ASSOCIATION OF NORDIC ENGINEERS

COMPETENCES FOR A SUSTAINABLE FUTURE

Future skill and workforce requirements for engineers working with climate technologies in the Nordics

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FOREWORD

When we talk about the green shift or new tech solutions for addressing climate change, we assume, hope, and proclaim engineers and other STEM professionals as the custodians of our smooth transition towards sustainability and net-zero emissions.

But we are stuck in a paradox. On the one hand, politicians and industry are sounding the alarm about the catastrophic shortage of engineers, IT, and STEM talents to address the current and future challenges. On the other hand, it is unclear what concrete competences and skills the industry needs to drive the green shift. Squeezed in between are the higher education institutions, racing against time to adapt curricula to match the skills provision with the skills demand.

The Nordic countries have ambitious carbon-cutting strategies, and the region is considered a frontrunner in that regard. But while there are many similarities in the region, each country has individual strengths in developing and deploying climate technologies.

To shed light on the skill and workforce requirements, we have commissioned a small-scale analysis of the highly prioritised industry sectors regarded as strongholds in the Nordic region. The report you have in front of you is a unique overview of specific technical and soft skills in demand for engineers and STEM professionals in the sectors such as Power-to-X, wind power, batteries, hydrogen, biomass, geothermal energy, and carbon capture storage and utilisation.

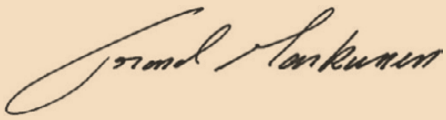
The report also identifies critical trends for climate technology development, including the electrification of society, systems thinking, data utilisation, soft skills, and attracting young talents. The recurring pattern in these key trends is the clear interdependency between the Nordic countries, the shared need for solutions, and the shared need for more robust value chains. Thus, the report accentuates the importance of increasing knowledge sharing and collaboration across borders.

We hope the findings of this report will boost Nordic cooperation both in academia and the industry to capitalise on existing synergies and strongholds. If we can avoid a silo mentality, there is vast potential for exporting skills and know-how, which could be a significant competitive advantage for our region.

We urge Nordic politicians to work with relevant stakeholders to familiarise themselves with the recommendations of this report to better align political incentives with the demands of the market. The education system, in particular, requires a substantial upgrade to secure the provision of specialists matching the skills demand. If we want to develop and implement new climate technology, and if the expectations of the STEM professions are high, then we must have an education system which can deliver engineers, IT, and STEM professionals with the right skills at the right time.

We must act now, and we hope the findings of this report will stimulate a stronger focus in the Nordic region on securing the competences and skills needed for climate technology. We also encourage building on this report by prioritising and investing in the large-scale mapping of the skills demand for climate technologies in the region.

We want to thank our many colleagues who contributed to this report. A special thanks to DAMVAD Analytics for producing this report.



Trond Markussen
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EXECUTIVE SUMMARY

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This report aims to describe identifiable changes in the future skill and workforce requirements for engineers in selected climate technology sectors across the Nordics. The results presented in the report are based on interviews with representatives from academia and industry in all five Nordic countries. The report emphasises five key trends across countries and sectors which will potentially impact the future skill and workforce requirements for engineers:

- **The electrification of society**
- **A move towards systems thinking**
- **Increased knowledge sharing and big picture thinking**
- **The increasing role of data and digitalisation**
- **A future demand for engineers with soft skills**

Furthermore, developments within each climate technology across the Nordic countries are expected to influence the engineers' skills and workforce requirements.

Power-to-X

Power-to-X (PtX) is rising across the Nordic countries, and different PtX initiatives are under development. The Nordic countries are increasingly focused on using PtX to produce clean hydrogen and utilise captured carbon. The skills in demand for PtX are skills within chemical engineering and the fundamental understanding of the entire value chain for PtX, e.g., understanding the connection between high voltage, water, and chemicals.

Wind power

The wind power sector is expanding rapidly in the Nordics, with Iceland as an exception. Denmark and Sweden are currently at the forefront, but increasing development is expected in Norway and Finland. Plans for a rapid expansion of wind power capacity in Denmark increase the demand for various engineering competencies. In addition, software engineering plays an increasingly important part in the wind power sector, partly due to developments in turbine technology.

Battery

The growth of the battery sector across the Nordics is predominantly seen in Sweden, Finland, and Norway. Sweden is, in many ways, driving the development of battery production through the establishment of Northvolt in northern Sweden. The primary skills for the battery sector are mechanical engineering, chemical engineering, electrochemical engineering, electrical engineering, and automation engineering.

Hydrogen

Across the Nordics, respondents see a boom in the production of hydrogen. Iceland expects increased use of hydrogen for e-fuels due to readily accessible and green geothermal energy, and Finland is focusing on hydrogen as a critical solution to achieving the country's carbon neutrality target. Respondents see a growing demand for basic engineering skills in physics, chemistry, and mathematics. Furthermore, the hydrogen sector experiences a lack of skills in production technology and process engineering, safety knowledge, and hydrogen storage and handling.

Biomass

Bioenergy is expected to maintain an essential role within the Nordic energy system, and the demand for biomass is anticipated to increase. As an exception, Finland is not expecting any increase in the use of biomass, as the country is currently facing a challenge from the collapse of carbon sinks, which jeopardises the country's targeted carbon neutrality. The biomass industry requires skilled engineers for tree harvesting, such as technical and physical engineers to develop sawmills. Biochemical engineers are necessary for the pulp industry.

Geothermal

Geothermal energy is not gaining traction in the Nordics to the same extent as other renewable energy sources. Geothermal is a significant energy source in Iceland, with greater access to earth heat than the rest of the Nordics. The geothermal sector is expected to expand to some extent in Iceland; however, respondents do not expect any significant increase in skill demands for engineers as a result. As an exception, the process of further developing technologies for binding geothermal gasses in deep rock formations is predicted to increase skill demands. In general, little available knowledge and resources exist on the future needs for engineering skills in developing geothermal energy for the rest of the Nordic countries.

Carbon capture technology

Norway and Iceland are front runners in carbon capture technology. Sweden and Finland see potential in achieving negative emissions by capturing carbon dioxide from bioenergy sources. Iceland has successfully developed a new method for carbon capture (Carbfix), which is expected to be scaled across relevant sectors in the country and internationally. Expansion of carbon capture and storage (CCS) and carbon capture and utilisation (CCU) creates a demand for skills such as automation, electrical engineering, operational chemistry, programming knowledge, and test engineering.

Educational measures

The report lists a range of potential educational measures that respondents highlight as essential for bridging skill gaps across countries. These include a need to attract talent, upskilling in digital skills and general sustainability thinking, and enabling hands-on experience for engineering students. Bridging educational gaps also requires increased collaboration and synergies between the Nordic countries.

Overall, there is a need to strengthen the utilisation of academic specialisations across universities, including building on each country's expertise. The same need for collaboration exists in climate technology industries across countries. Industry respondents express a lack of knowledge of how far others have progressed in development and how industries collaborate across countries today. Respondents request more export of specialisation and expertise, and increased utilisation of country strongholds.

As a consolidation of the insights and perspectives presented, the report brings the following recommendations for actions needed to ensure that Nordic engineers have the necessary skills to drive the development of climate technologies and support the sustainable transition across the Nordics:

- Analyse the sector skill demand and align political incentives with the demands of the market
- Adapt the higher education system to bridge skills gaps
- Invest in lifelong learning and reskilling in green technologies
- Use the green agenda to recruit and retain a diverse pool of young people for engineering and STEM programmes
- Incentivise and increase Nordic knowledge sharing and collaboration
- Harmonise climate tech legislation in the Nordics to create a broader market.

2 INTRODUCTION

Engineers will play an essential role in the Nordic countries' sustainable transition. The literature, research and perspectives included in this report unanimously state that skilled engineers are and continue to be indispensable for reaching Nordic net-zero emission targets. The outlook for the future, with expected shortages of both engineers and tech skills, induces an urgent call for action.

The Nordic countries are at the forefront of carbon-cutting strategies, and each country has its strengths in developing and implementing climate technologies. Norway is a leader in hydropower, Denmark in wind power, Iceland has extensive geothermal energy, Sweden uses biomass as a significant renewable energy source, and Finland uses clean energy from nuclear power and renewables [1]. Furthermore, Sweden is growing its battery industry, and Norway and Finland are the biggest hydrogen producers in the Nordics [2].

The overall objective of this report is to highlight the future skills and workforce requirements for engineers working with climate technologies in the Nordics. The aim is to dive deeper and identify concrete skills needs for engineers in each country to guide stakeholders and policymakers about the future of climate technologies.

The data foundation for the analysis consists of interviews with technology representatives and experts from the five Nordic countries and an extensive desk research and literature review process.

1 Tresor-Economics (2021): Climate Strategies in the Nordic Countries.
2 Nordic Innovation (2020): Next Nordic Green Transport wave – large vehicles. Large scale hydrogen use in Nordic industry 2020-2030.

The aim of the analysis is fourfold:

1. Review existing knowledge of plans and sectoral roadmaps on the green transition in the Nordics, including the implications on the skill and workforce demands for engineers.
2. Analyse trends and future changes in skill and workforce requirements for engineers working with climate technologies in the Nordics.
3. Identify knowledge and skill gaps for each selected climate technology presented below, including possible educational measures needed to bridge those gaps.
4. Identify potentials for increased synergies and collaboration between the Nordic countries, including drawing on competencies from each other, large-scale projects, and bridging possible educational gaps.

The report zooms in on a selection of climate technologies: Power-to-X, wind power, batteries, hydrogen, biomass, geothermal energy, and carbon capture and storage/carbon capture and utilisation (CCS/CCU).

This report does not address solar, nuclear and hydropower climate technologies separately. Solar power is likely to grow in all Nordic countries, but the investment pipeline and government targets are not as clear as they are for wind power. Nuclear power plays a vital role in the Finnish and Swedish power supply, and nuclear district heating is under consideration for future use in Finland. Still, no other countries in the Nordics are planning to invest in nuclear power in the future. Hydropower is not included separately due to limited access to potential respondents from relevant companies. However, many of the technologies are highly intertwined. Thus, points related to climate technologies such as solar power and hydropower will also be made throughout the report.

The report provides insight into a selection of competencies that respondents expect will be in future demand within each climate technology sector but will not give a complete list of future skill demands for engineers. Due to different strengths in each Nordic country, not all chapters of this report will represent every country to the same degree. However, in-demand competences related to a climate technology sector in one country are likely to be transferable to other countries experiencing development in that sector and are not considered as having isolated relevance to a specific country.

KEY TRENDS

3

Before diving into each climate technology, we present some key trends identified across the Nordics. Each Nordic country and each climate technology sector has distinct trends and developments. However, some trends within the green transition seem to span across countries and climate technology sectors. A general trend influencing most insights presented in this report is the expected shortage of engineers needed to support the sustainable transition. Respondents stress a great need across sectors and countries to incentivise young people to study engineering.

The electrification of society

As the world phases out fossil fuels, the electrification of previously carbon-heavy solutions is becoming increasingly important. The electrification of society is one of the few routes to reduce CO2 emissions in fossil fuel-heavy industries such as steel and chemicals and increase clean power generation to produce hydrogen and other emission-free fuels. PtX and green hydrogen solutions are receiving growing attention and are perceived to play an essential role in the electrification of the Nordics [3]. Continued cost reductions in technologies such as wind and batteries drive this development further. As the electrification of society continues to develop, the need for clean energy increases. To avoid future energy capacity shortages, the development of stable, clean electricity from e.g., wind, solar, or hydropower must also increase.

3 Nordic Energy Research (2021): Nordic Clean Energy Scenarios.

We might be in a position where the lack of skilled workforce is going to create a barrier and mean that we're not going to be able to go through with the green transition at the pace that we need to.

Respondent, Denmark

Several respondents point to direct and indirect electrification as the only route forward for reaching the climate targets of the Nordic countries. Furthermore, they point to the fact that this increased electrification will require increasing technical skills and competencies. Making sure that these resources are readily available is the only way for the green transition to succeed.

A move towards systems thinking

Creating an entirely fossil-free value chain requires increasing interdependence between sectors. Most respondents across the Nordic region underline the need for holistic thinking and systems thinking when it comes to climate technology and the sectors involved in the green transition. The solutions of the green transition are, as opposed to its carbon-heavy predecessor, highly intertwined, since the value chains of the green economy are reliant on multiple parties and are increasingly becoming integrated across industries and markets. Being an engineer within these industries and markets requires understanding the larger perspective and the green value chains of which they are a part.

A focus on knowledge sharing and big picture thinking

With climate change comes the realisation that each country is part of the bigger picture. Solving the issues of climate change in one country does not solve the actual issue of climate change. Furthermore, each Nordic country constitutes a small market on its own, and many climate technologies are cross-sectoral.

We're very good at developing offshore wind but not in implementing it in our own country. But with battery development there's a lot of bust around it. We see that we'll have an energy deficit in some years, and now we're starting to act on it.

Respondent, Norway

Therefore, working in silos both country-wise and sector-wise is not an efficient way of working across the Nordic region. There is an understanding across the respondents that solutions must be developed on a global or at least a Nordic level to create impact. Creating similar initiatives in two countries is considered an inefficient use of resources, and respondents experience an increase in joint plans and projects across several Nordic countries. However, increasing efforts to share knowledge, expertise, and competencies is necessary across organisations, sectors, and countries to facilitate a swift transition to a net-zero Nordic region.

I think the electrification of everything is one of the big trends and it is very important for the green transition and creating renewable energy.

Respondent, Finland

The increasing role of data and digitalisation

Digitalisation in the form of robotisation, automation, software, and AI is a trend strongly influencing the requirements for future competencies [4]. Respondents across all countries point to digitalisation as a megatrend that will shape all green technology sectors. With the increased digitalisation and AI, the amount of data and information to be handled and stored is increasing. This means that all sectors require better and more efficient data handling. Respondents underline that the increased digitalisation of society means efficient data handling and efficient digital tools and innovation will be a growing priority. Increased dependence on data storage means a growing energy demand from data centres; and a need to focus on their decarbonisation potentials and efforts.

4 Teknikföretagen (2020): Framtidsspaning – Så påverkar teknikskitena behoven av ingenjörskompetens.

A future demand for more engineers with soft skills

As climate technologies evolve, so does the complexity of projects and solutions to fight climate change. Value chains within climate technology are becoming increasingly interconnected and interdependent. These developments create demands for engineers with competencies beyond technical expertise – "soft skills" such as human-focused impacts, multidisciplinary collaboration, communication, and stakeholder interaction are increasingly important [5]. The need for soft skills is emphasised across interviews and desk research, and demand is predicted to increase in the future.

As an example, there is a need for engineers who have skills in behavioural science and communication. These skills are seen as helpful in ensuring an open mindset enabling efficient problem solving and project work. Cooperation and communication are increasingly important within climate technology sectors; a fundamental understanding of and communication across the entire value chain increases cooperation and enables sector development.

Future technological advancement will occur through interconnections throughout the value chain.

Respondent, Sweden

The rapid development of climate technologies through large projects necessitates engineers with skills such as project management and stakeholder management. Furthermore, engineers must increasingly consider their work's social and environmental aspects, reflecting a need for holistic assessment abilities beyond the traditional perspective(s).

When researching job postings to identify the competences most in demand across the climate technology sectors included in this report, soft skills were predominantly at the top of the list. In table 1, we present an overview of the demands for soft skills identified for engineers through interviews, desk research, and a review of job postings.

5 NTNU (2022): Teknologiutdanning 4.0: Anbefalinger for utvikling av NTNUs teknologistudier 2022-2030.

Table 1 Selection of soft skills needed for engineers across climate technology sectors

Soft skills from job postings	Soft skills from interviews and desk research
• English • Communication • Development • Stakeholders • Optimisation • Project management • Risk assessment • Stakeholder management • Knowledge sharing • Problem solving	• Project management • Stakeholder management • Interdisciplinarity • Circular economy • Knowledge of social aspects of climate technology development • Visualisation and story-telling • Knowledge of political landscape • Behavioral science • Cooperation and collaboration

The right column summarises the soft skills mentioned in this chapter, which respondents expect to be in increasing demand following the development across sectors in the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of soft skills identified when researching skills needed for engineers across sectors using job postings.

The soft skills highlighted in job postings and the skills raised by respondents are highly aligned. The soft skills mentioned in both job postings and by respondents are communication skills, product management, and stakeholder management. Risk assessment which was also raised by respondents, is mentioned in multiple job postings, and will be elaborated upon in relation to many of the sector chapters below.

4 SKILL AND WORKFORCE REQUIREMENTS

In the following chapters, we describe the current developments within climate technology sectors considered strongholds in the Nordic region and how those developments influence the skill and workforce requirements for engineers. The climate technologies include: Power-to-X, wind, batteries, hydrogen, biomass, geothermal energy, and CCS/CCU.

Some points will be country-specific, whereas others will find relevance across multiple countries. The points emphasised in the report are derived from interviews with representatives and experts from the sectors, think tanks, universities, and energy authorities in the five countries. Some points are supplemented with desk research to contextualise the respondents' reflections.

Power-to-X (PtX)

Overall development of the sector

PtX is a unique climate technology as it is highly connected to other climate technologies described in this report. This is because PtX is a conversion technology that can transform renewable energy into various fuels, chemicals or materials that can be applied in various contexts.

PtX is essential to the sustainable transition. Firstly, the technology enables the storage of excess energy from renewable energy sources by converting the energy into easily stored products. Secondly, PtX enables the production of fossil-free fuels for parts of the transportation sector and manufacturing industry that cannot yet be electrified. According to the Nordic Clean

Energy Scenarios project, PtX is one of five solution tracks that captures most options needed to reach carbon neutrality across the Nordic region [6]. Stakeholders and governments across the Nordics see great potential in PtX technologies because of the abovementioned opportunities. Furthermore, the fact that PtX can break the dependence on fossil fuels creates a strong interest in the technology across the Nordics [7].

PtX is a way to make this bridge between the renewable energy production and the energy intensive industries. I think this new bridge, this new way of thinking, is another area where both new skills are needed, but also where a lot of engineers are needed.

Respondent, Denmark

In Denmark, PtX has the potential to create 22.000 jobs over ten years. 880 of them with a diploma-, academy- or technical-engineer education (medium-cycle programmes), and 440 with a higher technical education level (long-cycle programmes) [8]. This includes the sectors: offshore wind, electrolysis, hydrogen storage, biomass gasification, CO2 hydrogenation, and biomass hydrogenation. Denmark is planning two energy islands in the North Sea and the Baltic Sea which will host large offshore wind farms and have the capacity to connect to PtX facilities on the islands or onshore.

Norway's PtX developments are primarily projects focusing on aviation fuel plants and the production of ammonia via hydrogen, which can be used for maritime freighters, agriculture, and industrial applications [9]. The industry consortium Norsk e-Fuel [10] aims to use PtX technology to transform CO2, water and electricity into renewable fuels (e-fuels) for the aviation industry. The first plant is scheduled for 2023, with expected production in 2024, and with the ambition to reach a production of 25 million litres of e-fuels by 2026. Norway has an advantage in scaling PtX technology, as the country has high availability of electricity from renewable sources, especially hydropower.

Sweden and Finland see potential in using PtX technology to produce iron and steel. The iron and steel industry is a large emitter of CO2, and PtX technology

6 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.
7 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.
8 Arbejderbevægelsens Erhvervsråd, (2020), Power-to-X-teknologier kan skabe 22.000 job over ti år.
9 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.

is promising in reducing those emissions. There is more than one route to reduced emissions when applying PtX to iron and steel production. For example, PtX technology can reduce emissions in the production process by converting renewable energy into hydrogen, syngas, or methane used in iron and steel production. These products can reduce the need for coal and other fossil fuels traditionally used. The HYBRIT technology [11] – a PtX technology developed by SSAB, Vattenfall, and LKAB – allows for the substitution of coking coal with fossil-free electricity and hydrogen. Sweden is also planning a plant in Ornskoldsvik to produce e-methanol through PtX. Iceland already has two sites for Power-to-hydrogen production located by geothermal power plants, one of which exports hydrogen. Plans to export more green hydrogen from Iceland are underway [12].

Specific skill demands for engineers in PtX

PtX encompasses several different sectors and competency needs. An engineer working along the value chain of PtX needs to understand engineering basics such as working with water, chemicals and high voltage electricity. Respondents especially emphasise chemical engineering and knowledge of electrochemical processes as important skills. Furthermore, mechanical engineers are necessary to support the operation of PtX plants.

Besides basic engineering skills, ensuring safety around the process is important for engineers working within a PtX sector. In addition, reducing energy loss is a critical focus in making PtX a sustainable solution. Thus, the industry demands engineers who understand how to utilise the excess energy from PtX in the form of heat, which will ensure efficiency throughout the process and across sectors.

As PtX is intertwined with other climate technologies, the following sections of this report will dive deeper into the specific skill needs for various PtX processes such as Power-to-hydrogen and the production of e-fuels through Carbon Capture and Utilisation.

To finish all of the projects that are on the table within Power-to-X, then we need to educate more people with chemical engineering skills.

Respondent, Denmark

10 Norsk e-Fuel: https://www.norsk-e-fuel.com
11 HYBRIT: https://www.ssab.com/en/products/brands/greencoat/sustainable-building-with-greencoat/hybrit-fossil-free-steel?gclid=EAIaIQobChMImcu5m8zz-QIVm94YCh16hgJMEAAYASAAEgJw9fD_BwE
12 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.

Table 2 Selection of technical skills needed for engineers working with Power-to-X

Technical skills from job postings	Technical skills from interviews and desk research
• Scada • Lean • Root cause analysis • Optimisation • PowerFactory • Pscad • Building Management System • Data processing • Optimisation • Programming • Six sigma • Validation • Chemical engineering • Electrical systems Integration	• Chemical engineering • Knowledge of the connection between water, chemicals, and high voltage • Energy efficiency • Safety • Mechanical engineering • Electrochemical engineering

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the PtX sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for engineers in the PtX sector using job postings.

We see that skills related to Supervisory Control and Data Acquisition (SCADA) and Root Cause Analysis are in demand. These can be connected to the systems perspective needed to understand the entire process and value chain around PtX and ensure safety around this process, which the interview respondents also highlighted. In addition, Lean and Optimisation are often mentioned in job postings as skills in demand, which can be related to the need for energy efficiency during the process highlighted by interview respondents. Finally, Chemical Engineering is present in both interviews and job postings as a skill in demand.

Wind

Overall trends in development

Denmark has long been at the forefront of renewable energy development, especially when it comes to wind energy technology, and this development is expected to grow in the coming years. In May 2022, Denmark, together with Germany, Belgium, and the Netherlands, pledged to work on a tenfold increase in offshore wind capacity in the EU, meaning that at least 150 GW of offshore wind capacity will be built in the North Sea by 2050 [13]. Wind technology development in Denmark is expected to create overall demands for more engineers with many different backgrounds, including classical engineers and energy technology specialists. Respondents expect a shortage across the sector, especially for smaller and lesser-known companies that are a part of the supply chain. It is expected that these companies will have a more challenging time accessing the talent pool compared to larger companies like Vestas or Siemens Gamesa, which have international reputations that may be advantageous for attracting foreign talent.

While the largest single source of electricity generation in Denmark is wind, Norway relies mainly on hydropower, and Sweden on hydropower and nuclear power. However, wind power generation is expected to increase rapidly in Sweden. According to an analysis from The Swedish Energy Agency, Sweden is experiencing a boom in wind power generation with a predicted increase of 70 per cent by 2024 compared to 2021 [14].

The Norwegian government recently revealed a development target of increasing offshore wind capacity to 30 GW by 2040. Furthermore, the country recently announced its first offshore wind auction, awarding up to 1.5 GW of bottom-fixed offshore wind capacity. Norway has plans to tender off floating offshore wind capacity as well – though, the timeline for this auction is unclear. Some respondents highlight that a few years ago, Norway expected the shift from oil and gas to long-term green solutions to happen more rapidly. However, the recent global energy crisis due to the Russian invasion of Ukraine has created a significant demand for oil and gas, which has shifted the focus away from developing long-term solutions in Norway. Nevertheless, respondents still see an increasing potential to expand the country's offshore wind capacity, as Norway has a technological edge in floating offshore wind due to experience of similar technology related to the oil & gas industry [15].

13 Arbejderbevægelsens erhvervsråd (2022): 150 GW havvind i Nordsøen kan skabe op til 745.000 årsværk i dansk beskæftigelse.
14 Statens energimyndighet (2022): Kortsigtsprognos vinter 2022 – energianvändning och energitillförsel år 2020-2024.
15 Menon Economics (2021): Kartlegging av behovet for ingeniørkompetanse innen bærekraftig industri.

According to the Finnish Wind Power Association, Finland's electricity consumption covered by wind power is expected to increase from 9.3 per cent in 2021 to 25 per cent in 2025 [16]. Both on- and offshore wind is forecasted to rise in Finland by 2035 [17]. There is a potential for increasing demand for engineers within the wind sector in Finland. However, Finnish respondents emphasise that a challenge in the energy sector is that the sector is not "trending" amongst students and newly educated engineers in the country. Lack of interest results in a shortage of industry newcomers and an absence of technology-specific skills and knowledge in the workforce, which poses a potential threat to the possibilities of wind power development.

If there are available engineers with relevant study backgrounds – like some skill in wind power once they complete their studies – then there would be work for them, definitely.

Respondent, Finland

Interviews with the Icelandic respondents show that, in general, wind power technology is expected to develop less rapidly than what is the case for the other countries in the Nordics. In Iceland, renewable energy provides almost 100 per cent of the electricity consumption, with the largest share coming from hydropower and the rest from geothermal power [18]. Iceland started producing wind power in 2013 when the national power company Landsvirkjun set up two wind turbines as part of a pilot project for wind power expansion. Respondents see the potential for the expansion of wind power in Iceland due to the country's good wind conditions. However, since Iceland already has much of its energy consumption covered by other renewable energy sources, respondents see less of an incentive from both the government and the public to develop more wind power capacity. Thus, the development is currently limited to research projects on the potential for future development.

According to one respondent, there is a general lack of public knowledge regarding how an expansion of wind power might influence the country's environment, mainly in relation to nature-based tourism. Iceland's landscape and wild nature are tourist attractions, and the construction of wind farms may alter how this landscape is perceived. Research suggests that building wind farms in Iceland may cause conflicts between the energy sector and the tourism industry [19]. Furthermore, respondents see a challenge in expanding offshore wind capacity in

16 Finnish Wind Power Association (2022): Finnish wind power statistics 2021: A record year behind the construction of wind power.
17 Engineers Finland (2022): The Effects of the Green Transition to the Employment and Educational Requirements of Engineers in Finland.
18 Government of Iceland (2022): Energy.
19 Sæþórsdóttir, Wendt & Tverijonaite (2021): Wealth of Wind and Visitors.

We have quite skilled engineers for hydropower and geothermal, but for wind power we just haven't had any large-scale projects, so we would have to acquire those skills.

Respondent, Iceland

Iceland, as the country's deep seas make it challenging to create foundations for wind turbines. Despite the expected slower development, respondents still see a demand for specific knowledge necessary to drive future development.

Specific skill demands for engineers in the wind sector

The expansion of wind power capacity will first and foremost create a demand for geotechnical engineers with skills and knowledge in analysing geological data to construct wind turbines. Furthermore, the technologies for developing and operating wind turbines continue to evolve and increasingly rely on software. Representatives from the Danish wind industry are already experiencing shortages of engineers with digital skills, especially software engineers, and the demand is expected to increase. Software skills such as coding, expertise within system simulation tools, and even knowledge of cyber security to prevent wind turbine cyber-attacks are needed to support wind power's expansion in the Nordics.

As described in this chapter, there is an expected demand for engineers with more soft skills to drive the development of wind power technology in the Nordics. However, the need for technical specialists was highlighted as equally important for some parts of the industry, if not more important. Some respondents emphasise that while soft skills such as communication and project management are in high demand and will continue to be so, they are skills that are primarily relevant for companies such as consultancies working with wind technology. For large wind engineering companies in the Nordics, their continued growth results in increased specialisation, and respondents also deem this the case for the sub-suppliers. These companies face a challenge because generalist skills are trending, and increasingly fewer engineers have the level of specialisation that the wind power companies desire.

The engineering skills and knowledge needed to drive the increasing development and specialisation of wind power companies are civil engineering, mechanical engineering, electrical engineering, software engineering, power engineering, knowledge of generator technology, and controlling technologies (for controlling

13 Arbejderbevægelsens erhvervsråd (2022): 150 GW havvind i Nordsøen kan skabe op til 745.000 årsværk i dansk beskæftigelse.
14 Statens energimyndighet (2022): Kortsigtsprognos vinter 2022 – energianvändning och energitillfärsel år 2020-2024.
15 Menon Economics (2021): Kartlegging av behovet for ingeniørkompetanse innen bærekraftig industri.

wind turbines and systems). Respondents also mentioned the need for test and validation engineers to test and pre-test the systems and components needed for wind technology development. Danish respondents mention a potential bottleneck, as Denmark currently lacks an education that addresses systems testing and validation. Today, companies must hire engineers and provide further training for these skills.

Some consultancy companies are requesting more generalists, but production companies like us and our sub-suppliers – we need the classical engineering skills. For our needs, too many of the engineers are more generalists than specialists. We cannot hire generalists, because what should they do on day one? They can't do what we need. Their competencies are like ... knowing a bit of everything, and that's not our world.

Respondent, Iceland

Respondents from Iceland anticipate a future need for skills within wind power technology. Because of the lack of large-scale wind power projects in Iceland, the country lacks skilled engineers in that area compared to the climate technologies they are already working extensively with (hydropower and geothermal power). Some of the wind power-specific competencies mentioned are knowledge of fluid dynamics, generator technology, and knowledge of structural requirements for the wind turbine towers.

Norway is renowned for its oil and gas industry activities, and some respondents see this experience as a potential advantage in driving offshore wind development. Although the technologies are different, respondents deem it likely that engineers from the oil and gas industry might have knowledge relevant to the wind industry and that skills related to running big projects offshore are an advantage when it comes to expanding offshore wind. Currently, Norway is facing a challenge with creating foundations for offshore wind, as the wind turbines create vibrations. For this challenge, there is a need for structural engineering and floating engineering skills. Overall, respondents from Norway estimate that universities produce engineers with the right skills. However, much of the engineering training in Norwegian universities is focused on the oil and gas industry and scenarios specific to this sector. As a result, engineers have the right skills but lack the knowledge of how to apply their skills in renewable energy sectors.

Table 3 Selection of technical skills needed for engineers in the wind power sector

Technical skills from job postings	Technical skills from interviews and desk research
• Python	• Test and validation
• Software development	• Structural engineering
• Test	• Floating engineering
• MATLAB	• Fluid dynamics
• C and C++	• Generator technology
• Lean	• Structural requirements for wind turbines
• Iatf16949	• Geotechnical engineering
• Programming	• Software engineering
• Software	• Cyber security
• Validation	• Civil engineering
• Pfmea	• Mechanical engineering
• Pscad	• Electrical engineering
• Pss	• Power engineering
	• Controlling technology

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the wind power sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for engineers in the wind power sector using job postings.

We see that skills related to software engineering are in high demand within the wind power sector today. These include coding skills such as Python, C, and C++. With respondents expecting increasing future demand for software engineers, demand for these skills may increase as well. Furthermore, we see that both test and validation skills are in high demand in job postings today. The lack of education in Denmark for engineers specialised in test and validation has the potential to create a bottleneck, as engineers need upskilling to match the current skill sets with the industry demands.

Batteries

Overall trends in development

The demand for batteries on a global level is increasing along with the electrification of society. This trend is seen across the Nordics to a varying extent. Sweden is considered one of the drivers of the battery sector within the Nordic region. The Swedish strategy for a sustainable battery value chain from 2020 highlights Sweden's ambition to contribute to the European battery industry development [20]. The strategy emphasises the importance of creating synergies around the sector and ensuring skill development within the battery sector to fuel the transition. A significant contributor to this ambition is the battery company Northvolt, whose production stretches across the larger part of the battery value chain – from the production of active materials to cell assembly and recycling. The Swedish battery sector is expected to grow and create new jobs. Northvolt has 3,000 employees and expects to expand to 10,000 in the next six years. In addition, The Volvo Group and Scania have invested considerably in establishing battery factories in Sweden in recent years.

The battery industry is a completely new industry in Sweden and in Europe, so the skills are not here, and the experience is not here.

Respondent, Sweden

Finland is another Nordic country perceived as an attractive location for battery production plants and mineral extraction [21]. Finland is considered strong in raw materials, active materials, and battery recycling [22]. Because of this, the battery market within Finland is expected to increase. The Finnish National Battery Strategy states that "in 2025, the Finnish Battery and Electrification sector will be a forerunner that provides skills, innovation, sustainable economic growth, well-being, and new jobs for Finland", underlining the country's ambition within the sector [23]. The importance of building and developing skills within the country is evident in the strategy's six building blocks, one of which is education, training, and research supporting the development of a circular economy and sustainability.

20 Fossil Free Sweden (2021): Strategy for fossil free competitiveness. Sustainable Battery Value Chain.
21 Engineers Finland (2022): The Effects of the Green Transition to the Employment and Educational Requirements of Engineers in Finland
22 Business Sweden, (2021), Den Nordiska Batterivärdekedjan.
23 The Ministry of Economic Affairs and Employment Enterprises, (2021): National Battery Strategy 2025.

Norway is another Nordic country with a strong focus on battery production. Within Norway, there is an understanding amongst private sector actors, academia, and public sector actors of the importance of making use of the opportunities in the Norwegian battery sector. The value chain within Norway is expected to create a potential revenue of 9 billion EUR in 2030. In 2050 this is predicted to double to 18 billion EUR and have created 15,000 new jobs, indicating a rapidly growing sector [24]. The market in Norway encompasses strong actors in raw materials, active materials, production of battery packs, and battery usage. NTNU estimates that around 20 per cent of the workforce necessary for the Norwegian battery factories are engineers, and around 2000 engineers are needed in the battery industry by 2025 – excluding engineers for research and development [25]. Following the establishment of new battery factories in Norway, the battle for qualified engineering talent will intensify [26].

Denmark does not have a strategy for battery production, and the activity around batteries is lower. However, some R&D focused on batteries is taking place in the educational system and by private sector actors. Even though the market is younger, there are leading battery usage and integration companies in Denmark. Iceland, too, has a younger market in battery production, and the country lacks the raw material needed for battery production. However, since Iceland runs on renewable energy to a large extent, there is an incentive for developing capacity for energy storage. With a strong aluminium industry, the country has the potential, and Iceland has plans to produce aluminium batteries [27].

Accessing the right engineering skills across the Nordics to match the ambitions of battery production is perceived as difficult. An increase in both new graduates in the sector and battery-specific knowledge among engineers is necessary for expanding the sector.

Most engineers can describe how a car is manufactured, or how a combustion motor works, but less understand exactly how a battery works, and that is a challenge.

Respondent, Sweden

24 Business Sweden, (2021), Den Nordiska Batterivärdekedjan.
25 E24 (2021): Er nærmest sikret jobb: Norge mangler batteri-ingeniører som Ingvild.
26 Menon Economics (2021): Kartlegging av behovet for ingeniørkompetanse innen bærekraftig industri.
27 Business Sweden, (2021), Den Nordiska Batterivärdekedjan.

Specific skill demands for engineers in the battery sector

Skills in demand within the battery sector can be found across the entire battery lifecycle, from raw material production to recycling technology and next-generation charging.

Raw material production requires understanding basic skills such as mechanical engineering, chemical engineering, and electrochemical engineering. Electrical engineers and automation engineers are essential for this stage as well.

The production of batteries has primarily been concentrated in China; therefore, Europe lacks skills in battery production. As the European battery production market expands, the demand for engineers with hands-on knowledge of production and process engineering, including machine design and commissioning processes, is expected to increase. Specifically, understanding what process parameters will control electrochemical performance in battery production is essential. With the market expanding within Sweden, respondents point to a lack of engineers with the direct experience required to work on the production floor.

Respondents underline a specific need for quality compliance engineers working with quality requirements in Sweden. The quality requirements of the production of batteries are very high, which leads to increased demand in the sector for engineers with these skills.

Along with understanding the lifecycle of the batteries comes a need to understand the raw materials used for battery production and how to recycle batteries after use. Respondents underline the importance of recycling for the battery value chain and how recycling volumes are expected to increase. With this comes the need for skills and competencies within battery recycling and recycling technology. In the Nordic region, Finland specialises in recycling batteries using hydrometallurgy. In Sweden, Northvolt aims to have more than 50 per cent recycled material in their batteries by 2030, which is expected to further drive a need for competences.

Apart from specific skills required for battery production, there is a need for engineering skills on how to utilise the batteries and develop the sector. An example is competences in battery operation and electricity network optimisation using batteries. Engineers also need to consider future battery chemistries and what will happen in terms of next-generation batteries. This includes how to design the next-generation machines that will run on batteries in the future, what the battery charging ecosystem will look like, and how the batteries can and should be charged in the future. When reaching a capacity where large machines within the mining industry run on electricity, it will be increasingly important for engineers to understand and manage the machines' hydraulics and electricity.

Table 4 Selection of technical skills needed for engineers in the battery sector

Technical skills from job postings	Technical skills from interviews and desk research
• Simulation tools (MATLAB/Simulink) • Analysis and design of battery components • Electronic/computer engineering, information systems, software engineering • Knowledge of mining, paper mill, semiconducters, fine chemicals • PLC/SCADA • FMEA • Structural mechanics • Fluid mechanics • CAE • OrCad, Altium designer, powerCAD • PI and SI simulation analysis • AMI and EMC design • Programming languages (C, C++, Python, etc.) • CATIA, Pre-E, AutoCAD • Thermal management design • Properties of plastic and metal materials • ISO/TS 16949:2009, ISO9001, ISO 14001 • Data analysis software • Test reports, 8D analysis reports • Electrochemical kinetics • Thermodynamic mechanisms • Parameter calibration • Force-electric coupling • Thermal-electric coupling	• Process engineering • Raw material production • Mechanical engineering • Chemical engineering • Electrochemical engineering • Electrical engineering • Automation engineering • Process engineering • Production engineering • Machine design • Commissioning processes • Knowledge of quality requirements • Battery recycling and recycling technology • Knowledge of optimisation of electricity network using batteries • Battery operation • Knowledge of the future of battery chemistry • Design of machines running on batteries • Battery charging ecosystem • Management of hydraulics and electricity for vehicles

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the wind power sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for engineers in the battery sector using job postings.

We see that skills related to the analysis and design of batteries are needed within the sector. This is underlined by the respondents as well as identified in job postings. Furthermore, as underlined by respondents, there is a need to understand ISO standardisation, quality requirements, and testing.

Hydrogen

Overall trends in development

Hydrogen is an essential feedstock in industrial processes across the Nordics and globally. However, hydrogen is currently responsible for the usage of approximately 6 per cent of global natural gas, 2 per cent of the global coal consumption, and 2 per cent of all global energy-related greenhouse gas emissions [28]. Following the demands for a green transition, increased interest in clean hydrogen and synthetic fuels, known as e-fuels, can be seen across the globe.

Along with global trends, the demand for clean hydrogen is increasing across the Nordic region. Respondents point towards a hydrogen boom, with increased funds pouring into the sector. For example, Iceland aims to increase the use of hydrogen e-fuels. Because of its access to green, hydro- and geothermal energy, the country has ample opportunities to become competitive within the space of hydrogen production. In Sweden, industry projects focusing on hydrogen are driving the transition across the country [29]. Finland is increasingly funding hydrogen projects, and there is a call from the Finnish industry to develop Finland's hydrogen and electricity infrastructure [30]. Clean hydrogen is considered a significant element for achieving Finland's carbon neutrality target for 2035 [31]. The key goals outlined in Finland's Green Transition – Recovery and Resilience Plan include making Finland a world leader in hydrogen and emission-free systems [32]. Norway also has ample opportunities to scale its hydrogen industry, especially because it has experience in the advanced process industry, including producing hydrogen from electrolysis. A range of Norwegian actors are well advanced in developing hydrogen projects, but increased funding is needed to scale the projects fast enough [33].

Maybe earlier it was boring to be an engineer or study combustion technologies and power plants because they were polluting and running on dirty fuels, but now with this transition to the green we can really show society that that we are a part of the green transition.

Respondent, Iceland

28 Ørsted (2020): Decarbonising society with Power-to-X. A path to scaling production and uptake of renewable hydrogen and sustainable e-fuels.
29 Fossil Free Sweden (2021): Strategy for fossil free competitiveness. Hydrogen.
30 Fingrid, (2022): Intermediate report: Energy transmission infrastructure as enabler of hydrogen economy and clean energy system.
31 Fingrid, (2022): Intermediate report: Energy transmission infrastructure as enabler of hydrogen economy and clean energy system.
32 Engineers Finland (2022): The Effects of the Green Transition to the Employment and Educational Requirements of Engineers in Finland.
33 Energi Norge (2021): Norge må satse på storskala grønn hydrogenproduksjon.

Respondents also underline how the transition from gas to hydrogen via CCS will bring interest to previously carbon-heavy industries as they shift towards green energy sources. However, the capacity to produce hydrogen across the Nordic region is being developed. For example, Iceland needs the proper infrastructure to support its hydrogen strategy's ambitions. The same goes for Finland, where the bottleneck will be scaling up the manufacturing capacity for hydrogen equipment and systems. Respondents highlight that few people across the Nordic region have the necessary skills and competencies to produce and utilise green hydrogen. As an example, Iceland sees a need to import international skills to meet the demand; otherwise, there will be a lack of skills in the next few years. The competition for engineering talent is fierce, and many countries experience a shortage of skilled professionals. It is difficult to estimate from where talent attraction is possible – and if it is possible.

Specific skill demands for engineers in the hydrogen sector

Regarding specific tech competences, producing green hydrogen requires technical skills combined with systems thinking [34]. The hydrogen market will require the formation of systems tightly interlinked with other sectors at multiple levels. This means that technical experts within the process industry will need to understand sector integration, the life cycle of materials, and the utilisation of side-streams and waste.

We have ample opportunities for increased production of green electricity here in Iceland. So, we could be quite competitive in producing hydrogen e-fuels.

Respondent, Iceland

The demand for basic engineering skills in physics, chemistry, and mathematics is also expected to increase. Iceland, for example, lacks chemical engineers due to the lack of chemical industries. Sector-specific competencies include production technology, hydrogen storage and handling, and safety. Knowledge of medium voltage engineering, different test models, AI, automation, data science, and digital modelling and simulation is also mentioned as increasingly in demand for clean hydrogen production.

34 Engineers Finland (2022): The Effects of the Green Transition to the Employment and Educational Requirements of Engineers in Finland.

A new value chain is developed as the world transitions towards clean hydrogen. Along with this development comes a need for an increased understanding of how to continue developing the electrolysers used to produce hydrogen. Although the technology around electrolysers is old, there is a need to understand how to modernise and integrate hydrogen production into the value chain of machines expected to run on hydrogen. In the Nordics, Finland still lacks competencies in low-temperature electrolysis within the Finnish industry [35]. However, this knowledge exists in research institutes, universities, and start-up companies, and there is a need for partnerships to acquire the right competencies and skill sets.

The hydrogen fuel chain utilises renewable energy to power the electrolysers that create green hydrogen. This PtX process requires an increased need for engineering skills within chemical engineering. There is also a need for people knowledgeable about the connection between water, chemicals, and high voltage to understand the whole power-to-hydrogen chain. The respondents underline the need for these skills as the new processes around utilising green energy to run the electrolysers require engineering skills that ensure energy efficiency and secure processes. Further, there are opportunities to consider total energy efficiency - e.g., utilising excess heat from the process in district heating.

There will be increasing demand for people who understand how to use PtX to bridge clean energy production and energy-intensive industries. For example, engineers working with new hydrogen fuel sources will need to understand how a combustion engine can transition from natural gas to hydrogen, as the properties will be very different from the previous combustion engines running on natural gas. Hydrogen has explosive properties, which require other safety considerations than natural gas. As the usage of hydrogen increases, demand for these skills will evolve.

Lastly, there is a need for more holistic assessment skills and knowledge of the entire value chain to understand the impact of new fuels and how they can be utilised and introduced. Understanding impact and lifecycle assessment (LCA) will be imperative for those engineers working in the sector.

35 Hydrogen Cluster Finland (2021): A systemic view to the Finnish Hydrogen economy today and in 2030 - Common playbook for the way forward.

Table 5 Selection of technical skills needed for engineers in the hydrogen sector

Technical skills from job postings	Technical skills from interviews and desk research
• Mechanical design	• Physics
• Quality control	• Chemistry
• Technical documentation	• Mathematics
• Welding	• Chemical engineering
• div	• Production technology
• Inspections	• Hydrogen storage and handling
• Installation of process equipment	• Safety
• Mechanical engineering	• Medium voltage engineering
• Metallic materials	• Test models
• Piping	• AI
• Proprietary equipment design	• Automation
• AutoCAD Mechanical	• Data science
• Capex	• Digital modeling and simulation
• Catalyst development	• Knowledge of electrolysers
• Chemical engineering	

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the hydrogen sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for the hydrogen sector using job postings.

When researching technical engineering skills in demand in the hydrogen sector, skills in mechanical engineering recur on the list – skills such as mechanical design and AutoCAD Mechanical. In addition, knowledge of physical engineering processes is also in demand, including knowledge of installations of process equipment, welding, and piping. Furthermore, skills related to safety appear on the list, such as ASME codes for safety, quality control, and inspections. With the increasing demand for engineers working with hydrogen as a fuel source, skills related to mechanical engineering, chemical engineering, and safety may be increasingly in demand in the hydrogen industry in the future.

Biomass

Overall trends in development

Bioenergy is an energy source that will continue to play a crucial role in phasing out fossil fuels in the EU [36]. Phasing out fossil fuels is expected to increase the demand for biomass and electricity [37]. Bioenergy is essential to the Nordic energy system, and the expectation is that it will maintain this role through 2050. In Sweden, Finland, and Denmark, the share of biomass in the total gross energy consumption is close to 25 per cent [38]. Nordic Energy Research points to the likelihood that biomass use will shift from power and heat energy towards fuels for heavy long-distance transport, like shipping, aviation, and industrial processes. This is mainly due to the increasing electrification of heating and the fact that biofuel is currently one of few alternative fuel sources for heavy transportation [39]. Although biomass is a renewable energy source, it is important to consider its potential as it is not an unlimited resource and is highly dependent on forestry industry developments [40].

Bioenergy is Sweden's largest energy source and has played an essential role in reducing Sweden's greenhouse gas emissions by 29 per cent compared to 1990. The bio-strategy of Fossil Free Sweden estimates that the need for bio-based feedstock in Sweden will increase to around 193 TWh by 2030 - an increase of 22 per cent compared to the current use of bioenergy. This increase is primarily due to the road transport sector's need for biofuels to meet the target of reducing emissions from domestic road transport [41].

Biomass is also a dominant energy source in Denmark. However, only a partial amount of the biomass accessible in Denmark is utilised today, and there is potential for increased use of biomass in the Danish energy supply . In 2020, the Danish Energy Agency published a report analysing the prospects for biomass in Denmark. The report argues that biomass use has increased due to the rapid phasing out of coal. However, as part of the long-term renewable energy strategy, the use of biomass is expected to decrease due to an increase in wind and solar power [43].

36 Fossil Free Sweden (2021): Strategy for fossil free competitiveness – Bioenergy and bio-based feedstock in industry transition.
37 Naturvårdsverket och Statens Energimyndighet (2022) Industrins klimatomställning: Underlagsrapport till regeringsuppdraget om Näringslivets klimatomställning.
38 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.
39 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.
40 Nordic Energy Research, (2021) Nordic Clean Energy Scenarios.
41 Fossil Free Sweden, (2021), Strategy for fossil free competitiveness – Bioenergy and bio-based feedstock in industry transition.
42 Danish Energy Agency, (2022), Biomass.
43 Danish Energy Agency (2020): Biomasseanalyse.

Finland is another Nordic country with a large market for bioenergy, and biomass is an important resource for renewable energy [44]. Around 85 per cent of the country's renewable energy supply comes from biomass [45], and the use of solid biomass in the industry has been steadily increasing [46]. The production of combined heat and power (CHP) has a long tradition within Finland, and a growing number of CHP plants across the country are fuelled by wood. However, the development in Finland has recently come to a halt, as the country's land use sector is now (2022) a source of emissions instead of a carbon sink. The collapse of the carbon sink means that Finland is now initiating rescue programmes to strengthen the carbon sink and must consider other measures for emission reductions [47]. As a result, biomass is expected to be used less in electricity and heat production in Finland going forward.

The usage of biomass in the energy system [...] there are a lot of projects right now on changing the use and making the use of biomass more efficient in the energy system. I think that is an area where we have special knowledge and interests.

Respondent, Denmark

Compared to Sweden, Finland, and Denmark, Norway's use of biomass as a share of total gross energy consumption is lower, reaching just above 5 per cent in 2019 [48]. However, the amount has increased in the past five years, indicating a growing market. Norway has the natural resources, knowledge, and capital to invest in a bioeconomy, resulting in new job creation across the country [49]. In 2015 the Norwegian government launched the national strategy SKOG22, which underlines the importance of securing competencies and recruitment to technical areas focusing on developing new solutions to convert Norwegian biomass into new bio-based products [50].

44 Arbets- och näringsministeriet (2017) Statsrådets redogörelse om nationell energi- och klimatstrategi fram till 2030.
45 IEA Bioenergy (2021). Implementation of bioenergy in Finland – 2021 update.
46 IEA Bioenergy (2021). Implementation of bioenergy in Finland – 2021 update.
47 The Finnish Climate Change Panel (2022): The net sink in the land use sector needs to be strengthened urgently.
48 Nordic Energy Research (2021): Nordic Clean Energy Scenarios.
49 SKOG22 (2022): Nasjonal strategi for skog- og trenæringen.
50 SKOG22 (2022): Nasjonal strategi for skog- og trenæringen.

Specific skill demands for engineers in the biomass sector

Within the biomass sector, understanding the larger perspective and cross-disciplinary thinking is considered necessary for engineers entering the market. With a growing focus on joint ventures, a mix of disciplines, and a need for more efficient integration of the different value chain steps, respondents highlight the need for engineers to know the ecosystem around them. A greater understanding of the entire value chain creates valuable solutions, as opposed to a narrow focus on specific functions that is part of a larger value chain. In connection with this, it is important for an engineer entering the biomass sector to have a basic understanding of the sector and its intricacies in advance. Something that newly educated engineers often lack.

Looking at the new, interesting solutions to our energy problems – they are in general multidisciplinary in their thinking.

Respondent, Denmark

Technical skills perceived as lacking within the industry are related to tree harvest. Developing the sawmills requires civil, mechanical, design and industrial engineers, and the pulping process requires biochemical engineers. Energy production requires energy and systems engineers. General sector development will increasingly require skills within AI and digitalisation. Finally, in addition to general social skills and the ability to collaborate easily, engineers need to understand and efficiently handle information and data sets.

Table 6 Selection of technical skills needed for engineers in the biomass sector

Technical skills from job postings	Technical skills from interviews and desk research
• Inventor • ANSYS • AutoCAD • Empirical design • En1090 • Sap • 3d programs • SOLIDWORKS • Anaerobic processes • Biotechnology • Strength calculations • Biogas processes	• Biochemical engineering • Technical engineering • Physical engineering • Systems engineering • Energy engineering • AI and digitalisation • Knowledge and understanding of data and data utilisation

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the hydrogen sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for the hydrogen sector using job postings.

Respondents have highlighted a range of engineering disciplines as important in the overall picture of in-demand skills for engineers in the biomass sector. Software-related skills are at the top of the list of skills identified in job postings in the left column. These include modelling and simulation software such as Inventor, AutoCAD, SOLIDWORKS, and ANSYS. With respondents expecting increasing demand for engineers with knowledge of AI and digitalisation, such software-related skills will potentially increase demand in the biomass sector moving forward. Furthermore, knowledge of anaerobic processes and skills in biotechnology recur across job postings.

Geothermal Energy

Overall trends in development

Geothermal energy is not gaining traction in the Nordics to the same extent as other renewable energy sources. However, Iceland's access to green energy is better than in its neighbouring Nordic countries. Iceland benefits from access to active volcanos and is the only Nordic country that uses geothermal energy for electricity generation in addition to domestic heating. Other Nordic countries utilise geothermal energy for heating, but it is a more complicated and expensive energy source for them. The related deep drilling process is technically arduous, involves greater uncertainty, and requires higher investment costs.

Norway and Sweden are progressing in terms of developing geothermal energy. Actors like Geothermal Energy Nordics (GTML) are continuously gathering competences, creating networks around the sector, and building a pipeline of geothermal projects in Norway and Sweden. Norwegian knowledge of drilling from the oil and gas industry is considered an advantage when developing technology for geothermal heat extraction. Sweden is a leader in terms of capacity installed in geothermal heat pumps. In 2020, the German company E.ON announced its plans to build deep heat geothermal power plants in Sweden. However, due to Covid-19, the project, along with other geothermal projects, has been stalled. In 2021, Finland was the first country in Europe to commission a geothermal district cooling project, according to the European Geothermal Energy Council [51].

Several research projects have identified the presence of substantial geothermal resources in Denmark. Some sources estimate that geothermal resources have the energy potential to supply the district heating of up to 50 per cent of the Danish households. However, only a fraction of these resources is in use today [52]. Moreover, Denmark generally lacks frontrunners and investments in the technology, which is stagnating [53]. However, respondents expect that if geothermal energy develops in Denmark over the following years, the most important technical skills needed are knowledge of integrating geothermal energy into the existing district heating system.

The geothermal sector is a driving sector within Iceland, with hydrogen e-fuels on the rise. A significant amount of Icelandic energy depends on geothermal energy. However, the transportation sector, including motor vehicles, fishing vessels, cargo ships, and aeroplanes, still relies on carbon-heavy energy sources and needs to transition towards green energy. Tech solutions for road transition already exist but will take years to develop for aeroplanes.

51 European Geothermal Energy Council (2021): EGEC Market Report.
52 Poulsen et.al. (2019): Geothermal Energy Use, Country update for Denmark.
53 Energiforum Danmark (2020): Geotermi kan blive fremtidens grønne fjernvarmeforsyning.

Of course you need a lot of technical skills. You need to know about the geology, the technical aspects around drilling, and then of course running the power plants. It's basically a very broad field.

Respondent, Iceland

Specific skill demands for engineers in the geothermal sector

Generally, little knowledge and resources exist on the future demands for engineering skills in developing geothermal energy for the rest of the Nordic countries. The technology is not gaining traction to the same extent as other renewable power technologies, and the development is equally not as rapid as some other technologies described in this report.

The demand for skills within the geothermal industry in Iceland is not expected to increase substantially in the next few years, except for further development of binding geothermal gasses in deep rock formations, which is addressed in the following chapter on CCS & CCU. The skills required within the geothermal sector in Iceland are considered broad, and they are generally related to running the geothermal plants – e.g., geological drilling and the technical aspect of drilling and running the power plants. Iceland is still expanding the geothermal plants and developing new fields within geothermal, which are expected to grow to some extent.

Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU)

Overall trends in development

Reducing emissions is the most significant necessity for Nordic countries to reach carbon neutrality. However, as implementing climate technologies takes time, technologies like CCS can reduce emissions in sectors where viable alternatives do not yet exist or haven't scaled enough [54]. Whereas CCS is considered a necessary technology to reach fast large-scale reductions of emissions on the journey towards climate neutrality, CCU is a part of the long-term vision, where captured CO2 is turned into fuels through a PtX solution.

The market for CCS and CCU is expected to grow within the Nordics. The Swedish sector for CCS and CCU is expanding, and according to respondents, new initiatives are expected to launch in the coming year. In the Nordics, Norway is a frontrunner in CCS, with technological experience and extensive history with offshore energy industries. Furthermore, Norway has good storage potential for carbon dioxide [55]. The country has invested 1.7 billion euros in the Longship project, a full-scale carbon capture, transport, and storage project aimed at storing CO2 on the bottom of the North Sea [56]. In April 2022, Sweden and Norway agreed to intensify cooperation on CCS, specifically on the permanent storage of carbon dioxide in the Norwegian continental shelf [57]. According to a report by the Nordic Energy Research, one of the most critical actions for the development of CCS is to coordinate infrastructure development, like in Norway and Sweden, to reduce entry barriers for individual actors [58].

In Finland, the CCU sector is seeing organic growth, which respondents expect to increase. Both Finland and Sweden have strongholds regarding bioenergy, which, combined with carbon capture, can result in negative emissions. According to the Ministry of Economic Affairs and Employment in Finland, CCS and CCU will play important roles in carbon-neutrality actions towards 2035. Among emerging possibilities in Finland is using biomass with carbon capture in the bioenergy industry and CCS and CCU in connection to PtX technologies in hydrogen production. However, the market is just starting to develop [59].

In Iceland, projects around CCS have proven successful. For example, the CarbFix Pilot Project developed an approach to CCS where carbon dioxide is dissolved

54 Nordic Energy Research (2021): Nordic Clean Energy Scenarios.
55 Nordic Energy Research (2021): Nordic Clean Energy Scenarios.
56 Government of Norway (2020): The government launches 'Longship' for carbon capture and storage in Norway.
57 Government Offices of Sweden (2022): Norway and Sweden agree to intensify cooperation on carbon capture and storage.
58 Nordic Energy Research (2021): Nordic Clean Energy Scenarios
59 Finnish Ministry of Economic Affairs and Employment (2021): Summary of sector-specific low-carbon roadmaps.
60 Carbfix website: https://www.carbfix.com/how-it-works.

We have the knowledge that Norwegian engineers have in operating at deep sea because of our oil industry. We have very high competencies in these areas related to experience from the oil industry. That is now transferring to renewable energy and projects based in the ocean.

Respondent, Norway

in water and injected into rock formations, thus turning solid [60]. According to respondents, CarbFix is now looking into possibilities for exporting the technology to sectors where it can prove useful, indicating future CCS development in Iceland. In the 2020 national plan, the government of Iceland describes an intention to reduce CO2 emissions from geothermal power plants – for example, through the CarbFix method [61]. Since Iceland has almost 100 per cent of its energy demand covered by renewable energy sources, the country is increasingly focused on the transportation sector. Thus, Iceland is increasing efforts around producing e-fuels that, among other options, use carbon for feedstock through a PtX solution. Iceland's plan to expand the production of e-fuels for the transportation industry has the potential to increase the development of carbon capture technologies like CCU alongside the utilisation of energy from well-established sources like geothermal and hydropower. Further possibilities exist in combining CCS with hydrogen produced from natural gas as a route to CO2-free hydrogen. The development of CCS/CCU technologies in Iceland is expected to impact the future demand for engineers within the field. However, Iceland already possesses engineers with relevant skills from the geothermal sector.

In Denmark, much the same as in the other Nordic countries, CCS and CCU are critical components in reaching the 2030 target of a 70 per cent reduction in greenhouse gas emissions. Denmark possesses specialised operational knowledge and technical understanding needed for CCS due to offshore oil and gas fields and onshore gas storage sites. Several Danish companies are currently working to develop carbon capture systems, whereas activities around CO2 utilisation are limited to a few players [62]. Innovation Fund Denmark expects solutions for subsurface storage to be ready by 2025-2030 at the latest [63].

61 Government of Iceland (2020): Iceland's National Plan.
62 Innovation Fund Denmark (2021): The Green CCUS Roadmap – Towards a fossil free future.
63 Innovation Fund Denmark (2021): Missions CCUS – a roadmap for Carbon Capture, Utilisation and Storage.

Specific skill demands for engineers in the CCS/CCU sector

The market for CO2 capture is new, and new skills are required to meet the demands in the market. Further, new skills are needed for new business concepts.

The CCS and CCU-specific technical skills described as being in demand by respondents are automation, electrical engineering, operational maintenance, and mechanical and operational chemistry. Respondents particularly stress the importance of electrical engineering. Skills within this field, such as programming knowledge and test engineering, are increasingly in demand.

In terms of production and setting up a plant, operations and maintenance are two skill sets required amongst engineers for this market to develop. One respondent points to a specific need for front-end engineers (FEED) as well as knowledge of Balance of Plant (BOP) for the setup and operation of a new plant.

As CCS and CCU are still somewhat abstract concepts, visualisation and storytelling skills can help engineers communicate how a potential solution might look to different stakeholders in the industry.

Table 7 Selection of technical skills needed for engineers in the CCS/CCU sector

Technical skills from job postings	Technical skills from interviews and desk research
• Lean • Test methods • Iso 9001 • Carbonation • Epoxy • Iso 17025 • AutoCAD • Composites • Design and operation of processing plants • Heat exchangers • Pre-treatment of gasses • Syngas/ammonia plant design • Simulation tools (Aspen, ProTreat etc.) • Chemical engineering • Steam cycles • Power plant applications • Technical safety • Plant commissioning and operations • Carbon injection modeling (using Eclipse or GEM) • Flow assurance • Reservoir engineering	• Automation • Electrical engineering • Operational maintanance • Mechanical and operational chemistry • Programming knowledge • Test engineering • Front-end engineering • Knowledge of BOP (Balance of Plants)

The right column summarises the technical skills mentioned in this chapter, which respondents expect to be in increasing demand following the development of the hydrogen sector across the Nordics. The list of skills mentioned by informants is supplemented with skills derived from desk research. The left column lists a range of technical skills identified when researching skills needed for the hydrogen sector using job postings.

The list on the left reflects demands for engineering skills specific to the application to CCS/CCU, such as plant commissioning and operations, carbon injection modelling, carbonation, reservoir engineering, and design of processing plants. With the development of CCS and CCU across the Nordics, these skills will potentially increase in demand. The list further reflects a need for skills and knowledge within the use of simulation tools as well as knowledge of gasses and other processes related to chemical engineering.

5 EDUCATIONAL MEASURES

For this chapter of the report, we present some areas where respondents see a need for educating new students and reskilling or upskilling the current engineering workforce to match the demand from the climate technology industry. In connection to these points, we present a list of educational measures that respondents mention during interviews, which are believed to be necessary to overcome some of the current educational gaps or enable re- or upskilling to drive the future development of climate technologies. The list does not provide a complete overview of all the educational measures and upskilling required but gives insight into some of the potentials that are most prevalent from the respondents' point of view.

A need to create attraction to the energy sector

As previously described, Finland is facing the challenge of engineers' lack of interest in the energy sector. However, this challenge is not limited to Finland. As the energy sector competes for talent with other sectors, such as tech and pharma, respondents deem it critical to increase attraction by raising awareness around the possibilities for engineers in the sector. Respondents from several Nordic countries experience that engineering students lack knowledge of their career opportunities within the climate technology sectors – in their home countries, but even more so in the other Nordic countries. This creates a potential barrier to talent flow across national boundaries and the number of engineering students choosing to specialise within a climate technology area during their studies. One measure to avoid a bottleneck in the development of climate technologies in the Nordics

We are now facing a technological shift that is most likely the most significant one since the second world war and this means that there needs to be sort of a rapid movement and very targeted efforts also from the political leadership [...] trusting the way that we normally renew our education system – that is the major bottleneck because that system is not working when it comes to these volumes and this pace.

Respondent, Sweden

is to increase collaboration between universities and thus increase the visibility of options and awareness among the students (more on this point under the chapter "6. Potentials for increasing Nordic synergies"). Although it is important to create awareness of the energy sector and its possibilities among existing engineering students, it is also – probably even more – crucial to focus on attracting more students to engineering programmes. As emphasised in this report, future shortages of engineering talent are expected across all climate technology sectors and generally in the Nordics. Measures to increase the attraction to engineering programmes are vital in mitigating the risk of future bottlenecks in climate technology development. In this context, respondents also emphasise the need to address the gender imbalance in engineering and attract more female students, as a big part of the untapped potential lies here.

More wind power-specific training is needed

Finnish and Icelandic respondents emphasise the need for more university wind power-specific training for engineering students. Denmark, Sweden, and Norway have universities that offer wind power-specific study programs – e.g., the European Wind Energy Master's program, which is a joint program between DTU (Denmark) and NTNU (Norway) and with universities in the Netherlands and Germany. Finland has plans to increase wind power capacity noticeably within the coming years, and more engineers with wind power-specific training are needed to drive that development. In Finland, there is currently little access to wind power-specific training for engineering students while studying at university. Wind power companies thus face a challenge when it comes to recruiting talent and must upskill employees themselves. Iceland is generally lacking knowledge and research on wind power. Although there are currently no large-scale plans to develop wind power capacity in Iceland, there is a need to prepare the engineering workforce for potential future development.

A need for upskilling the engineering workforce

Respondents experience a growing need for upskilling engineers to work with emerging climate technologies. A general view is that newly educated engineers, to some extent, have the skills needed, whereas the current engineering workforce is falling behind the skills demands of the market. To a large extent, the established engineering workforce is working with traditional engineering practices; however, respondents see an urgent need for these to reinvent their profession to follow the development. Especially energy engineering disciplines are moving rapidly into more digital spaces where upskilling is needed. Furthermore, the growth of climate technologies calls for more integration of sustainability themes in engineering professions, which respondents experience as lacking in the existing engineering workforce.

You can't study wind power as a major in Finland, not necessarily even a minor. Some technical universities have some wind power-related studies, but it's often a part of general renewable energy technology studies. It goes for all levels of education in Finland that we are lacking wind power-specific training.

Respondent, Finland

A call for increased collaboration between academia and industry

Multiple respondents from the industry and academia bring up the need for more collaboration. Representatives from academia see the potential for greater collaboration with industry, as engineering students would be able to get a better sense of what type of technologies with which they would like to work. Furthermore, students could acquire preliminary and up-to-date knowledge of the problems and challenges for industries working with specific technologies. Representatives from the industry are generally experiencing an engineering workforce that lacks applied knowledge. Through closer collaboration with academia – for example, through casework – students can contextualise their skills and gain valuable technology-specific knowledge before they enter full-time positions. Some respondents from the industry express a need for this collaboration to be introduced early in education. This would enable students to get prior knowledge of multiple technologies and allow them to choose a specific direction at an earlier stage of their education.

We feel that some of the engineers we want to hire don't know the forest industry. The forest industry has to be a part of the education, and I'm quite sure that goes for other industries as well, so that the students are aware of the different pros and cons and the challenges in different sectors.

Respondent, Sweden

A need to broaden academic attention to include a focus on climate technologies

All respondents emphasise the importance of ensuring that engineering students work with climate technology cases and scenarios during their education. Respondents from Norway are, for example, experiencing a discrepancy between the knowledge demand in climate technology sectors and the focus on oil and gas scenarios in engineering education. They highlight the need for more focus on climate technologies in engineering education, mainly for two reasons: 1) the predominant focus on oil and gas scenarios in engineering programs potentially creates a lack of interest in climate technologies from engineering students, which potentially poses a current and future recruiting challenge to industries working with climate technologies, and 2) when entering the labour market, the engineering workforce lacks knowledge of how to apply their skills in industries besides oil and gas, which results in an increasing need for upskilling.

Expanding the battery workforce

To prepare the engineers for the rapid development of climate technologies across the Nordics, respondents highlight the importance of taking advantage of the existing knowledge and skillsets in other sectors. For example, in the battery sector in Sweden, a respondent mentions engineers from the automotive

We have most of the technical skills taught in university today, but they are applied mainly towards oil and gas scenarios. The major change we need to see is that the universities start to use cases and tasks on the exams that are more related to industries of the future.

Respondent, Noeway

industry with knowledge of combustion motors or engines as professionals with the potential to be upskilled for the battery sector. This would demand battery-specific courses in areas like battery chemistry. Furthermore, Swedish respondents see a general need for more battery-specific education at the universities. One respondent estimates that the battery sector will need approximately 1000 newly educated engineers annually when looking across the Nordics. Not all of these will need battery-specific education, but many of them will have to have some knowledge specific to batteries. Many battery experts go through PhD programs to reach an expert level, as there is a less battery-specific focus in bachelor's and master's programs. In Norway, an analysis from Norwegian Industry reveals that knowledge related to the battery value chain, safety, and battery technology is just now entering the curricula, whereas skills in battery cell production, battery technology and cell design, EU battery regulation, and various manufacturing technologies for batteries are sparsely covered at the Norwegian universities . All these skills are essential to ensure a future flow of battery specialists from university to the battery sector. Respondents see a need to expand the volume of engineers with battery-specific knowledge at both the bachelor's and the master's level, as it will take too long to build the capacity of engineers needed for the battery sector if all must reach a PhD level.

In addition, another respondent highlights the need for creating a targeted effort to build competency clusters at a selection of educational institutions where battery-specific programs are available and teachers have battery-specific knowledge. An example of such efforts is the Nordic Flow Battery Network [65], which aims to promote collaboration on battery research in the Nordic region through networking grants, workshops, research visits, and summer/winter schools. Increasing such efforts would demand support and resources from the government dedicated to building an educational infrastructure around battery-specific engineering. Furthermore, the education would have to cover the entire value chain for battery technology. The respondent emphasises that, as of now, knowledge of different parts of the value chain is somewhat scattered between various educational institutions – meaning that some have knowledge of materials chemistry and electrochemistry, whereas others have knowledge of control systems, mining, and recycling modelling. Creating academic clusters around battery-specific engineering would require increased collaboration between the universities.

65 Nordic Flow Battery Network: https://sites.utu.fi/nordicflowbatterynetwork/

We need battery experts, and we need large volumes. But not all of them need to have this super expensive and very targeted PhD education, which are the ones we are educating right now, because we don't have any masters education in battery technology.

Respondent, Sweden

6 POTENTIALS FOR INCREASING NORDIC SYNERGIES

In this chapter of the report, we highlight some possibilities for increasing synergies and collaboration between the Nordic countries. This concerns both collaborations in academia and industry as well as on a political level. Some of the points made in this chapter relate closely to key points under the chapter on educational measures and upskilling needs, as increased collaboration between the Nordic countries has the potential to bridge some of the educational gaps for engineers highlighted throughout this report.

Here we provide insight into the areas within climate technology sectors respondents believe have the most significant potential for increased collaboration in the future. In addition, we highlight current barriers to increased synergies in the Nordics.

A need to strengthen the utilisation of academic specialisations

The need for increased collaboration between universities on bridging educational gaps regarding engineers for the climate technology sector is emphasised across interviews. As was described in the chapter on educational measures, some respondents experience a lack of attraction to or interest in climate technology sectors from engineering students. One explanation was that students have little knowledge of career options in their home country and other Nordic countries. Increased academic collaboration can potentially increase awareness around exciting projects and possibilities for specialisations in engineering for climate technologies across the Nordics. Respondents see a need for concrete projects and grants to facilitate

Why don't we share competencies? Because we all need them, and we need each other. So why don't we find a way to share skilled people?

Respondent, Sweden

collaboration between universities, visitation between delegations, and more platforms for discussions – e.g., concerning divisions of specialisations. For example, both Finland and Sweden are at the forefront regarding battery recycling programs, which creates the potential for more collaboration in that area. Ideally, that existing expertise should feed into education programs in other Nordic countries to avoid building academic areas from scratch. Among suggestions for initiatives is shared research funding facilitating cooperation, as several representatives experience financial resources and lack of shared funding as the main barrier for collaboration today. Furthermore, respondents stress a need to ensure that researchers from all Nordic countries have access to and can benefit from initiatives happening in the region – such as the Norwegian Hydropower Centre (NVKS). Joint initiatives such as the Nordic Five Tech alliance between technical universities in Denmark, Sweden, Norway, and Finland are also emphasised as important to increase academic collaboration across countries.

If you look at the Nordic perspective, I mean, it's a small geographical area and there is a lot of interconnections between the different industrial players. So, that part of the ecosystem is being built and why not build it the same way when it comes to research and education?

Respondent, Sweden

However, it is important also to consider how Iceland can become a more integrated part of collaborations. The difference in energy sources in Iceland compared to the rest of the Nordics creates a present mismatch and potential barrier to collaboration. Iceland has expertise in terms of geothermal power and lacks expertise in technologies such as wind power. Enabling student mobility and knowledge sharing between Iceland and the rest of the Nordic countries

I think that if the Nordics pool their knowledge and expertise together, then they have a pretty strong and broad field to cover in terms of climate technologies, and they can compete with many countries in the world.

Respondent, Iceland

can bridge skill gaps in both Iceland and the other Nordic countries. Iceland does not have the institutional capacity to educate specialised engineers in all areas concerning climate technologies. Thus, Icelandic respondents see potential in taking advantage of the study programs available at universities across the Nordics – e.g., by engineering students to do an exchange or take full degrees in other Nordic countries to bridge an educational gap, for example, on wind power. Several academic respondents emphasise this potential for expanding the collaboration and wind power initiatives between Nordic universities.

Potentials for increased export of skills and expertise between sectors in the Nordics

In line with the previous point, a general insight from the interviews is the lack of knowledge sharing between industries working with climate technologies in the Nordics. There is little knowledge of cross-country sector collaborations and how development is progressing in other countries. As a result, it is a challenge to identify potential partners for collaboration. More robust communication between companies, industry cooperatives, and universities concerning fundamental challenges and developments makes for easier access to fruitful partnerships in climate technologies. Working in silos poses a barrier to the joint action needed to scale development across the Nordics.

A respondent highlights a best-practice example – Nordic Circular Hubs [68] – where partners from academia and industry in several Nordic countries have formed a cluster aiming to make the Nordics a pioneering region for sustainable growth.

68 Nordic Circular Hubs: https://www.nordicinnovation.org/programs/nordic-circular-hubs

In relation to CCS there are no permanent geological storage potentials in Finland, and very little in Sweden in the Baltic Sea. The potential here for shared transportation and storage with other countries is clear.

Respondent, Finland

The purpose is to increase communication, knowledge sharing, and integration concerning sustainability and digitalisation. The matching of existing competencies and expertise in each partnering country is emphasised as a stronghold, as the hub strives for collaboration rather than competition between partners. Generally, respondents see a need for more export of specialisation and utilisation of strongholds between the Nordic countries. As an example, Finland and Sweden do not have permanent storage possibilities concerning CCS, whereas Denmark and Norway have better offshore storage infrastructure. This creates the potential for increased shared transportation and storage of carbon dioxide between countries – a process already underway, as described in the section on CCS/CCU. A value chain such as this one has the potential to influence the way university programs are designed, which some respondents argue should be increasingly focused on value chain engineering. Furthermore, Sweden has a long history of research and development of CCS and possesses a great deal of know-how and engineering expertise. Respondents see growing potential for this knowledge to be exported - e.g., through consultancy on constructing CCS plants and sharing knowledge and information regarding transportation and storage.

Lastly, there is a need for more collaboration on a political level. For example, respondents see the potential for increased collaboration on energy policy and energy strategies between Sweden and Finland, as several representatives highlight similarities between the two countries regarding the energy mix. Both countries have bioeconomy as an asset, and there is potential for increased collaboration in developing the area and enabling the export potential of Finnish and Swedish companies.

RECOMMENDATIONS

7

Based on the insights and perspectives presented in this report produced by DAMVAD Analytics, the Association of Nordic Engineers working group has created the following recommendations to ensure that Nordic engineers have the skills needed to drive the development of climate technologies and support the sustainable transition to greener energy sources.

Analyse the sector skill demand and align political incentives with the demands of the market

A stronger focus on securing the necessary competences and skills for climate technology is needed in the Nordics. Politicians talking in hypotheticals is not enough. Political strategies for the green transition must be better aligned with skills demand. There is a need for prioritising and investing in the large-scale mapping of the skills demand for the green technology sectors in the region. Securing the necessary competences and skills should be supported by relevant policies and research, development, and innovation subsidies targeted for the green transition

Adapt the higher education system to bridge skills gaps

Higher Education Institutions should benefit from public financial support to re-evaluate and adapt the educational programmes to secure the provision of specialists matching the skills demand. In addition, there is a need to enhance the cooperation between Nordic universities to bridge educational gaps as well as to incentivise educational and career measures that allow for a greater talent and knowledge flow between countries.

Invest in lifelong learning and reskilling in green technologies

Investing in education to upskill the existing supply of engineers and STEM professionals will be crucial to further the transition towards green solutions. The number of engineers already in employment far outweighs the output of new students, and the investment in green reskilling for the existing workforce will have an immediate and much more pronounced effect. Higher education programmes should be incentivised to offer more short courses and study modules on climate technologies explicitly developed for flexible upskilling and reskilling. Employers must also act in time to identify upskilling needs and provide both space and time for competence development and life-long learning opportunities.

Use the green agenda to recruit and retain a diverse pool of young people for engineering and STEM programmes

The green transition provides an opportunity to motivate young people to make a difference by becoming STEM professionals. Many companies already use their green profile to attract the best talent. Similarly, higher education institutions could increase student retention and recruitment by adapting the profile of their engineering and STEM programmes. An explicit green profile may unlock a larger pool of applicants for STEM programmes and improve the diversity and gender balance.

Incentivise and increase Nordic knowledge sharing and collaboration

For the Nordic region to remain and become increasingly competitive within climate technology, there is a need for more substantial knowledge sharing and collaboration across borders, organisations, and sectors. It is essential to avoid a silo mentality to capitalise on the vast potential for exporting skills and know-how from the region. Expanding existing and building new collaborations between the private sector, STEM professionals, and universities is also recommended.

Harmonise climate tech legislation in the Nordics to create a broader market

Political collaboration across borders must increase. Shared energy strategies could, for example, be implemented bilaterally or across the whole region. The individual Nordic countries are small markets, but together they comprise almost 30 million people. Harmonising regulation for climate tech in the Nordics would help to scale up businesses in the Nordic market, which would then boost businesses in the global market.

METHODS

8

The principal method for this analysis is qualitative research, where interviews and desk research constitute the primary sources of knowledge in the analysis. The research and analysis were carried out by qualitative analysts from DAMVAD Analytics.

Insights in this report should be read as expressions of respondents' experiences related to technology developments and skill demands. DAMVAD Analytics has substantiated insights from interviews with desk research to the extent possible, but DAMVAD Analytics does not vouch for discrepancies between facts and experienced realities of respondents.

Interviews and desk research

A total of 19 interviews were conducted with representatives from five Nordic countries. The division of interviews between countries is: 4 in Finland, 4 in Denmark, 5 in Sweden, 2 in Norway, and 4 in Iceland. A lack of access to representatives from organisations in Norway is the main reason for the uneven representation of Norwegian respondents compared to the other countries.

Interviews were conducted with representatives from the following organisations:

Organisation	Country
Wärtsila	FI
Finnish Wind Power Association	FI
University of Turku	FI
VTT Technical research centre of Finland	FI
Green Power Denmark	DK
Concito	DK
The Danish Society of Engineers (IDA)	DK
Siemens Gamesa	DK
Northvolt	SE
SSAB	SE
Skogforsk	SE
Stockholm Exergi	SE
Uppsala University	SE
Equinor	NO
Eyde Cluster	NO
Orkustofnun	IS
Landsvirkjun	IS
Grænvangur	IS
Georg Geothermal Research Cluster	IS

The interviews were conducted in May and June 2022. The interviews followed a semi-structured interview guide, including all themes presented in this report. Most interviews were focused on one or two climate technologies; however, some respondents provided general perspectives on developments across sectors and technologies.

All interviews were recorded and analysed through a research platform. The insights from interviews have been extracted through coding of themes relating to trends, skill demands, and potentials for educational measures and increased synergies across the Nordics.

Insights from interviews have been supplemented with extensive desk research. The desk research included a review of plans and sectoral roadmaps on green transition/climate change in the Nordics, sources on skill demands for engineers, and literature and document review of other relevant sources.

Review of job postings

In addition to the information derived from interviews and desk research, DAMVAD Analytics reviewed job postings and extracted the in-demand skills for engineers in each climate technology sector. Two different methods were used for the review of job postings:

1. DAMVAD Analytics' Labour Intelligence Tool (LIT) was used to identify relevant companies working with the respective climate technologies. The search had a limited time period to include only the previous two and a half years (January 2020-June 2022) to ensure an up-to-date data set. Further, job postings from these companies were used to extract all in-demand engineering skills through machine learning algorithms built in LIT. Through a qualitative assessment, the list of in-demand skills was divided into technical skills and soft skills.

2. As LIT only allows access to Danish job postings, the review was expanded to include a general search of job postings online across the Nordic countries. Firstly, companies working with the respective climate technologies in each Nordic country (besides Denmark) were identified. From this knowledge, a search for engineering-specific job postings from those companies was done, and in-demand skills were qualitatively extracted and divided into technical skills and soft skills. Only active job postings were included in the analysis.

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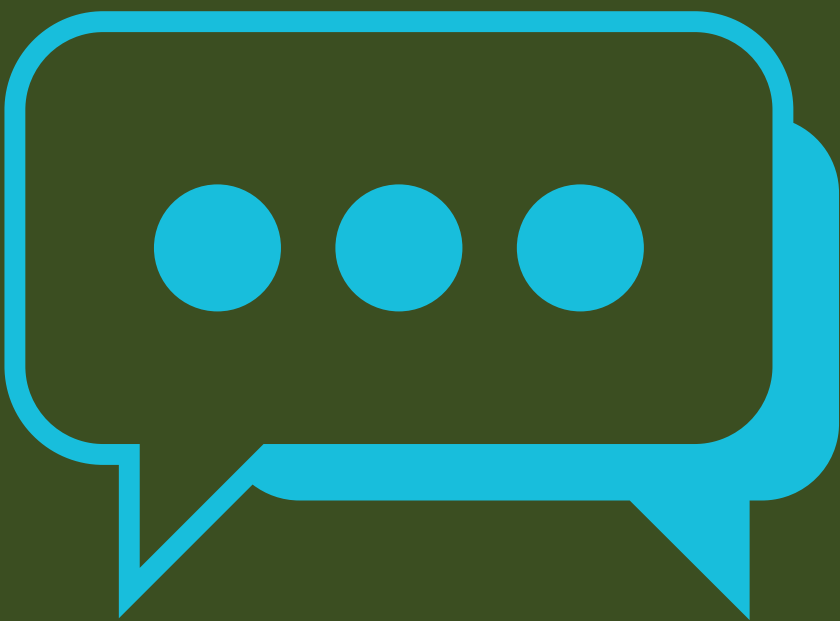

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The Swedish Association of Graduate Engineers
The Danish Society of Engineers (IDA)
The Norwegian Society of Engineers and Technologists (NITO)
The Association of Chartered Engineers in Iceland (VFÍ)
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