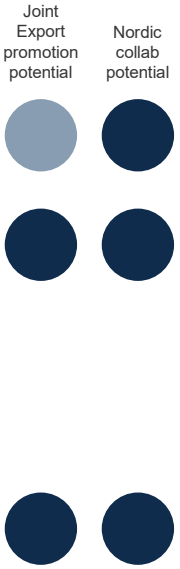
- A clear vision from Nordic governments on how to stimulate the market to build all required electricity generation is needed
  - The energy system must be transformed extensively in the coming years, including **energy storage, grid balancing, flexible operation**
- Development of the **electrical network** to transmit higher load of green energy needed
  - A **prioritisation** of grid connection for energy generation and certain types of industries might be needed
- **Permitting** for renewable energy projects (for electricity grids, pipelines and electricity production) needs to become shorter and transparent
- **International developers** could bring speed and size to on-shore and offshore wind investments



Source: Report interviews and Analysis

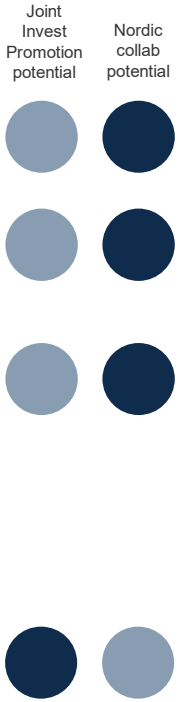
Self-sufficiency in clean hydrogen and biogenic CO2 – the springboard to climate neutrality, global Power-to-X offer and a leading Nordic off-take industry





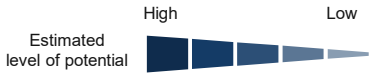
Potential

- Potential for **self reliance** of both **clean, cost efficient hydrogen** and abundant amounts of **biogen carbon** can make Nordics total climate neutral and enable a global leader power-to-X-offer
- A power-to-X **market within the Nordics** and **globally**
  - Increasing numbers of **cross-Nordic** conversion investments and projects
  - Trade within and export from Nordic of **hydrogen derivates** and enabling technologies for all application areas
  - Collaboration within Nordics to **pool competence and reach scale**
- **Value chain verticals** – potential for Nordic supply chain for key conversion and adjacent technology as **electrolysers (synergies within fuel cells), CCUS and CO2 storage**
  - Chance to take technology leadership through healthy competition between **blue and green hydrogen** tracks towards zero-carbon footprint



Needs

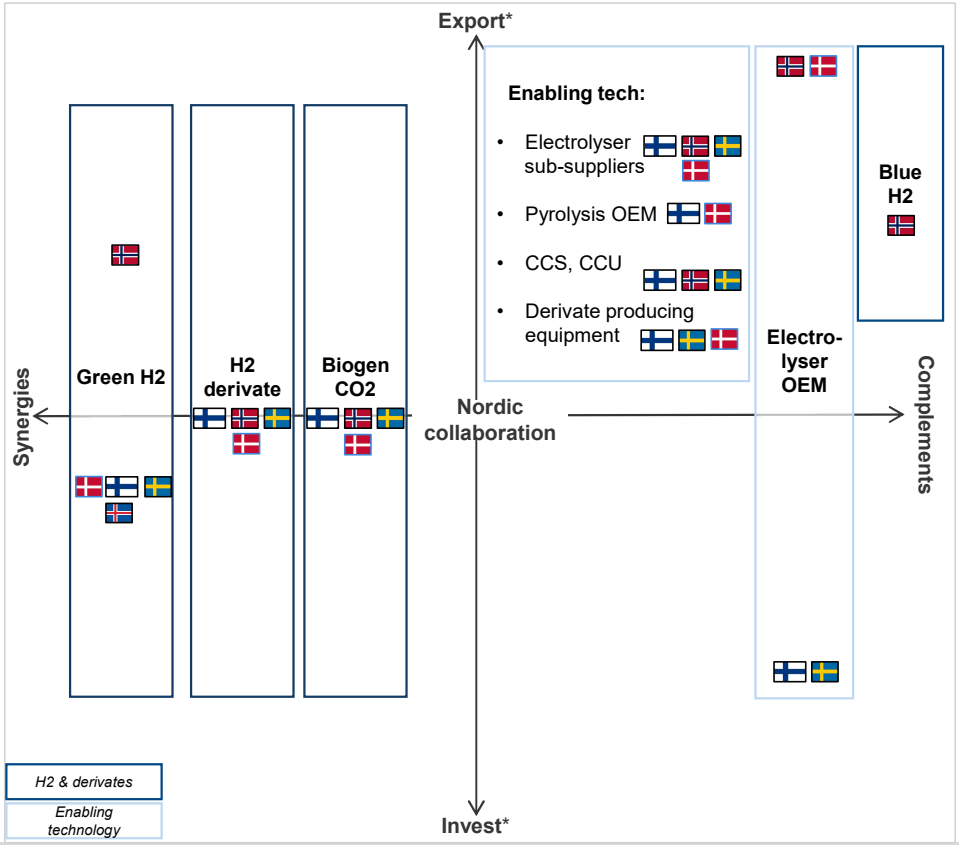
- An optimized Nordic strategy to deliver on green transformation, **maximum value-add,** job creation and Nordic self reliance – export and invest strategy as a consequence
- EU-guiding policy to be simplistic and **favor minimal carbon route i.e. technology neutral** for hydrogen production
  - Carbon pricing, EU/national CapEx and OpEx incentives to catalyse investments of scale
- **Timing is now** – expressed need for commercial **market frameworks** beyond pilots for speed, cost efficiency and trust
  - Pricing models to **manage volatility** in cost and market levels
  - **Technology to scale** alongside market growth
  - Nordics show offer through **increased visibility** in EU, global hydrogen network and business platforms
  - Develop and attract **competence and dedicated R&D&I**
- **Attract investors** to speed up scaled projects and contribute with additional conversion technology



Source: Report interviews and Analysis

The conversion step shows an interdependent potential of export of hydrogen derivates and enabling tech as well as investments to speed up development

Illustrative visual of key synergies and complements for export and invest



Highlighted areas for possible value add

Synergies

- Production and domestic use of **green hydrogen available across all Nordic countries**, while especially Norway provides offer for blue hydrogen
- Pulp and Paper (FI, SE), farming (DK) combined with CCU know-how (NO) provides opportunity to **supply biogenic/captured CO2 to growing low carbon industry for e-fuels and chemicals**
- Increasing volume (DK) and investments (FI, NO, SE) in derivates is **an opportunity for export and domestic use of maritime fuels (NO, DK), aviation fuels (DK) and hydrocarbon for industrial feedstock (SE, FI)**

Complements

- Access **of green and blue hydrogen**, blue enabled by Norway, provide **two low carbon possibilities** – a complementary offer for **exports** and **domestic use**
- With **complementing industrial legacy and technology**, Nordics can build resilient value chain verticals and strong hydrogen enabling technology export offer
- Chance to **contribute to global electrolyser supply and technology development** – the Nordic offer entails OEMs (NO, DK), sub suppliers (FI, SE) and other derivate enabling tech (FI, SE)

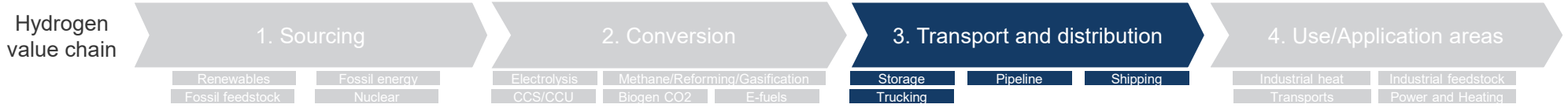
Process field: *Hydrogen and derivates*

Tech field: *Enabling technologies*

Proactive export and invest promotion should focus on value adding areas as technology, derivates and enabling applications rather than on hydrogen in itself

Source: Report interviews and Analysis
Note: *Export of hydrogen derivates resp. enabling technology, Invest in production assets and R&D

Strong Oil & Gas, maritime and hydro power legacy sets Nordics up for investments in all types of hydrogen infrastructure



Joint Export promotion potential | Nordic collab potential

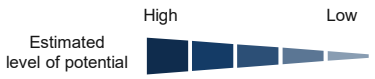
Potential

- Several major pipelines, **largely following the European Hydrogen Backbone outline**, have been announced. The pipelines could strengthen the joint Nordic hydrogen economy as **security of supply would increase**
  - It presents an opportunity to pool experience and competence with Norway having a particularly strong legacy
  - The timeline aiming towards 2030 and 2040 respectively is uncertain but as many projects in the Nordics are **onsite production focused**, the time gap before pipelines are constructed is less critical
- There is a potential to create an **integrated Nordic hydrogen transport system**, both on land and on sea
  - Substantial experience with short and long-haul maritime solutions and many maritime actors actively working to build infrastructure together with industry clusters
- Storage and distribution of **hydrogen and derivates** is being developed, strengthening export opportunities for higher value goods. Pipeline will also serve as storage

Joint Invest Promotion potential | Nordic collab potential

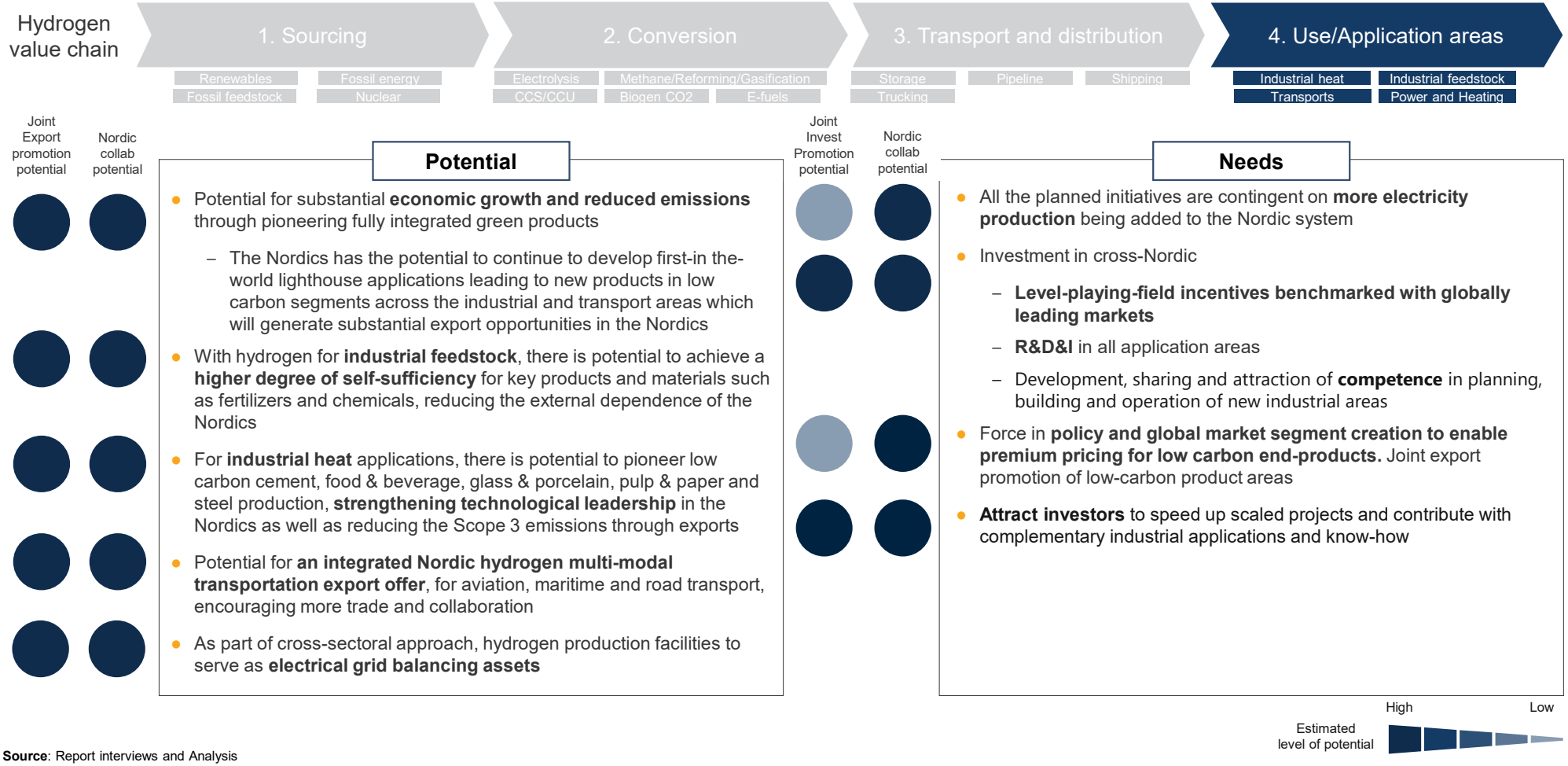
Needs

- Establishing **a joint Nordic view on the development of pipelines**, connecting the Nordics and connecting the Nordics to continental Europe, and their respective impact on the Nordic hydrogen economy is crucial
  - It is necessary to create synergies by avoiding building overlapping infrastructure
  - Need of Nordic strategy of export that focuses on export as high up in the value chain as possible
- Removing barriers for infrastructure solutions to be implemented
  - International laws **for transportation of hydrogen across borders** needs an overhaul and road and maritime infrastructure must be implemented and harmonised
- Storage of hydrogen and its derivates is at an early stage with technical and economical challenges remaining
  - Major trading hubs as being developed **could transform current oil storage systems to hydrogen**, but business models and financing are lacking



Source: Report interviews and Analysis

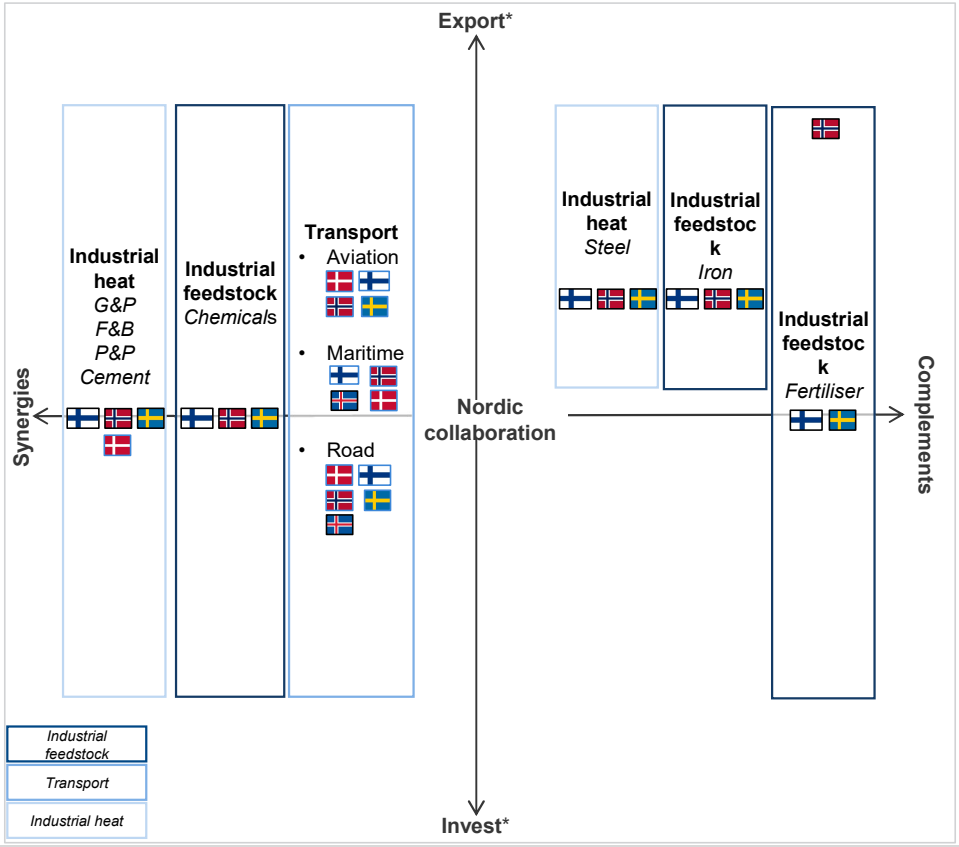
The Nordics are pioneering all industrial and transport off-take areas with sustainable fully integrated production processes



Source: Report interviews and Analysis

The speed in low carbon end products depends on industrial lighthouse projects combined with promotion to create a market segment and demand

Illustrative visual of key synergies and complements for export and invest



Highlighted areas for possible value add

Synergies

- Nordics viewed **as pilot region** by international and domestic actors **within chemical**. First projects for bulk hydrocarbon chemicals (FI, NI, SE) based on clean hydrogen and biogenic CO2 are under execution
- Strategic projects available in key transport sectors to provide low carbon products – from **fuels** such as **SAF**, to **OEMs for trucks and busses**, **fuel cell providers** (NO, SE) to **infrastructure** providers (NO, FI, SE)
- Nordics holds key examples of clean hydrogen **decarbonizing hard-to-abate process industries**, such as Cement (FI, NO, SE), Glass & Porcelain (DK, FI, SE), Pulp & Paper (FI, SE), Recycled steel (FI, SE)

Complements

- World's first green steel (SE) with help of green H2 shows **opportunity of price premium**. Similar projects are increasing (NO, FI). Given **high energy demand**, **combined use of blue hydrogen** could be considered
- Fertilizer are key for resilience and low carbon food chain which will be driven by international (FI, SE) and domestic (NO) investors and enable export potential for the Nordics

Industrial feedstock

Transport

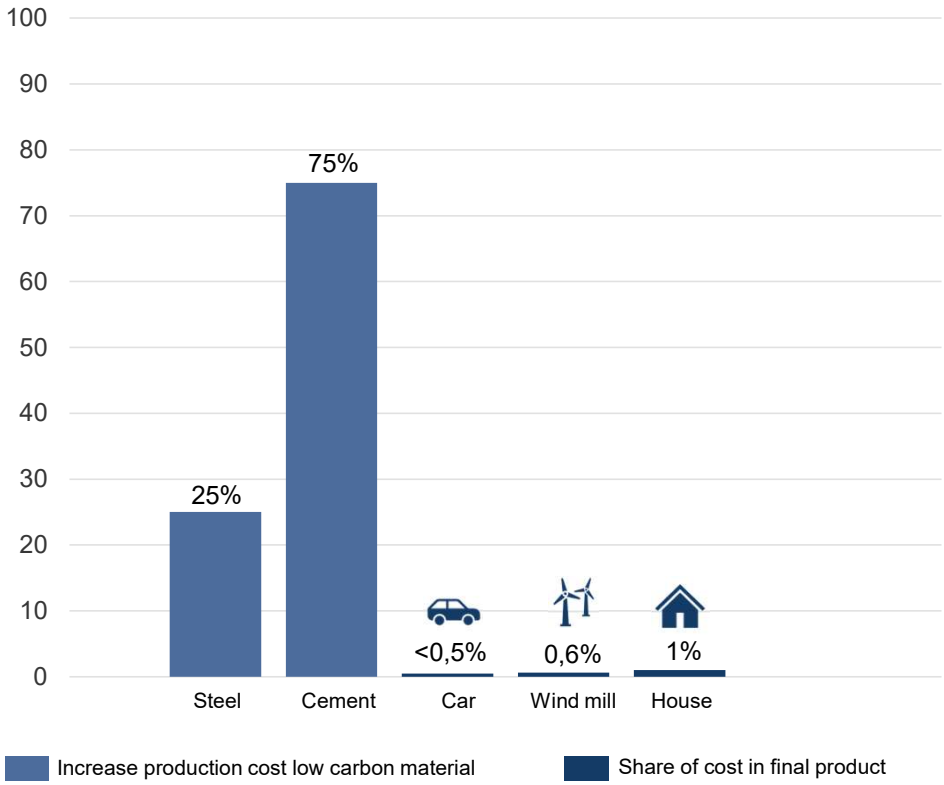
Industrial heat

Market segment and price premium should be developed for low carbon end use products to the benefit of Nordic industry

Source: Report interviews and Analysis **Note**: *Export of low-carbon end-products resp. enabling technology, Invest in production assets and R&D

Nordics will benefit from creation of market segment where a premium is established for low-carbon products

The increased cost on low carbon materials and the cost share in final product



Low carbon products is a sweet spot for the Nordics

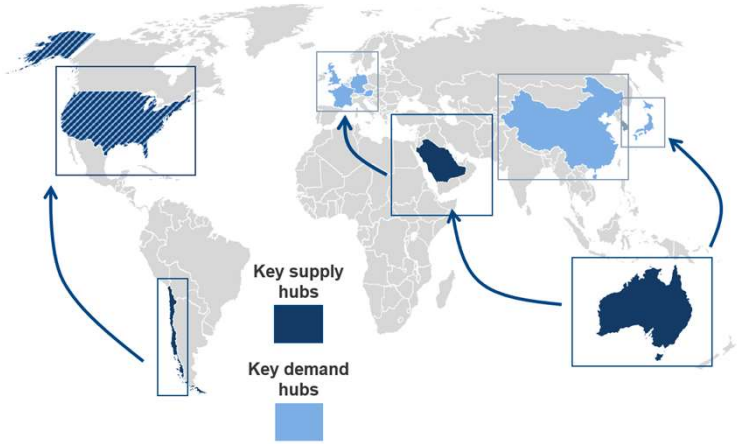
- **Low carbon footprint potential to receive premium price**
  - Cost of producing low carbon materials is typically higher than current production of commodities while **impact on the overall cost of final product is relatively small**
  - The value increase of end products based on low carbon materials can be higher, creating a premium segment
    - Steel is one of the first cases where it has been shown where customers such as the automotive sector **pay +25% for material considered a commodity**
- **Trigger points for creation of low carbon market segments**
  - Sectors where low carbon material has small cost impact but large overall climate footprint and thereby value addition
  - **Few value chain steps from low carbon product to end product** enable easier impact on the sales process.
  - Both demand and policy regulation contributes to the low carbon segment creation
- **The Nordics have a unique position to cater to low carbon premium segments**
  - Nordic has potential to be **the originator of low carbon material, fuels and enabling technology** across several end use sectors
    - Cases of clean hydrogen-enabled materials are being developed and has the potential to find its way to new premium segments
    - clean hydrogen-based fuels as ammonium, e-methanol and SAF as well as transport modes to utilise these new fuels are developed in the Nordics.
    - The total Nordic industry can cater towards growing premium segments as it only stands for very small part of total global commodities demand

A key joint effort of the Nordics could be to promote development of low carbon premium market segments through demand creation and input to regulation

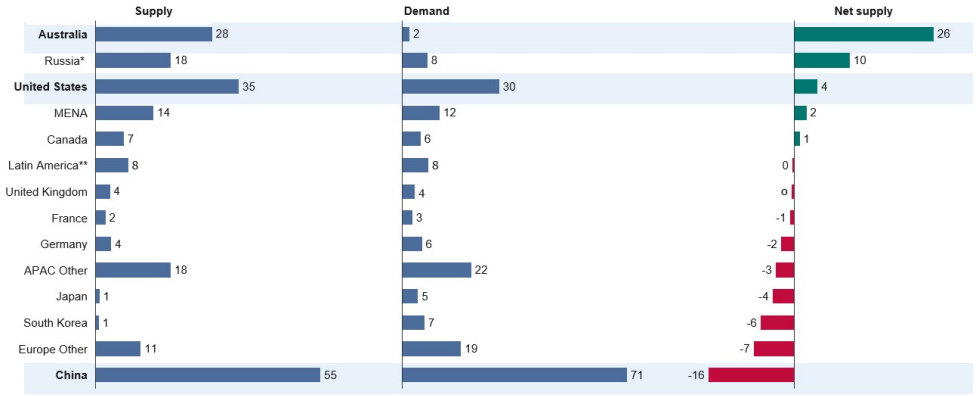
Source: Report analysis; EHB.eu; government.is; FN.no * Climate emissions reduced by 90-95% compared to 1990, Fossilfritt Sverige 2023

Overall, global demand and supply hubs respectively will be key export markets for the different scope from the Nordic hydrogen offer going forward

Supply and demand hubs including key supply routes
Illustrative



Global clean hydrogen supply and demand, 2050
Mt p.a.



- By 2030, hydrogen could be shipped from supply hubs such as Australia, Chile and Saudi Arabia to projected demand centres in Asia, Europe and USA.
  - Approximately 60% of all global supply will come from three markets: Australia, China and the US – however, China will still be a net importer
  - **Global supply hubs** as **Australia, Chile, China, MENA, India and US** are potential key markets for **Nordic export** of hydrogen conversion as well as down-stream application **technology**

- While the feasibility of long-distance hydrogen transportation choice will differ depending on end-use, shipping will help unlock demand globally
  - **Global demand hubs as China, South Korea, Japan, EU, and UK** are potential key markets for Nordic **export of hydrogen derivates**
  - Nordics has the potential to aim at trading **goods higher up in the value chain** (low carbon steel, chemicals, fertilizers etc and OEM products) to the demand markets rather than hydrogen
- **Potential investors** that could contribute to building the Nordic hydrogen value chain are found in both **supply and demand hubs**

Note: US is expected to be a key demand hub with some supply going to export
Source: Report analysis, Hydrogen Council, IEA, Fitch Solutions, Wood Mackenzie

Potential for innovation partnerships are mainly seen among the global supply and demand hubs, a next wave of key markets are emerging

Hydrogen strategy and policy map – next generation of key hydrogen markets
Illustrative

Many nations are developing robust regulatory frameworks to drive demand and investment in clean hydrogen

	Financial measures			Regulatory measures			R&D initiatives			Supply scale-up strategy			Demand pull-in measures		
China		Mid				High			High		Mid				High
South Korea			High			High			High		Mid				High
Japan			High		Mid				High		Mid				High
Australia			High			High			High			High		Mid	
European Union			High			High		Mid				High			High
Germany			High			High			High			High			High
France			High		Mid				High		Mid		Low		
UK			High			High			High			High			High
Sweden		Mid				High		Mid			Mid			Mid	
Finland	Low				Mid		Low					High		Mid	
USA			High		Mid				High		Mid			Mid	
Canada		Mid			Mid				High			High		Mid	

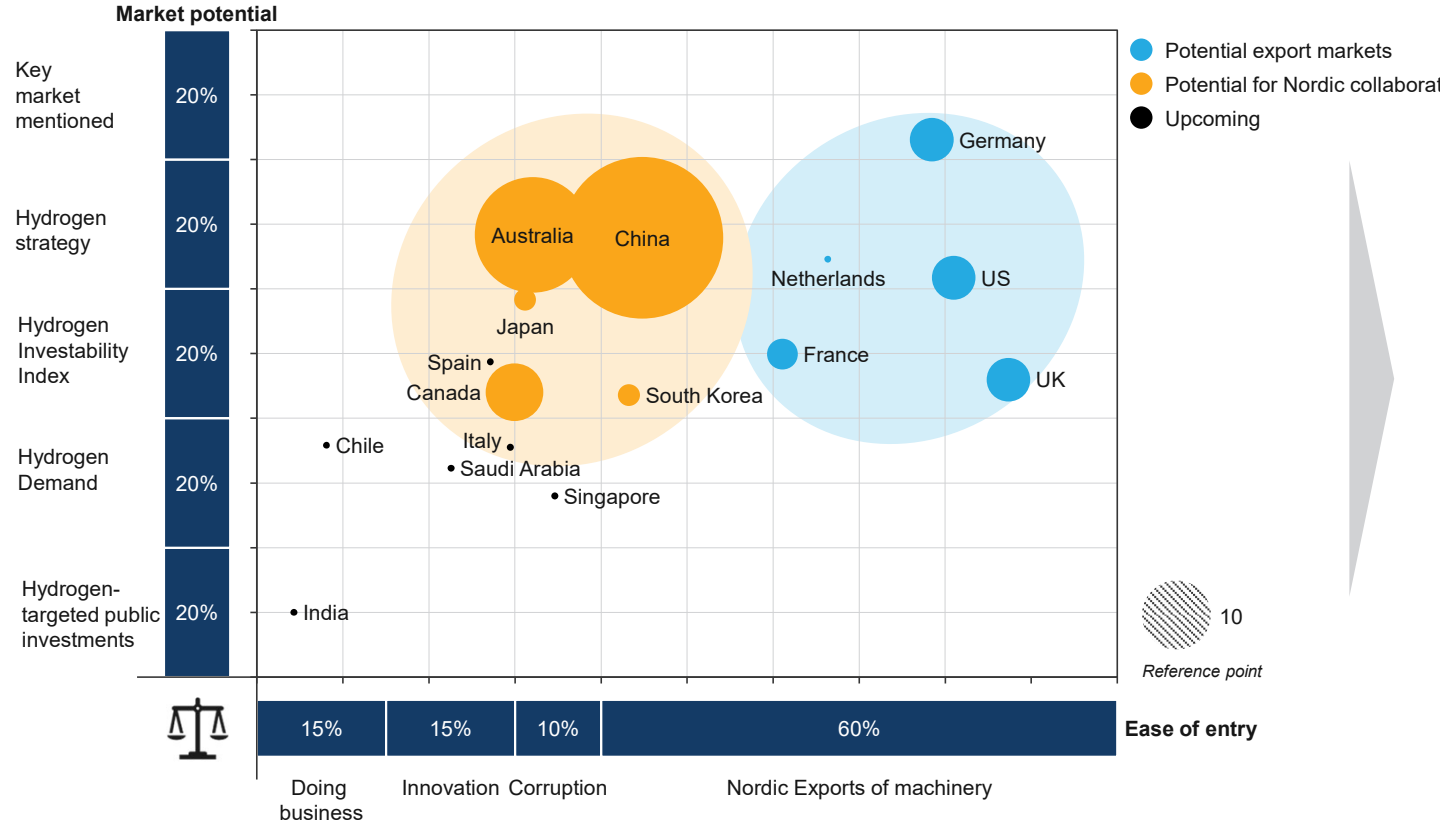
- Numerous nations in the Middle East, Africa and South America published draft and final strategies in 2021 and 2022
  - Besides the largest global supply and demand hubs, **an indication of next generation of key markets** (mainly from technology export perspective) **for the Nordics can be indicated by countries that are about to launch national strategy and/or have launched initial projects**

- Companies that **rank high on R&D initiatives** are mainly found among the among the global supply and demand hubs
  - Hence, markets likely to **have potential for R&D collaboration are found among the same countries that will be the export and invest partners** of Nordic industry

Note: Map is indicative of current situation as of November 2022
Source: Report analysis, World Energy Council, IEA

Favourable hydrogen technology export markets are found in near proximity, while the Nordic collaboration might have more impact on faraway markets

Potential markets for Nordic exports of hydrogen enabling technology



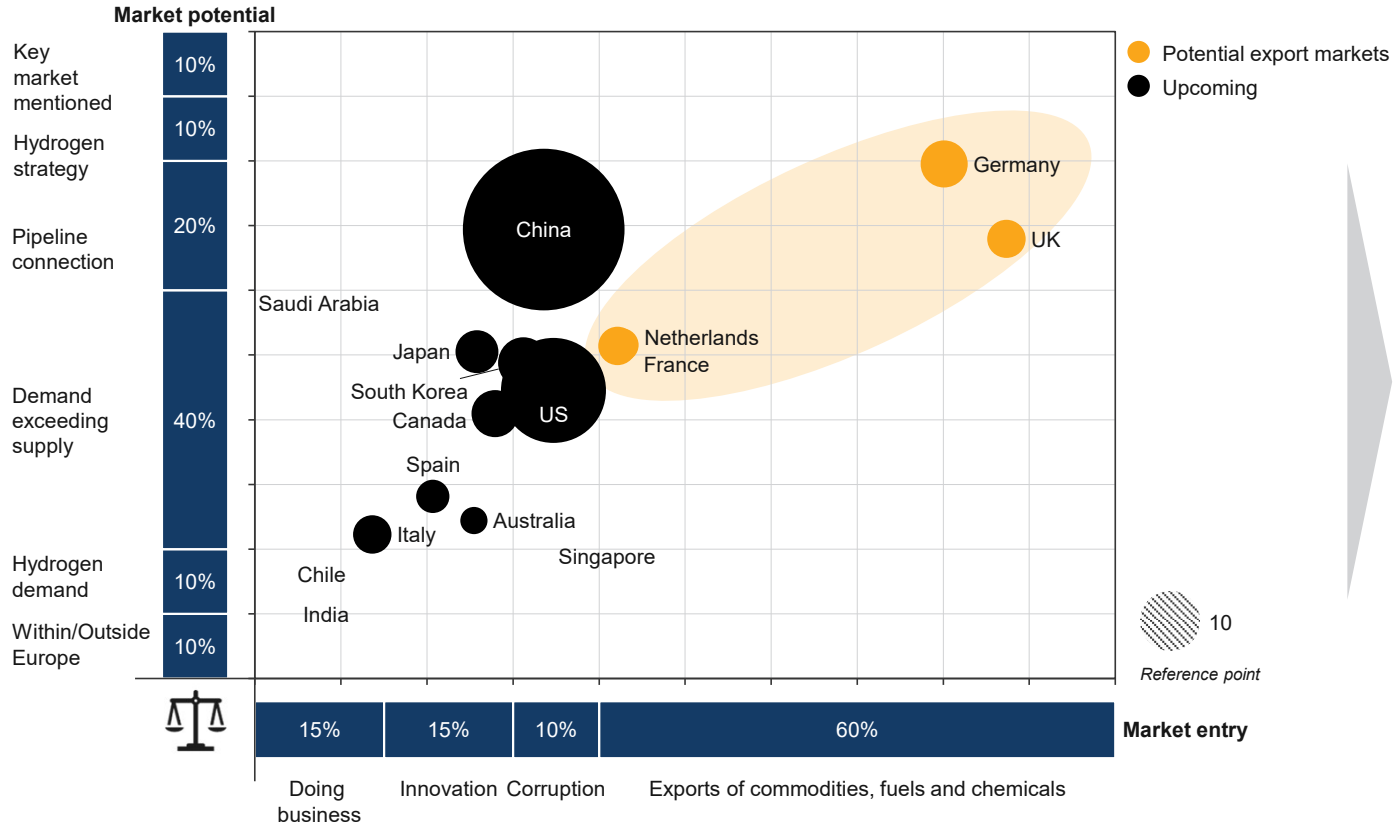
Comments

- **Germany, the US, the Netherlands, the UK and France show favourable conditions** for export hydrogen-enabling technology
- The priority 1 outcome reflects on
  - Existing trade connections with the Nordics*
  - Relevance for interviewed industry actors
  - Declared government focus with more or less earmarked investments
- Key markets **explore both green and blue hydrogen opportunities**, which could offer an opportunity for the broader Nordic hydrogen value chain
- **Global key supply markets** such as **Australia and China** could also provide potential
  - Given the distance and lower existing trade, **joint Nordic collaboration is assumed to be have more impact** for the Nordic hydrogen ecosystem

Source: UN Comtrade 2021; Statistics Norway; Statistics Sweden; H2I.2021; WB Ease of Doing Business 2020; Transparency International Corruption Perception Index 2021; Report analysis
Note: Bubble size = clean hydrogen supply in 2050, Mt p.a. No bubble = missing data | Demand data partly derived by benchmarking to EHB report from 2021 | *Nordic trade data includes Finland, Norway, Sweden | Hydrogen Investability Index incorporates national strategies and Ease of Doing Business (2020); National hydrogen strategy is included as a separate parameter to mirror any updates since the report publishing.| Key markets reflect markets mentioned as interest for hydrogen business, not specific exports and investments

Key markets for hydrogen and derivatives build on geographical closeness, projected net demand and existing trade relations

Potential markets for Nordic exports of hydrogen and hydrogen derivates



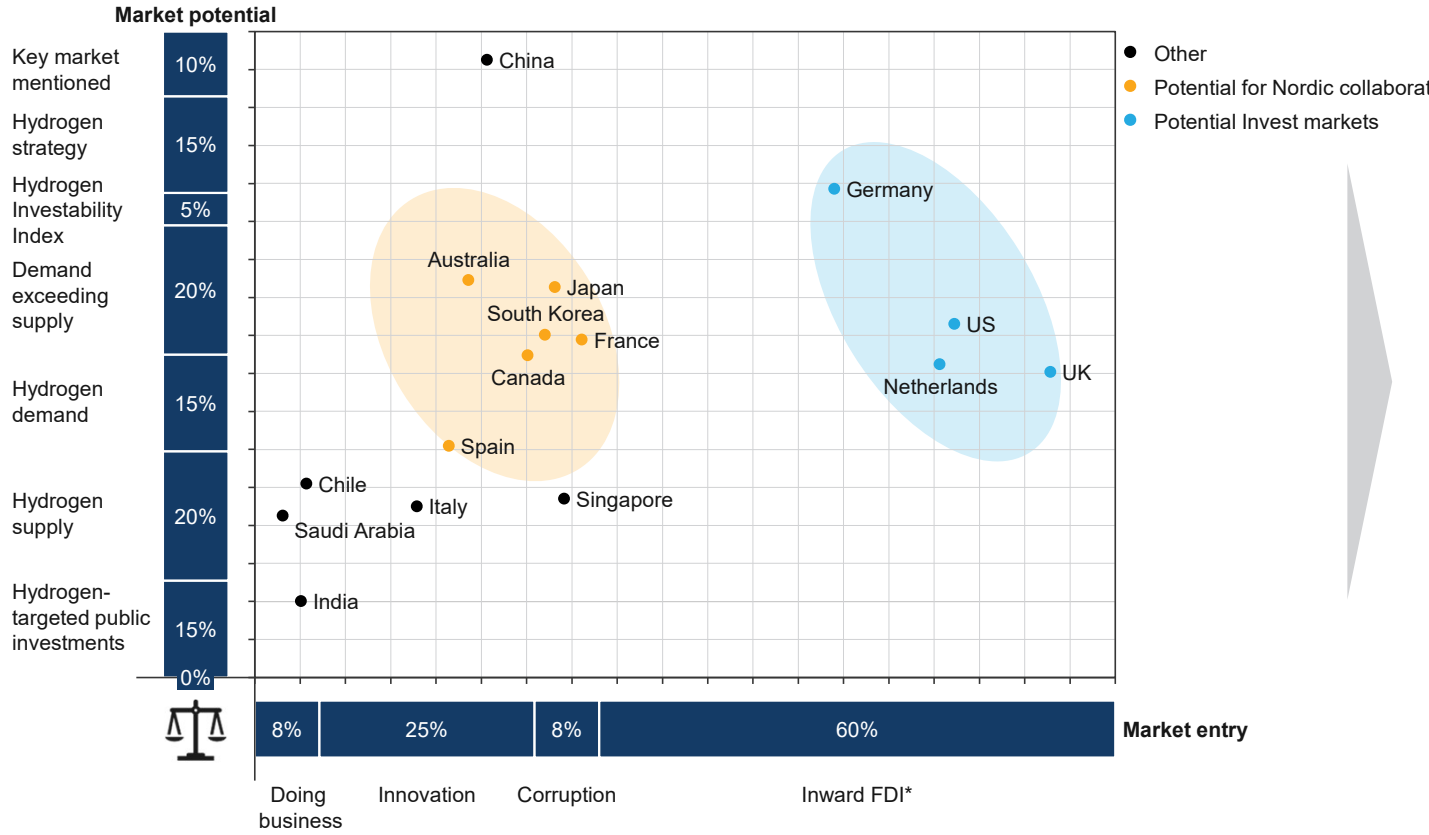
Comments

- Notably **Germany and the UK, followed by the Netherlands and France**, are considered **key export markets** for hydrogen and hydrogen derivates (such as ammonia)
- The priority 1 outcome reflects on
  - Close distance as well as pipeline connection (planned via EHB or existing) to the Nordics
  - Potential for exports, given that projected demand is expected to exceed supply by 2050
  - Existing trade relations of fuel, chemicals and commodities, i.e. existing networks and experiences to build on
- **Shipping of hydrogen and derivates** will **open up the export potential** to additional far-away global hydrogen hubs
  - Likely demand hubs as China, South Korea and Japan of additional interest

Source: : UN Comtrade 2021; Statistics Norway; Statistics Sweden; H2I.2021; WB Ease of Doing Business 2020; Transparency International Corruption Perception Index 2021; Report analysis
Note: Bubble size = clean hydrogen demand in 2050, Mt p.a. No bubble = missing data | Nordic trade data includes Finland, Norway, Sweden | Key markets reflect markets mentioned as interest for business in general, not specific exports and investments

Potential FDI markets already invest in the Nordics, are strong innovation players and have a fostering domestic industry – faraway markets potential for growth

Potential markets for foreign direct investments to the Nordics



Comments

- **Germany, US, the Netherlands and the UK** are considered **immediate potential key markets for FDI** to the Nordics
- Other faraway markets such as Australia, South Korea and Japan are key for further FDI exploration
  - Given the distance and lower existing trade, **joint Nordic collaboration is assumed to be have more impact** for the Nordic hydrogen ecosystem
- The potential invest markets reflect on:
  - Strong **existing FDI relations** to the Nordics
  - **High rankings** in innovation
  - **Mentioned markets**** in the industry interviews
  - **Supportive public investment schemes** for hydrogen, assumed to foster a local industry ready to find growth opportunities abroad
- National R&D initiatives identified in all top markets - could provide **good prerequisites for increased R&D collaboration**

Source: UN Comtrade 2021; Statistics Norway; Statistics Sweden; H2I.2021; WB Ease of Doing Business 2020; Transparency International Corruption Perception Index 2021; Report analysis
Note: *Nordic trade data includes Finland, Norway, Sweden | Hydrogen Investability Index incorporates national strategies and Ease of Doing Business (2020); National hydrogen strategy is included as a separate parameter to mirror any updates since the report publishing.| **Key markets reflect markets mentioned as interest for business in general, not specific exports and investments

The highest concentration of large key hydrogen events is in Europe and brings together stakeholders from all parts of the hydrogen value chain

CERAWEEK
Location: Houston, Texas, USA
When: 6 – 10 March 2023 | annually
Focus: Broader but high-profile energy conference, with a dedicated section for innovative hydrogen technology
Key actors: US policy makers, The White House, Shell, NextEra Energy, OPEC, bp

Canadian Hydrogen Convention
Location: Edmonton, Canada
When: April 25 – 27 2023 | annually
Focus: Production, storage and infrastructure
Key actors: Worley, TC Energy, ATCO, Enbridge, wsp, Fluor, governmental representatives

The Australian Hydrogen Conference
Location: Brisbane, Australia
When: 25 – 26 May 2023 | annually
Focus: Policy, infrastructure, electrolyser manufacturing, heavy industry applications
Key actors: GHD, bp, Worley, Woodside Energy, LETA, Arup, DNV, GFG, GE

H2 MEET
Location: Seoul, Korea
When: 13 – 15 September 2023 | annually
Focus: All parts of the value chain (mobility, energy, environment, technology)
Key actors: A&G, Yest, RWE, Synopex, Korean Ministry of Trade

World Smart Energy Week
Location: Tokyo/Osaka, Japan
When: 15 – 17 March 2023 & 13 – 15 September 2023 | bi-annually
Focus: High profile energy event, with broad H2 expo from the whole value chain
Key actors: Hitachi, ABB, Alfa Laval, Tokyo Gas, Enogia, Daido Steel, NEL

World Hydrogen Technology Convention
Location: Foshan, China
When: 22 – 26 May 2023 | annually
Focus: Broader tech event, with dedicated section on hydrogen and fuel cells
Key actors: Governmental rep., municipalities, IAHE, China Machinery Industry Federation, China Electrical Equipment Industrial Assoc.

Hydrogen Technology Expo Europe
Location: Messe Bremen, Germany
When: 27 – 28 September 2023 | annually
Focus: Largest suppliers trade fair for H2 technologies, materials, components, and engineering solutions
Key actors: Air Liquide, Baker Hughes, AVL, Siemens Energy, FEV, ABB, E.ON

European Hydrogen Week
Location: Brussels, Belgium
When: 20 – 24 November 2023 | annually
Focus: All parts of the value chain
Key actors: Hydrogen Europe, Clean Hydrogen Partnership, Advent, NEL, Plagazi, Sunfire, Airbus, HYVIA, bp, RWE

World Hydrogen Summit
Location: Rotterdam, Netherlands
When: 9 – 11 May 2023 | annually
Focus: All parts of the value chain, mainly mobility, energy and manufacturing industry
Key actors: SmartEnergy, Bosch, bp, AirProducts, HyCC, Emerson, Gexcon, Cepsa

Connecting Green Hydrogen Europe
Location: Madrid, Spain
When: 05 – 06 July 2023 | annually
Focus: clean hydrogen production, efficient storage, stationary and mobile applications
Key actors: Eurogas, Hydrogen Europe, E.ON, Enagás, bp, port representatives

Hyvolution Paris
Location: Paris, France
When: 1 – 2 February 2023 | annually
Focus: All parts of the value chain, mainly mobility, energy and manufacturing industry
Key actors: France Hydrogene, engie, EDF, Air Liquide, McPhy Energy, Vinci Energies, Teréga

Green Hydrogen 2023
Location: Birmingham, UK
When: 03 May 2023 | annually
Focus: Policy, incentives, infrastructure, industry
Key actors: RWE, Burges Salmon, Schneider Electric, Statkraft, sse Renewables

Source: Report analysis

The Nordics have several favourable prerequisites for a global role in the clean hydrogen value chain

Outline of key pillars of the Nordic Value Proposition for the clean hydrogen economy

Fossil free power systems	• The power system of the Nordics is cost efficient, resilient and fossil free with outstanding conditions and plans to increase renewable and fossil-free power generation
Complementary clean hydrogen offer	• The Nordics' offer includes blue and green hydrogen – complementing one another on carbon foot-print, volume and price over time
Access to biogenic carbon	• Nordics provide abundant amounts captured and biogenic carbon. Combined with clean hydrogen supply, gives the region possibility to produce any Power-to-X fuel and feed-stock
Leading energy, industrial and mobility ecosystem	• The Nordics provides a complementary all round energy, industrial and mobility triple-helix ecosystem matching the needs of the hydrogen value chain with actors ready to lead the way, take risk and open for new partnerships
Sustainability leaders and innovation pioneers	• Nordics are innovation and sustainability leaders with a highly skilled workforce conducting groundbreaking R&D&I
Favorable business climate, stable society, collaborative culture	• Nordics are top ranked on all parameters providing the basis for driving a cross-sectorial technology and business model shift such as democracy, resilience, corruption perception, digital competitiveness and network readiness

> ***"As soon as someone showed that green steel is possible, demand is popping up from all kinds of sectors"***
>
> [Swedish company]

> ***"We aim as high as possible in the hydrogen value chain"***
>
> [Finnish company]

> ***"We are an open culture. Working with partners that have the same mindset is great"***
>
> [Norwegian company]

The Nordics have a unique opportunity to position itself as an innovative, collaborative business partner on the global hydrogen arena

Source: Report interviews and analysis of statistics

The industry is convinced that the Nordics have role to play in globally booming hydrogen market based on the right strategic choices

Recommendations from the Nordic industry

Complementary clean hydrogen offer

- The clean hydrogen value chain is intertwined, spans over and make use of major natural resources and **impacts all parts of industry, transport, power system and housing**
- Hydrogen will **play a key role for Nordics** from green transition and business potential
- It is a strength of the Nordics to offer blue and green hydrogen – complementing one another on carbon footprint, volume and price over time

Nordic collaboration

- Nordic has potential to **build leading solutions based on complementary capacity of low carbon products** (e.g. low carbon windmills, low carbon shipping), and core enabling technology (such as. electrolysers, CCS/CCU, fuel cells, storage technology)
- **Nordic can be a global testbed** by speeding and scaling up first-in-the-world hydrogen enabled lighthouse projects based on areas of industrial capacity and first mover attitude

Export focus

- As a free-trade region, Nordics will **export from all steps of hydrogen value chain** (hydrogen, hydrogen derivates as fuels, low carbon material, products based on low carbon material and fuels, as well as enabling technology for all steps)
- However, the proactive export strategy should be targeted towards **high value addition exports** e.g. by development of market segment for low carbon products through regulations and demand creation

Investment focus

- Investment strategy should be **targeted to fill gaps in the Nordic offer rigged towards high value addition** (both in enabling technology and process ownership)
- Nordics has a strong investment business case but Nordics need to work **for creating an incentive level playing field within EU** and other key markets, such as the US
- **Development and attraction of competence** and global key R&D&I arenas to Nordics will be crucial

> ***We need to get investments to the Nordics; all governments need to focus on this***
>
> [Finnish company]

> ***We need more Nordic pilots where we have a chance to test our solutions together***
>
> [Norwegian company]

> ***We need to create the internal market within the Nordics***
>
> [Swedish company]

The industry suggests that Nordic export and investment strategy should aim at value addition within Nordics, climate neutrality and resilience

Source: Interviews and analysis

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The conducted report indicated that overall, joint actions for Nordic collaboration, trade and invest promotion can benefit the Nordic hydrogen market

		Nordic Collaboration *the extended home market*	**Exports from the Nordics** *premium low carbon products & enabling tech*	**Global Investments in the Nordics** *scale, speed to complement the Nordic VC*
The Nordics story - originator globally of clean hydrogen enabled products Together we reach scale and have a full value chain offer	1) Formulate the Nordic offer	A Nordic value proposition positioning the Nordic high up in the hydrogen value chain	Toolkit for joint Nordic high-value trade promotion in global markets**	Toolkit for joint Nordic promotion in global markets**
	2) Position the Nordics	Set up joint collaboration forum to agree on joint export and invest promotion	Joint export promotion on key global platforms America/Asia//MEA (such as H2 Meet (Korea) CERAWEEK (US)– create exclusive Nordic meets	Joint invest promotion on select key arenas**
	3) Develop the Nordic value chain offer	Build Nordic leading offer of low carbon products (such as steel, SAF) and core technology (such as. electrolysers, CCS/CCU, fuel cells) – adapted to countries' complements	In select key markets**, promote development of premium segment for low carbon products and leading enabling technology	Attract key technology actors to increase speed of growth and fill gaps in Nordic offer of key technologies
To thrive, Nordics partner with the best and is the cradle of and capture key projects	4) Capture global key partners and projects	Develop first-in-the-world hydrogen enabled lighthouse projects based on areas of industrial heritage as well as need for resilience	Identify key projects for joint "High Potential Opportunity" approach	Joint "High Potential Investment" capture in resilience need areas where Nordics has gaps
We increase speed to market for our SMEs in the hydrogen value chain	5) Enable Nordic SMEs	Open up business opportunities for SMEs with dedicated program for joint business opportunities/match-making/financing towards Nordic potential partners/customers/projects	Support Nordic SMEs in market entry global key markets**	*N/A*
Nordic framework of policy, financing, R&D&I, competence, infrastructure is in need	6) Team Nordic to establish the right conditions of key support elements*	Establish aligned Nordic policy, financing tools, R&D&I, competence development and integrated infrastructure for leveled global field	A joint Nordic voice in EU for hydrogen related policy. Access global key R&D&I arenas	Attract global key R&D&I arenas to Nordics Attract global talent to the Nordics

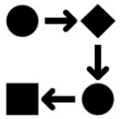
Timeline

- **Initiate/plan 2023**
- **Initiate/plan 2023**
- **Start 2024/25**

Note: Recommendations need to be further specified and anchored with other actors *TPOs not main responsible – relevant for greater Team Nordic ecosystem ** Key markets preliminary - to be further evaluated and agreed upon

The immediate first step is to familiarise within the Nordics

- Three initial tangible points of actions are agreed upon going forward

	Joint TPO Hydrogen Dialogue	**Nordic industry forum**	**First trials joint Nordic Export Promotion**
			
What:	H2 Nordic Collaboration Forum	Nordic industry forum at existing Hydrogen conference in Nordics	Joint export promotion
Why:	Coordinate efforts and initiatives	Create an industry meeting and collaboration spot	Try out how to create synergies in hydrogen promotion work
How:	3-4 meetings annually	Minimum 1 annual joint activity	In planned promotion events, add joint TPO support for Hydrogen promotion
Focus:	• *Market development and Nordic position* • *Upcoming key events for joint Nordic positioning* • *Ongoing export cases* • *Potential invest business cases*	*Example of activities to link up on* • *Norsk Hydrogenforum annual conference* • *Sweden Hydrogen Development Center Meet-Up*	*Example for discussion* • *COP28* • *Groeningen Hydrogen conference, Netherlands* • *Nordic embassy collaboration Australia*

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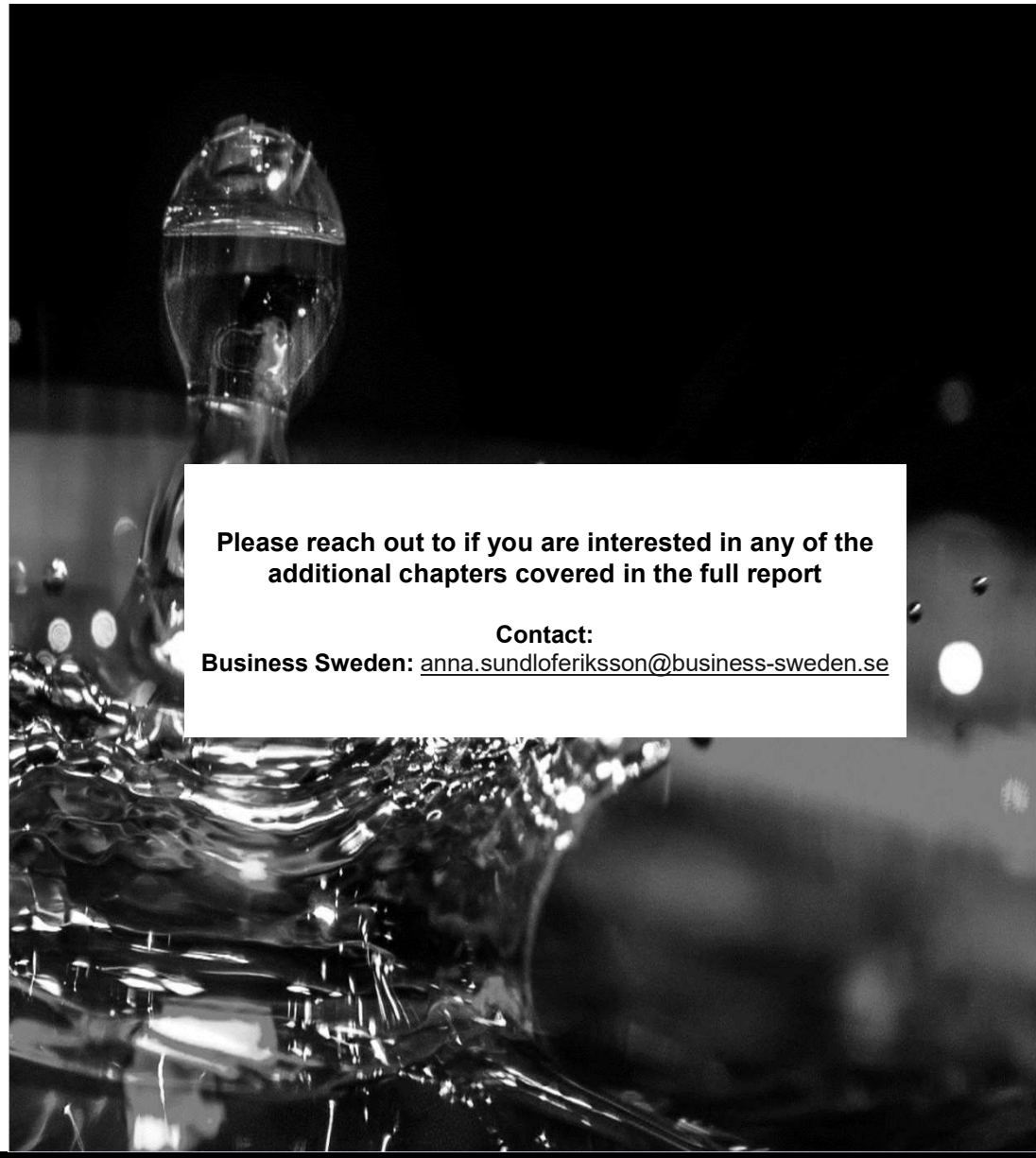

Please reach out to if you are interested in any of the additional chapters covered in the full report

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List of abbreviations and key terminologies

Technical	
GHG	Green house gas/gases
CCUS	Carbon capture, utilisation and storage
H2	Hydrogen
LNG	Liquified natural gas
LH2	Liquid hydrogen
NH3	Ammonia
RES	Renewable energy source/sources
LCOH	Levelised cost of hydrogen
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
SOEC (electrolysers)	Solid oxide electrolyser cell electrolysers
PEM (electrolysers)	Polymer electrolyte membrane electrolyser
AEM (electrolysers)	Anion exchange membrane electrolyser technology
Scenarios	
STEPS	Stated Policies Scenario
APS	Announced Pledges Scenario
NZE	Net Zero Emissions by 2050 Scenario
General	
CAPEX	Capital expenditure
OPEX	Operational expenditure
EHB	European Hydrogen Backbone
R&D	Research and development
EU, EC	European Union, European Commission

Terminology	
Clean hydrogen	Derived from Clean Hydrogen Monitor 2022 with definition input from Swedish Energy Agency: Hydrogen produced from electrolysis from both renewable electricity or low-carbon electricity and SMR-based hydrogen with carbon capture with a minimum greenhouse gas emission saving of 70% compared to the fossil fuel comparator set out in Annex V of Directive (EU) 2018/2001
Total primary energy supply	Total primary energy supply (TPES) is the total amount of primary energy that a country has at their disposal. This includes imported energy, exported energy (subtracted off) and energy extracted from natural resources (energy production).
Electrolysis	A chemical process where electricity is used to split water into hydrogen and oxygen
Electrolyser	The unit where electrolysis takes place
Power-to-X	Power-to-X means converting power into something else (x). As an example, power can be converted via electrolysis into hydrogen, to be further applied in hard-to-abate industries
Off-grid electrolysis / electrolyser	Electrolyser not connected to the main electricity grid
On-grid electrolysis / electrolyser	Electrolyser connected to the main electricity grid
EU regulation	Legal act that is automatically binding for all EU countries from the time it enters into force, without needed to be transferred into national law
EU directive	Legal act that requires all EU countries to achieve certain objectives but lets them choose freely how to do so by incorporating measures into national law. Member countries have a set deadline when the directive needs to be adopted
Policy	(Not description from EU) Set of guidelines used as basis for decision making
Strategy	Published summary of political goals in specific area
Roadmap	Communication plan to get all stakeholders aligned on one strategy and guides progress towards a common goal

List of select key reports sources

Organisation	Report name	Year published
Business Finland	National Hydrogen Roadmap for Finland	2022
Danish Ministry of Climate, Energy and Utilities	The Government's strategy for Power-to-X	December 2021
DNV	Energy Transition Outlook 2022	October 2022
European Commission	REPower EU Staff Working document	May 2022
Energinet	Winds of change in a hydrogen perspective - PtX action plan	November 2019
European Hydrogen Backbone	Analysing future demand, supply, and transport of hydrogen	June 2021
European Hydrogen Backbone	Five hydrogen supply corridors for Europe in 2030	May 2022
Finnish Ministry of the Environment	Government's climate policy: climate-neutral Finland by 2035	Spring 2022
Fossilfritt Sverige	Strategi för fossilfri konkurrenskraft	September 2021
Hydrogen Europe	Clean Hydrogen Monitor 2022	October 2022
International Energy Agency	Global Hydrogen Review 2022	September 2022
International Energy Agency	World Energy Outlook 2022	October 2022
International Energy Agency	Hydrogen Projects Database	October 2022
IFP Energies Nouvelles, SINTEF Energi AS and Deloitte Finance SAS	Hydrogen for Europe 2021	March 2021
KPMG, Evida, Energinet	Markedsdialog om brintinfrastruktur	October 2022
Kungl. IngenjörsVetenskapsAkademin	Om vätgas och dess roll i elsystemet	June 2022
McKinsey and Company	Norway tomorrow	March 2022
Menon Economics	The value of the Norwegian hydrogen industry	November 2022
Nordic Energy Research	Nordic Clean Energy Scenarios	February 2021
Nordic Energy Research	Hydrogen, electrofuels, CCU and CCS in a Nordic context	February 2022
NVE	Norwegian and Nordic impact balance until 2030	May 2022
Swedish Energy Agency	Förslag till Sveriges nationella strategi för vätgas, elektrobränslen och ammoniak	Fall 2021
Teknologisk Institut	Power-to-X - et forretningsområde i fremvækst	September 2022

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