The 2023 Hydrogen Conference

Authors

From left to right: **Jessica Lidberg** research engineer in economics, **Lisa-Marie Weniger** PhD student in Machine Elements, **Jim Allansson** PhD student in Energy Engineering, **Cecilia Wallmark** Director of the Centre for Hydrogen Energy Systems Sweden, CH2ESS. All at **Luleå University of Technology**.

The picture also includes **Örjan Johansson** professor of technical acoustics at Luleå University of Technology, who presented at the conference but did not take part in writing this report.

Contents

List of Figures

1 Opening statement

When, where, and how should we use hydrogen in Sweden? During the Hydrogen Conference 2023, which was held December 5–6 at Stockholmsmässan, nearly 350 participants were able to increase their knowledge of the role of hydrogen in the energy and climate transition through presentations, workshops, and networking. According to the mentimeter responses, the participants mainly consisted of representatives from energy companies, followed by the public sector, academia and institutes, consultants, and industries. Interest organizations were also present.

- Not many of us have had the overall perspective of how many investments are underway and how great the possibilities are in terms of hydrogen's possible contribution to climate benefits, growth, and increased security of supply in Sweden, said Cecilia Wallmark director of the Centre for Hydrogen Energy Systems Sweden, CH2ESS, at Luleå University of Technology.

During the conference, presentations were given by, among others, Scania, Nordion, Ørsted, Statkraft, the Government Office, H2 Green Steel, universities, and research institutes. Both trend scouting and the benefits and hopes of hydrogen, as well as current challenges, were raised.

In addition to some 40 speakers, panel discussion participants, and workshop organizers, the conference also had an exhibition section where 20 companies participated and where a poster exhibition of ongoing research projects was displayed. The entire conference program can be viewed here.

2 Summary of the conference sessions

The conference started with a plenary section addressing what Sweden excels at and what challenges we are facing. The rest of the conference took place in three different halls, with parallel lectures. A short summary of the plenary section and lectures are presented below. However, it should be noted that the authors of the report did not have time to attend all the presentations that were held and that the report only presents a selection of what was discussed during the conference.

2.1 Plenary Session

At the start of the plenary section introductory talks were given by Daniel Liljeberg, the State Secretary to Minister for Energy, Business and Industry Ebba Busch, Marcus Vråke, CEO for Energiforsk and Paula Hallonsten, responsible for the governmental assignment on hydrogen coordination at the Swedish Energy Agency.

This was followed by three panel discussions on the theme Sweden as a frontrunner. The panels consisted of guests invited by the moderator Cecilia Wallmark, director of the hydrogen initiative CH2ESS at Luleå University of Technology. The first panel was discussing the hydrogen and fuel cell research within Sweden which builds upon roots since the 60:ies, and have provided important research and innovation in co-operation with the industry and supported successful companies within the area such as Volvo, Scania, SSAB, LKAB, PowerCell, Permascand and Alleima.

The second panel stressed the fact that Sweden is a frontrunner within industrial use of hydrogen with companies such as Hybrit, having produced the first fossil-free steel in the world steered by the owners at LKAB, SSAB and Vattenfall, and H2 Green Steel with the ambitious plan to build a green-field green steel production. Both initiatives have encouraged many other steel companies worldwide to believe and engage in the transition to implement actual greenhouse gas reduction measures by having proven the marked demand.

The third panel discussed the importance of supporting the large initiatives, and to use the momentum to engage further stakeholders into the possibilities with hydrogen. This panel involved Sara Grundström at Invest in Norrbotten, Joachim Nordin CEO at Skellefteå Kraft and Thomas Fägerman CEO at Boden Business. They especially stressed the importance of other stakeholders already supporting the large green transition in the North of Sweden: to supply the required energy demand, to engage for new investments, and to introduce new infrastructure and services such as houses and new schools for all people moving here from around the world.

2.2 International outlook

During the International Outlook session, it became clear that hydrogen is gaining more and more interest from governments and companies all around the world. Several hydrogen-related projects are underway, and most countries have set up a national hydrogen strategy. The Nordic countries are no exception. Anna Liberg from Business Sweden emphasized that low-carbon hydrogen is identified to play a key role in the Nordic market's green transition and that the Nordics have the potential to establish leadership in the hydrogen value chain through collaborative innovation and first-in-the-world lighthouse projects.

Despite the increased interest in hydrogen, several speakers during the session pointed out that there are still several obstacles to the realization of the planned hydrogen projects. One of them is the fact that renewable hydrogen is a capital intensive business, leading to large financial risks for investors. Considering this background, Javier Garcia presented the European Hydrogen Bank's future investment plans that aim to build a market for renewable hydrogen, stimulate investments in the production capacity, and bring production to scale. The European Hydrogen Bank has a budget of EUR 40 billion to invest in 2020-2030 in the EU's climate-neutral future which will be provided through grants and auctions. The funding will be aimed at energy-intensive industries, renewables, energy storage, carbon capture use and storage, and net-zero mobility and buildings. The Innovation Fund 2023 (IF23) is part of the hydrogen bank. The IF23 auction objectives are to reduce the cost gap between renewables and fossil hydrogen, reduce the risks of hydrogen projects, price discovery and market information, and reduce administrative burdens. High focus on simplicity and implementation speed, EUR 800 million in support in the form of a fixed premium in EUR/kg hydrogen produced over a 10-year period.

Lise-Nielsen from Nordic Energy Research mentioned that energy research and common knowledge creation will play a key role for Nordic countries to be forerunners in building hydrogen value chains. A program from Nordic Energy Research consisting of five projects aims to realize this by showing the potential of hydrogen as a zero-emission energy carrier. The program is worth EUR 10 million with 55 partners from 5 countries and covers topics ranging from cross-sectoral linkage, storage and transport, materials and safety, and social acceptance.

But, even though it can be capital-intensive to start a hydrogen-related business, several companies have decided to invest in hydrogen-related projects. Martina Wettin from Nilsson Energy presented some of their hydrogen projects. Including a backup power system and electrical vehicle charging in Karlstad, a self-sufficient hydrogen system solution for offices and hydrogen dispensers for hydrogen refueling in Sjöbo, and several pre-studies for hydrogen at airports and hydrogen refueling stations.

Rose Sergeant, representing Örsted, mentioned that around 30% of global emissions come from sectors that are hard to electrify and need other solutions. Power-to-X offers such a solution through electrofuels or advanced biofuels. Roughly 800 power-to-X projects are announced globally, with a majority being in the EU which can be seen below in figure 1. Örsted's current announced electrolyser capacity reaches 835 MW, and their goal is to reach 1 GW of capacity by 2030. The company's flagship project in Örnsköldsvik is currently Europe's largest e-methanol plant, planning to produce 50,000 metric tons annually.

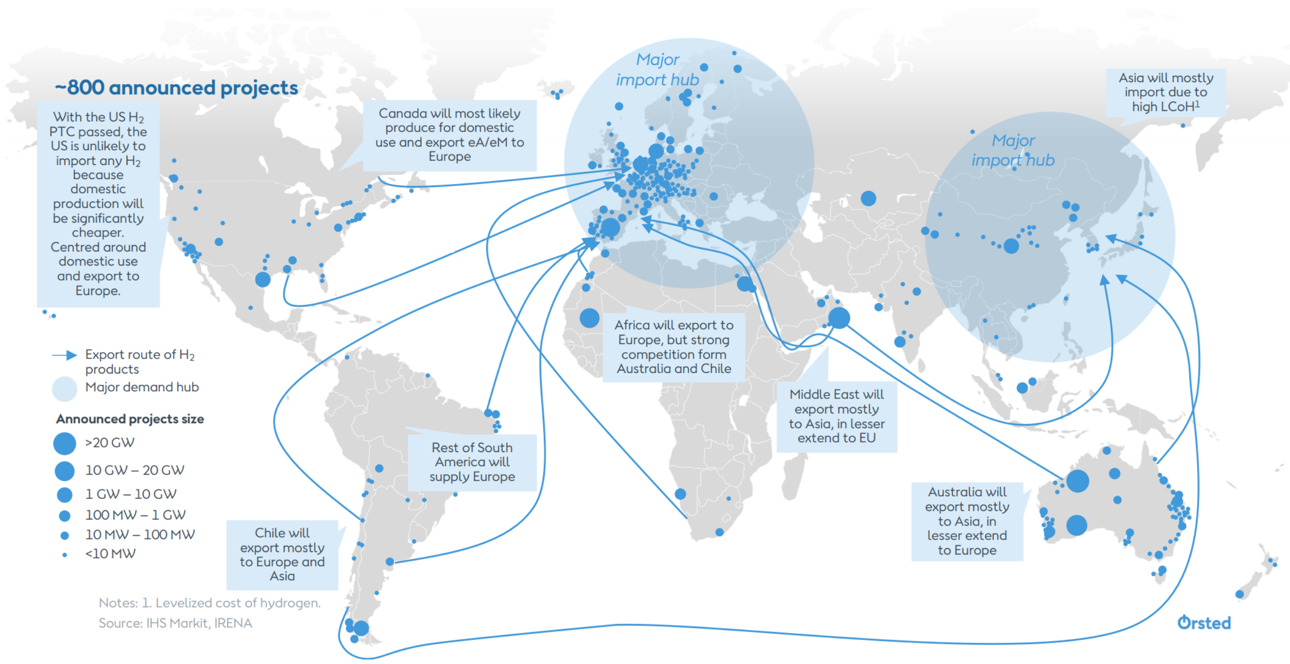

Figure 1: 800 P2X projects announced worldwide (Source: Örsteds presentation)

Juha Lehtonen from VTT mentioned that Finland has announced 47 hydrogen-related projects, mainly aimed at hydrogen production through electrolysis, with a total of 760 MW of electrolyzer capacity. Juha also mentioned that common power-to-X pathways are methanol through the synthesis of CO2 and H2, methane through biological/catalytic methanation of CO2 and H2, fisher tropsch synthesis, and ammonia synthesis. For these power-to-X pathways to be environmentally friendly, the hydrogen needs to be produced through renewable energy and the CO2 needs to come from biogenic sources. Which leads to many good opportunities for collaboration between Sweden and Finland since both countries have good conditions for both biogenic CO2 and renewable hydrogen.

2.3 Transportation and Fuel

The session on Transport and Fuel was characterized by discussions about the role and potential of hydrogen in the transport sector, challenges regarding scale-up of hydrogen vehicles and investments in refueling infrastructure. Sweden has two strong suppliers of heavy vehicles with adaptation for hydrogen as a fuel, and over 60 hydrogen filling stations in the planning stage. At the same time, getting the vehicle fleet to these filling stations is one of the most relevant challenges right now.

Transportation is responsible for almost 25% of the greenhouse gas emissions in the EU. Several sectors are seeing a transition in the form of electrification through battery electric vehicles, but some sectors of transportation are facing challenges due to the harsh operating conditions and heavy weight of batteries. Hans Pohl from Lindholmen mentioned that some strategies have changed their vehicle fleet plan from a 70/30 split in favor of battery vehicles (70% battery electric vehicles and 30% hydrogen fuel cells) to a 70/30 split in favor of hydrogen. However, a problem with hydrogen vehicles is a lack of experience. A study observing several different projects observing the usage of hydrogen-fueled vehicles with high mileage identified that the primary problems with hydrogen were a lack of expertise when serving vehicles at workshops and fuel availability. Some projects saw more than 7 million km of accumulated distance traveled across their vehicles and saw no more breakdowns than could be expected with a diesel equivalent.

Fuel availability is something that was frequently mentioned as a concern, together with the “hen and egg problem” of which should come first, the fueling infrastructure or the vehicles. Peter Rydebrink from Euromekanik mentioned challenges with hydrogen refueling stations. They are currently relatively expensive, handle low volumes, and need support across the whole value chain. He also mentions that uncertainties regarding safety, power, and space result in many planned, but few realized projects. But there is a need for hydrogen, especially in the heavy duty sector, and there are incentives for more refueling stations, such as the Alternative Fuel Infrastructure Regulation (AFIR) and Klimatklivet. Pawel Seremak mentions the Nordic Hydrogen Corridor (NHC) which is a market pilot for hydrogen mobility, including infrastructure such as hydrogen refueling stations, hydrogen fuel cell vehicles, and market evaluations. The strategy of the NHC is to connect the capitals of Sweden, Norway, and Denmark. This can be seen on the map of hydrogen refuelling stations in figure 2.

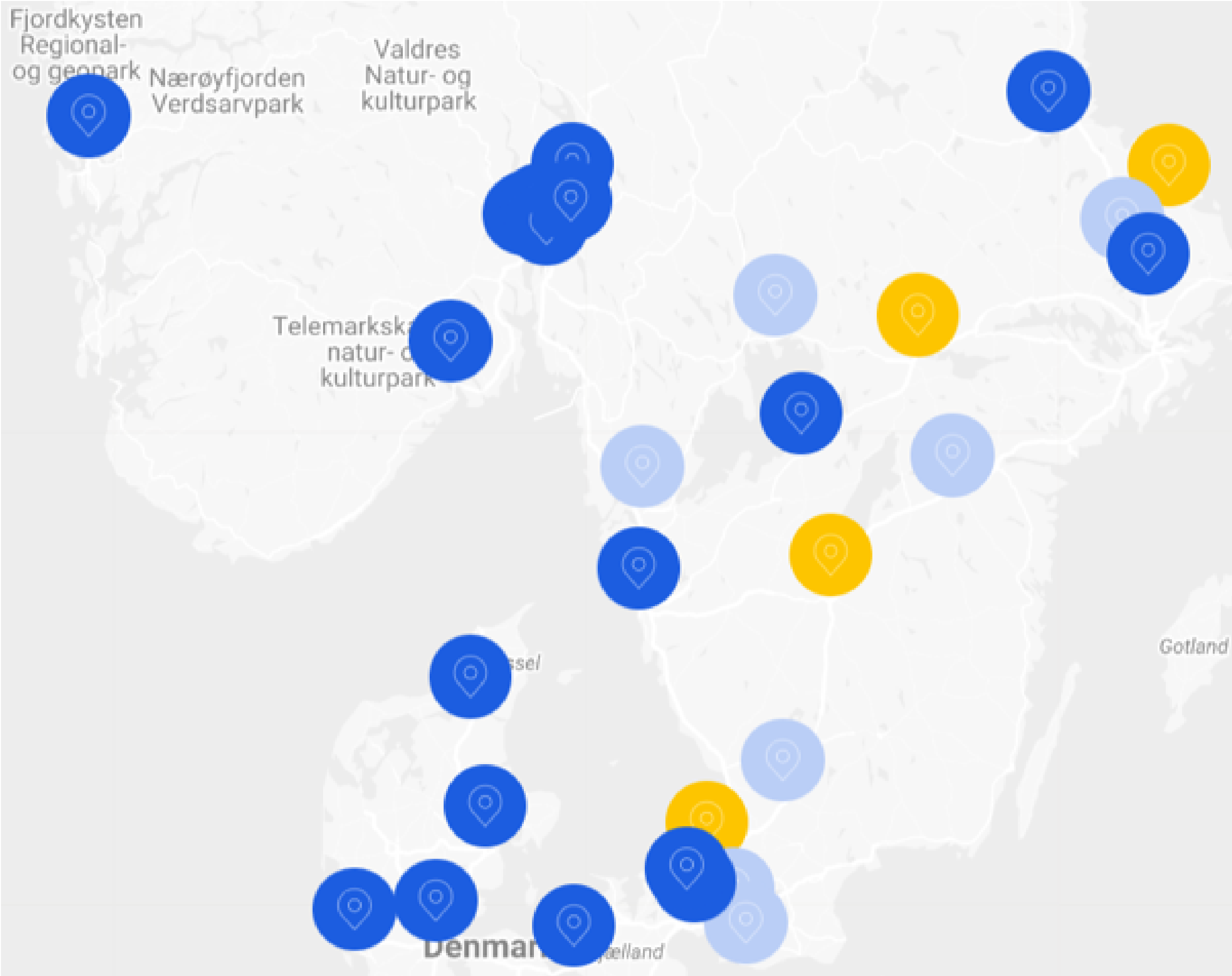

Figure 2: NHC hydrogen refueling stations. Dark blue = in operation, light blue = planned, and yellow = planned by Everfuel (source: Nordic Hydrogen Corridor)

Peter also mentioned that the internal combustion engine can act as a shortcut for the vehicle side due to its technical maturity. This vision can also be seen in both Volvos and Scanias strategies, including battery electric, hydrogen fuel cells, and hydrogen internal combustion engines. Staffan Lundgren from Volvo emphasizes that the advantages of the internal combustion driveline are that it is cheaper and has higher maturity. However, hydrogen internal combustion engines still emit oxides (eg.NOx). Ola Henriksson, Scania, mentions that biofuels have shown good environmental and economic results. However, Scanias main focus is on battery-electric vehicles, but they do see a market for hydrogen-powered vehicles, especially when payload, range, and uptime are of great importance. They believe in fuel cells, but since the internal combustion engine is more mature, the fuel cell is more of a future solution.

Fuel costs typically represent a third of a long-haul company's total cost of ownership; increased fuel costs would hit hard on the bottom line of their customers. For alternative fuels to become a reality, economic endurance is needed; it will not be profitable in the beginning. However, a larger part can be subsidized through increased taxes on fossil fuels. Long-term political support is also of importance, along with technical development.

2.4 The Potential of Hydrogen

The Potential of Hydrogen session covered a wide range of subjects, including discussions about how Nordic countries can become forerunners in hydrogen, how rural areas can use hydrogen for emergency backup power, and how the Nordic industrial clusters, despite their great emission reduction potential, will likely not benefit from the EU's hydrogen bank auctions. Staffan Sandblom from Fortum explains the latter by stating that the current design of the production auction, where the winners are the lowest bidders, has a built-in bias for projects with low production costs. Since the hydrogen production projects with low production costs are often those that are directly connected to renewable energy sources that produce low volumes of hydrogen, the heavy industries (iron & steel, chemical industry etc.) in the Nordic countries will likely not be competitive in auctions as they require a constant large scale hydrogen supply.

Moreover, Leena Sivill and Robin Falconer from Afry, discussed challenges and opportunities of a hydrogen transmission network. They mentioned that a hydrogen transmission network may be better compared to scaling up the electricity transmission network from a system cost perspective. With hydrogen transmission, demand and supply can be balanced through linepack (the naturally occurring storage inside a pipeline). Hydrogen transmission would develop a market with competitive prices and possibilities of selecting a supplier. Downsides are the uncertainties of volumes and parties connecting to the pipeline over time, large upfront investments, and risks of under- or oversizing. But the upsides outweigh the downsides, and several projects have reached common and mutual interest with other EU and non-EU countries.

Jatta Jussila presented the Baltic Sea H2 project, involving 40 partners from nine different countries, aiming to connect hydrogen valleys across countries. The project aims to cover the entire supply chain, and will demonstrate over 20 use cases. The Nordic countries already have existing electricity and gas grid connections, available emission free electricity, good availability of biogenic CO2, and clean water, resulting in good conditions for successful implementation. Herkko Plit from P2X Solutions also puts high emphasis on Nordic collaboration, striving for Nordic optimization instead of local or municipal sub-optimizations. Herkko also mentioned the good conditions of Sweden and Finland having access to cheap electricity and a good forest industry. In Finland, P2X solutions aim to have 1 GW of electrolysis capacity by 2031 and production of hydrogen and green methane by the summer of 2024. Fortum is another company looking at solutions for industries to decarbonise with the help of hydrogen. Fortum, together with Metsä Group in Finland, is looking at ways to further process carbon dioxide with the help of hydrogen. This can further be used in, for example, the chemical industry see figure 3 below.

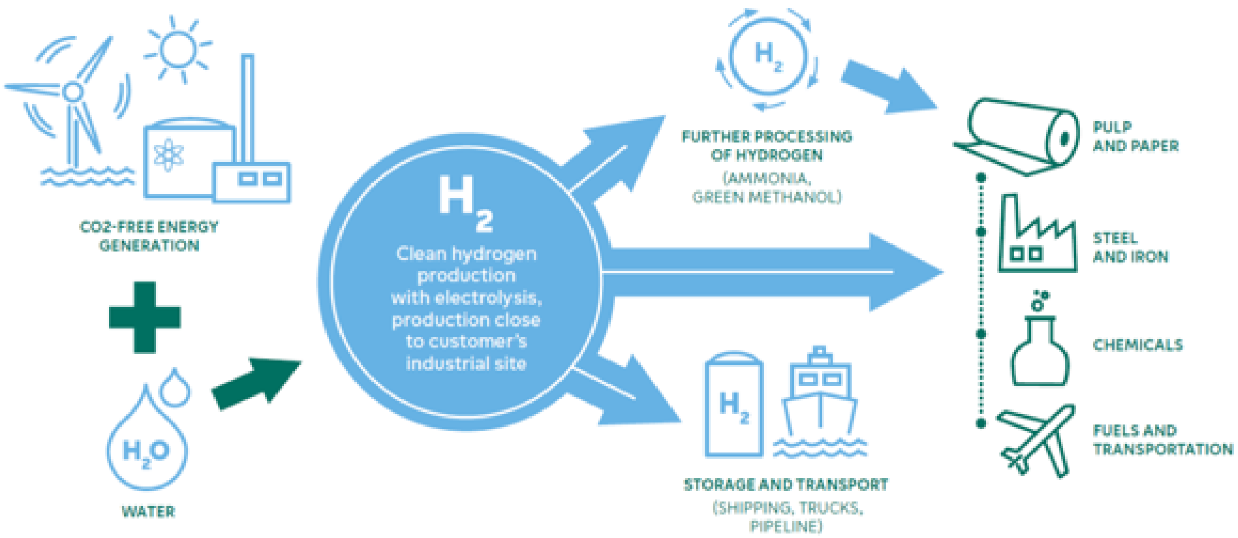

Figure 3: Different hydrogen pathways (Source: Fortums presentation)

Another project looking into the potential of hydrogen is the (H)elsäker landsbyggd project. The project aims to evaluate the potential of the countryside to become more self-sufficient by introducing an integrated energy storage solution. With such solutions, the countryside would be more resilient to crises and boost the local economy. The goal of the project is to go from idea to production and industrialization.

2.5 Potential and Conditions in the Energy System

The Potential and Conditions in the Energy System session began with 17 ongoing hydrogen-related research projects on different topics such as material properties, economics, and law being pitched to the audience. The project assessing the potential of hydrogen in Sweden concluded that hydrogen can play an important role in several aspects of our future energy system. Other projects looked into ways to improve the production of hydrogen through new technologies and materials used in the electrolyzers, showing promising results in increasing efficiency and reducing costs. For more information on the research projects see the dedicated chapter, Ongoing research, for the 17 projects.

The session proceeded with a presentation by Anna Alexandersson and Per Rosenqvist from Statkraft. They explained that electrification of transport, industry, and buildings will require more than double the power demand in 2050 compared to 2020. With renewable energy sources such as wind and solar, the power market is changing and becoming more intermittent. Hydrogen is believed to play an important role in mitigating this intermittency, as can be seen in figure 4 below displaying the projected global hydrogen demand in 2050. Statkraft has several planned hydrogen projects, including a 5 MW electrolyser in Gothenburg harbor for heavy transport, maritime, and harbor activities. 10+ MW electrolyzer in Emden, Germany, for heavy-duty transport and maritime use. 20-40 MW in Mo, Norway, for the steel and transport industries. 2-100 MW electrolyser in Hardanger, Norway, is used for the steel and transport industry, and 100 MW in north-western England is used for industry purposes.

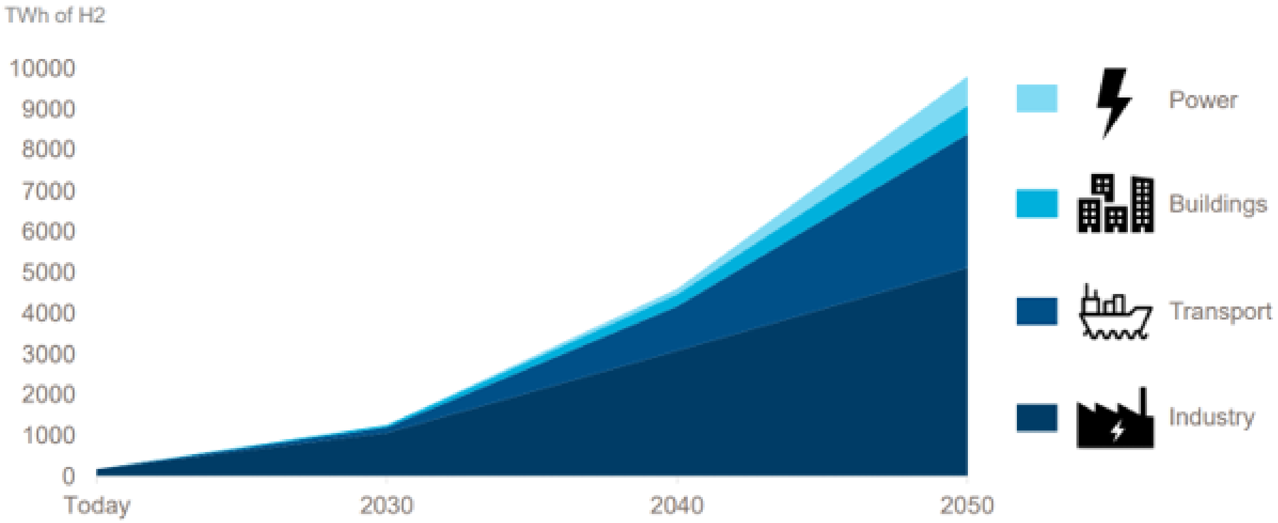

Figure 4: Projected global hydrogen demand of different sectors (Source: Statkrafts presentation)

Lars Andersson, Energiföretagen, mentioned that for large-scale hydrogen distribution to succeed, regulations for hydrogen pipelines need to be developed. Depending on which local authority you ask, you can get different answers on how to handle hydrogen and what is needed. A common ground for concessions on hydrogen operations is needed. According to Lars, there are benefits to including hydrogen in the natural gas law, both from a national and EU point of view.

2.6 Infrastructure / Resilience and Safety

Björn Santana Andersson, Nordion Energy, stated during the Infrastructure/ Resilience and Safety session that Sweden has excellent conditions for being a forerunner when it comes to hydrogen; we have plenty of forest, wind, and hydroelectric energy. Björn Santana mentions that Nordion Energy has large pipeline infrastructure plans for Sweden with both the Nordic hydrogen route, connecting Örnsköldsvik, Luleå, Kiruna, and Vaasa, and the Baltic Sea hydrogen connector, connecting Gävle, Åbo, and Germany through a pipeline network. Future plans involve connecting the north and south of Sweden through a pipeline network spanning the whole length of Sweden, see figure 5.

Anna Wallentin, Energigas Sverige, mentions that the current tax legislation is from 2003 and is not adapted for the recent developments in hydrogen. With today's legislation, the total tax cost can differ significantly depending on the "main activity" of the hydrogen plant and if it is used in a fuel cell or an internal combustion engine. Furthermore, hydrogen is taxed the same regardless of whether it is fossil or renewable. Thus, the current legislation hinders the technical development and transition to increased use and production of renewable hydrogen. However, good conditions for favourable policy instruments for renewable hydrogen are now given in EU law. For example, the EU Emission Trading System 1(ETS 1) will include the production of hydrogen gas, which will benefit renewable production of hydrogen as it can receive extra money from selling emission allowances.

Figure 5: Hydrogen gas grid. Solid orange = Planned hydrogen networks, Dotted orange = Future hydrogen network, Dark orange = Current gas grid, Yellow = Electricity grid (Source: Nordion presentation)

Concerning the safety of hydrogen Marcus Runefors from Lunds Tekniska Högskola explained that there will almost always be a small hydrogen leakage when dealing with hydrogen. It is thus important to have good ventilation in the room where hydrogen is stored or used to avoid the formation of a gas cloud. If a leakage would ignite and form a jet flame, measures should have been taken to make sure that the flame is pointed away from important parts, such as composite tanks. If a gas cloud were to be formed and ignited objects inside a detonation zone, it could accelerate the flame and cause problems. Due to the high pressure when storing hydrogen, a tank rupture must be prevented at all costs. When handling liquid hydrogen, some additional risks are introduced, but otherwise, it is similar to the gas form.

2.7 Fuel and Production

The Fuel and Production session opened with the fact that several transport industries have declared their interest in moving to renewable fuels, following the EU Fit for 55 package. This can be seen in the shipping industry, where only 6% of ships (gross tonnage) in 2023 were using alternative fuels (LNG, methanol, hydrogen, etc.) while over 50% of ships ordered to be built will use alternative fuels.

Julia Hansson from IVL presented a project called HOPE, where they evaluated different fuel production pathways and usages, see figure 6. In the project they found that hydrogen can be a cost-efficient way of reducing greenhouse gas emissions from a global long-term perspective. However, there are some uncertainties regarding availability, risks, and the high initial costs. Bio-e-methanol in an internal combustion engine seems most promising from a cost perspective so far. This can also be seen in the large investments in methanol production. Peter Svendsen, European Energy, presented a power-to-X project producing e-methanol in Kassö, Denmark. The project includes a 300 MW solar farm connected to a 52 MW PEM electrolyser; this, combined with biogenic CO2, will produce 32 000 tonnes of green methanol every year.

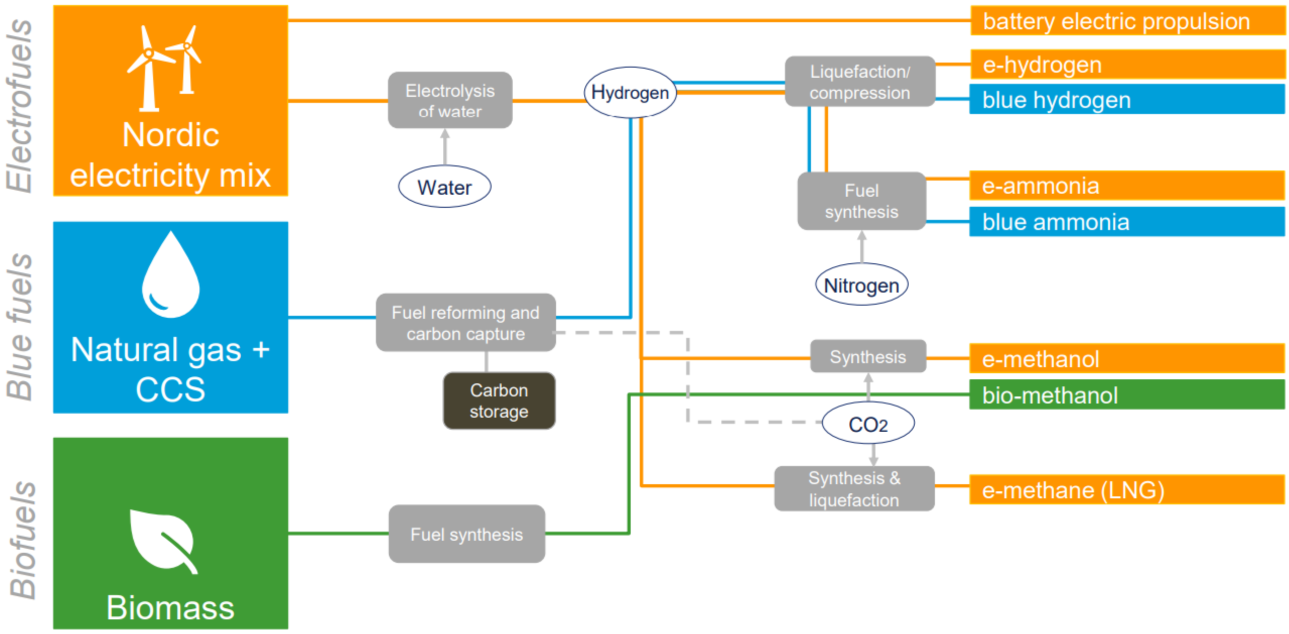

Figure 6: Different production pathways of alternative fuels (Source: IVL presentation)

According to previous speakers, methanol is looking like a promising option for decarbonising shipping. However, Sweden's oldest passenger shipping company is taking another route when transitioning from fossil to renewable fuels. Christer Bruzelius, Gotland Tech, presented that the Gotland Ferry will be aiming for pure hydrogen. Using a combined-cycle multi fuel turbine, they utilize the waste heat from the main turbine to generate extra electricity, increasing efficiency. Being multifuel, they will also be able to use other fuels in case of a hydrogen shortage. Two different ships are planned: one Ro-Pax (roll-on, roll-off passenger and freight ship) and one large-scale catamaran, both multi-fuel with the option of 100% hydrogen. The total demand, if all ships run on hydrogen, will be 20 000 tonnes per year, requiring 1 TWh of electricity.

Gas turbines can be used on more than ships. Johan Leirnes, Siemens Energy, presented Siemens recent developments in gas turbines and their potential to reduce average electricity costs and help provide plannable energy in decarbonized energy systems. Several of Siemens gas turbines can already run on a 75% volumetric hydrogen mix, with a target of 100% by 2025. The gas turbine offers both fuel flexibility, and operational flexibility producing both electricity and heat, making it a good candidate for stationary electricity generation backup.

2.8 Industry

During the Industry session, it was stated that the steel industry is one of the most emission- intensive industries in Sweden due to its use of coal or natural gas to reduce the iron oxides. But hydrogen could do the same job without any carbon dioxide emissions. Even though it is more energy-intensive there are already huge projects planning to utilize this method. H2 Green Steel is planning on starting their production of fossil-free steel in 2025, ramping up to a production capacity of 5 million tonnes of green steel in 2028. They plan to have between 700 and 800 MW of electrolysis capacity on site. But not only the steel industry can make use of hydrogen as a reduction agent. Ida Heintz from Swerim presented Swerim's latest research about using hydrogen as a reduction agent in the Zinc production. Through experiments, this has been proven to be possible in a safe way, however, the reduction efficiency was shown to be not as high as current industrial methods. Nonetheless, the research demonstrates that changes from traditional coal-based reduction processes are possible in several metal industries.

Another company heavily investing in hydrogen is Uniper. Uniper is active in the whole value chain for hydrogen. From renewable electricity production to upgrading to synthetic fuels and trading on the market. They plan on strengthening their position on the market with investments of over EUR 8 billion between 2023 and 2030 and plan to have over 1 GW of electrolyzer capacity by the end of 2030. Their projects across Sweden include the chemical, maritime, and aviation industry with a total capacity of over 300 MW. In the EU they run over 15 projects which totals more than 2 GW, see figure 7 for an overview of the projects.

However, not all hydrogen projects are on a large scale. Patrik Malm from SHG presented a project building a hydrogen factory producing 190 kg of hydrogen per day. The hydrogen is going to be used to fuel a local passenger ferry with a capacity of 147 passengers.

All of the previously mentioned projects utilize either alkaline, proton exchange, or a mix of both types of electrolysis. But they are not the only types of electrolysis. Sepanta Dokhani, RISE, talked about anion exchange electrolysis. A new promising type of electrolysis combines the benefits of cheap catalyst materials from alkaline electrolysis with the high current density, purity, and dynamic load operations of proton exchange membrane electrolysis. Current issues with AEM are its low

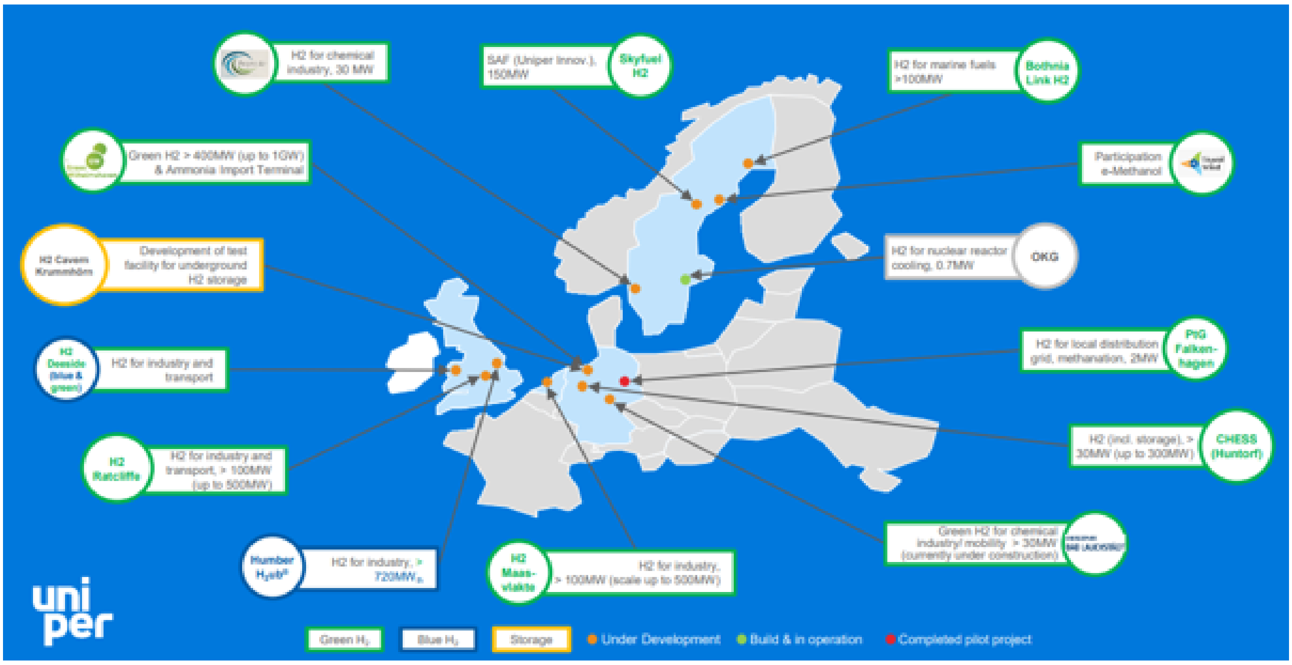

Figure 7: Unipers hydrogen projects (source: Uniper presentation)

stability and degradation in the membrane. So it is a promising technology due to its low cost and relatively high efficiency, but it is not a mature technology, and there are uncertainties regarding its long-term durability.

2.9 Ongoing research

In the ongoing research segment, Luleå University of Technology opened by presenting their competence center CH2ESS aimed towards research on hydrogen related topics including different projects. The projects span the whole value chain from production to usage from both the technological and social aspects, for all of CH2ESS projects click here. They also presented their online course on hydrogen aimed to teach the general public about hydrogen and its potential. The session was followed by four of the projects in CH2ESS being presented. The first was aimed towards hydrogen production through ultrasonic alkaline water electrolysis. The projects aim is to improve hydrogen production by utilizing ultrasound-controlled cavitation. The second project, named H2AMN, focused on hydrogen-based fuel pathways in ports. The project will be realized through four case studies, two located in Island and two in Sweden, and aims to outline ambitious pathways and strategies/guidelines for the implementation of hydrogen-based value chains for ports by 2030/2040. The REFORM project, renewable hydrogen production and storage via biotechnical interconversion of carbon dioxide and formic acid, aims to develop a biocatalytic cycle for hydrogen production, storage and release. The system uses hydrogenation of captured CO2 to produce formic acid with the help of enzymes as catalysts which are then regenerated in the system. The formic acid can then act as a hydrogen carrier and the released CO2 during dehydrogenation can be recycled in the system. By using enzymes as catalysts the system can achieve low energy demands with no byproducts, however current enzymes are expensive which is why enzyme regeneration is investigated in the system. The last project presented by LTU is called HERo and investigates hydrogen embrittlement in rolling element bearings. The aim of the project is to understand the effect of hydrogen in rolling element bearings and link the concentration of hydrogen and the damage it causes. The effects of hydrogen are examined through experiments where the bearing is charged with hydrogen and tested in an experimental setup.

IVL presented a project on hydrogens potential from a Swedish perspective. The project estimates Sweden's hydrogen demand to 32-49 TWh and the production to 18-23 TWh in 20230 meaning that Sweden would have to import hydrogen. However, the estimate for 2045 shows that production might exceed demand making Sweden an exporter of hydrogen.

The next two projects belonged to Energiforsks hydrogen programme and were presented by representatives from Profu. The first project, hydrogen for a balanced electricity system, examined how hydrogen might affect the electricity market and how it can offer flexibility to the grid. Results show that flexible operation of electrolyzers, in combination with hydrogen storage, shows great potential to contribute to a cost efficient way to reduce power requirements at high electricity prices and in turn balance the electricity market. The other project, hydrogens role in the energy and climate transition (VREK), evaluates hydrogens role in the energy and climate transition. The evaluation includes synergies and effects of introducing hydrogen to the energy system by compiling current hydrogen research and complementary quantitative system analysis. The project will further develop the knowledge on technical data, costs, policies, potential for emission reduction, and more.

RISE and SWECO presented several projects from both the socio-economic and technological perspectives. The first presented project took a socioeconomic perspective and evaluated when pipelines could be more favourable than new electricity grids for transporting hydrogen. The study did a SWOT-analysis of hydrogen pipelines, which is presented in figure 8 below.

Strengths	**Weaknesses**
• Supports grid stability. • Stores excess power production in H_2. • Occupies small land areas for energy transmission. • Allows for flexible localization of electrolyser.	• H_2 supply vulnerable without redundancy during disruptions. • Uncertain future demand changes. • High investment costs requires justification for large H_2 transmission.
Opportunities	**Threats**
• Repurpose natural gas pipelines to H_2 at a lower cost. • Enables connection of more H_2 providers and users. • Allows coordination of pipeline construction with other infrastructure investments.	• Potential low public acceptance for underground pipelines. • Limited local knowledge on large-scale gas infrastructures. • Unclear legislative framework for H_2 infrastructure. • Uncertainties around steering of H_2 infrastructure. • H_2 pipelines still under technological development.

Figure 8: Pipeline SWOT analysis (source: The Green Hydrogen from a Socio-economic Perspective project)

Another project studied the viability of hydrogen in heavy duty transport, the study was conducted as a case study on a food trucking company. The study concluded that it would be possible to transition to hydrogen with minor changes in operation but that the cost would be higher. However the total cost of ownership was highly dependent on the price of hydrogen, resulting in lower hydrogen costs being competitive. Another factor affecting the viability was if hydrogen was compressed to 350 bar or 700 bar in the truck. High compression is however not the only way to store hydrogen. Another project presented by RISE focused on the construction of liquid hydrogen tanks. Constructing these tanks can be difficult due to the low temperature of liquid hydrogen, -253°C. Another problem is the small size of the hydrogen molecule, making it diffuse between most materials. A solution to this can be using thin composite layers. The last project presented by RISE was HyCoGEn, focusing on connecting hydrogen production and district heating hence utilizing the waste heat produced when making hydrogen. The project concluded that if the EU:s production goal of 10 million tonnes per year would be realized the waste heat from the electrolyzer could be enough to fulfill Sweden's district heating demand four times over. Other synergies like utilizing the oxygen in electrolysis for better combustion in waste boilers or in water treatment plants are also presented.

A project by KTH presented a lifetime test on the anion exchange membrane for water electrolysis. The study found that the membrane showed good stability for 2500 hours and that the efficiency of the cell increased in low current density and low temperature. This phenomenon of higher efficiency for lower cell voltages will be further investigated in the project.

Uppsala University presented a project regarding corrosion on coated aluminum for bipolar plates. By replacing stainless steel with aluminum, lightweight bipolar plates for fuel cells can be produced. However, aluminum can not withstand the corrosive environment inside the fuel cell which is why it needs to be coated. The project tested three different coating designs, thus far there have been relatively small differences between the surface of the different coatings despite big differences in thickness and materials. Further tests will be done to see if the coated aluminum plates can meet the requirements for bipolar plates in a fuel cell.

Two projects from Chalmers were presented. One examining potential hydrogen infrastructure on the west coast of Sweden. The study examined four different scenarios alternating between high and low wind power investments and investing in pipelines or not. The results showed that investing in pipelines significantly reduced the need for storage and higher investments in wind power resulted in an overall lower system cost. The other project, NordicH2ubs, aims to evaluate how a successful hydrogen value chain could/should be constructed with a focus on opportunities and challenges. The project will also evaluate synergies between countries. It will finalize in scenarios for hydrogens role in the future Nordic energy system.

Kraftringen presented a project researching hydrogen as a fuel. The project will focus on the location of hydrogen production, business models, hydrogen and oxygen usages, and potential sector couplings. One of the use cases of hydrogen is as a fuel, in the project they will evaluate what types of vehicles would be the most interesting to convert to hydrogen.

More curious? The presentations from the conference can be viewed here.

3 Summary of the exhibitions

In the exhibition hall, more than 20 exhibitors demonstrated their knowledge and competence within different areas of the hydrogen sector. A summary of the topics presented at the exhibition booths is shown in the wordcloud, figure 9, below. The big spread of topics in the wordcloud demonstrates the versatility of the hydrogen sector and the collaboration across sectors to work towards a common goal: moving away from fossil-based energy carriers and enabling hydrogen-based technologies for a more sustainable future.

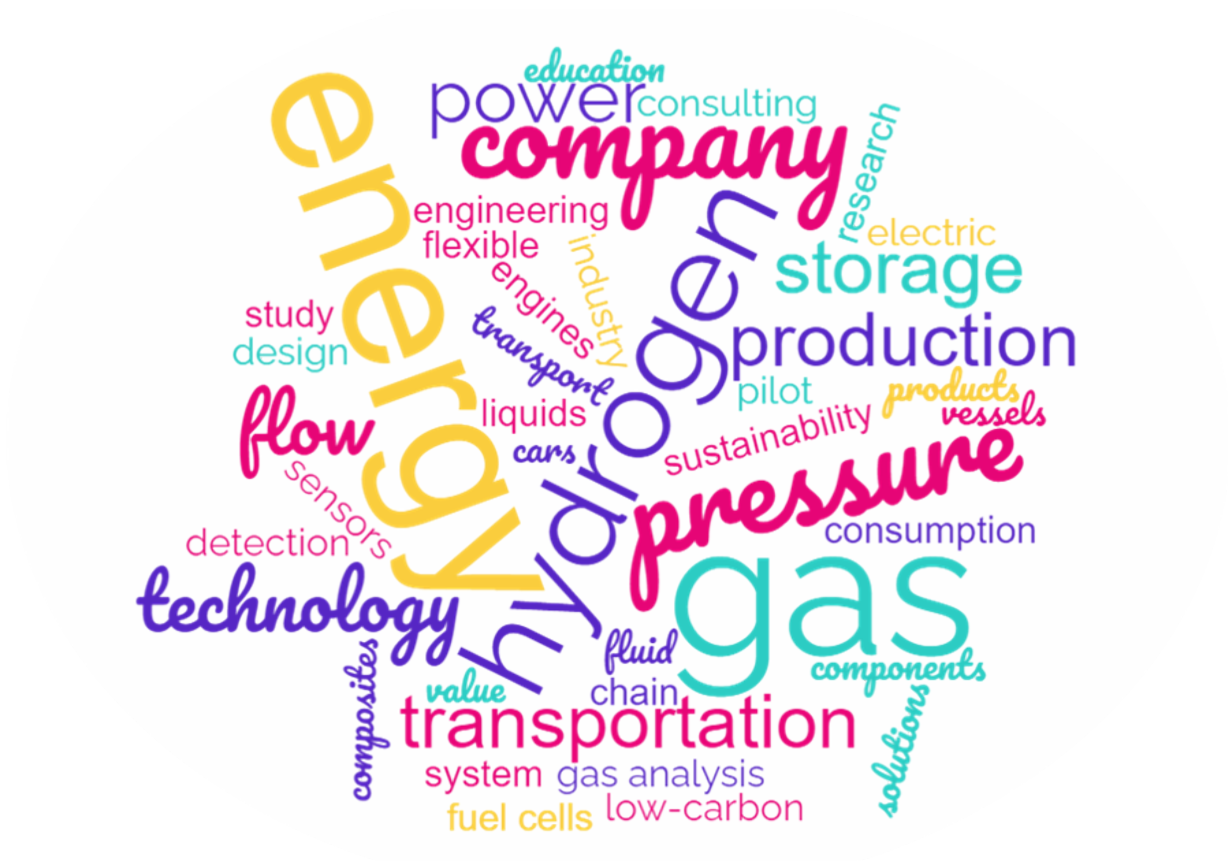

Figure 9: Summary of topics (source: WordClouds.com)

The exhibition booths provided exciting insights and demonstrations of the state-of-the-art within the hydrogen sector. One highlight was the possibility of test-driving a Toyota Mirai fuel cell car. PowerCell impressed by exhibiting one of their fuel cells.

Some of the exhibiting companies work with the full hydrogen supply chain, like ABB and MAN Energy Solutions, while other companies concentrated on one specific aspect or sector. One sector represented by multiple companies was the energy sector, where currently several companies like Uniper, Fortum, Siemens energy and Ellevio are working towards supplying green energy solutions. Further providers of hydrogen energy technologies represented at Vätgaskonferensen 2023 were H2Solo and Metacon. Next to the production and supply, also the storage of hydrogen is a critical aspect, where companies like UMOE and H2Hive presented their know-how. To enable a safe handling of hydrogen as well as secure hydrogen quality, flow technology, sensors and safety systems are necessary. In this field, companies like Alfakomp, Keller, Omni, Famkontroll, Armatec, Swagelok and MSR Nordic demonstrated their services and products. Further companies that drive the green transition were Afry, which offers consulting, engineering and design services towards sustainability, The Nordic Hydrogen Corridor, which is an exciting study pilot for hydrogen-based transportation as well as RISE, which performs research and education within the hydrogen sector.

Last but not least, a map in the exhibition hall invited the conference participants to add their hydrogen activities. This way, a map with the most important hydrogen developments all over Sweden was collected, showing that Sweden has a very wide range of actors and researchers who work within the entire value chain and in all maturity levels of components for hydrogen in their respective stages of production, storage, distribution and use.

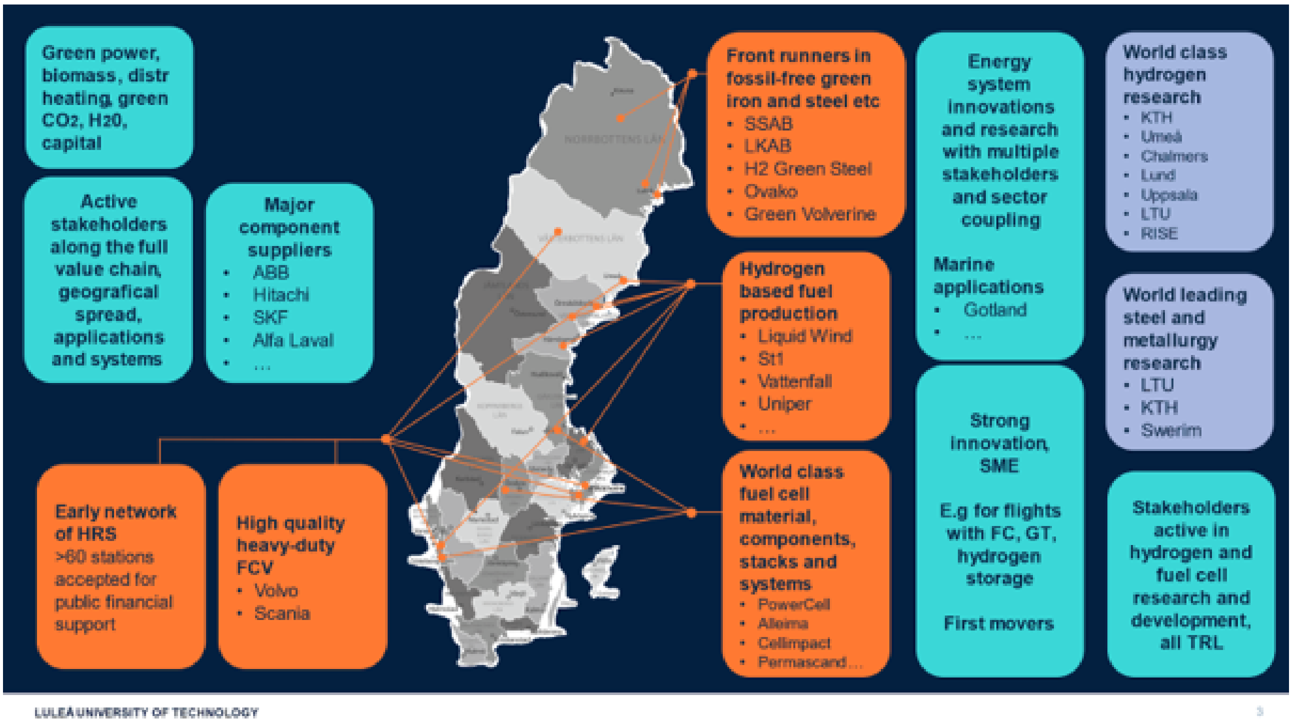

Figure 10: Hydrogen developments in Sweden. (Source: Luleå University of Technology and processed during the workshop "Sverige som föregångare")

In figure 10 we can see that the geographical spread of investments, innovation and product portfolios is large, with an emphasis on secured capital and public support in the far north. There are several facilities for electrofuels under construction, conversion and adaptation of the energy system, investment analyzes for operations in ports and not least suppliers, world-class research and development in metallurgy, hydrogen, fuel cells and electrolysers. Sweden has two strong suppliers of heavy vehicles with adaptation for hydrogen as fuel, and over 60 hydrogen filling stations in the planning stage. Sweden also has good conditions with fossil-free electricity, expanded district heating networks, renewable carbon dioxide, water, available capital for investments and a habit of strong collaborations, both nationally and internationally, which is a very good basis for all of this.

– By collaborating with several organizations, we have together managed to create a national meeting place for hydrogen development. We look forward to doing it again next year, as more knowledge is needed about how hydrogen can contribute to a robust and sustainable energy system, says Sara Hugestam at Energiforsk, who was a part of the program council.

In summary, the conference created a national meeting point for hydrogen development in Sweden where the participants could get an update on the market and discuss how to move forward.

Welcome to next year's Hydrogen Conference in December 2024!

The Hydrogen Conference 2023 was organized in collaboration between **Energiforsk, Luleå Tekniska Universitet, RISE Research Institutes of Sweden, Vätgas Sverige, Energigas Sverige** and **Energiföretagen Sverige**.