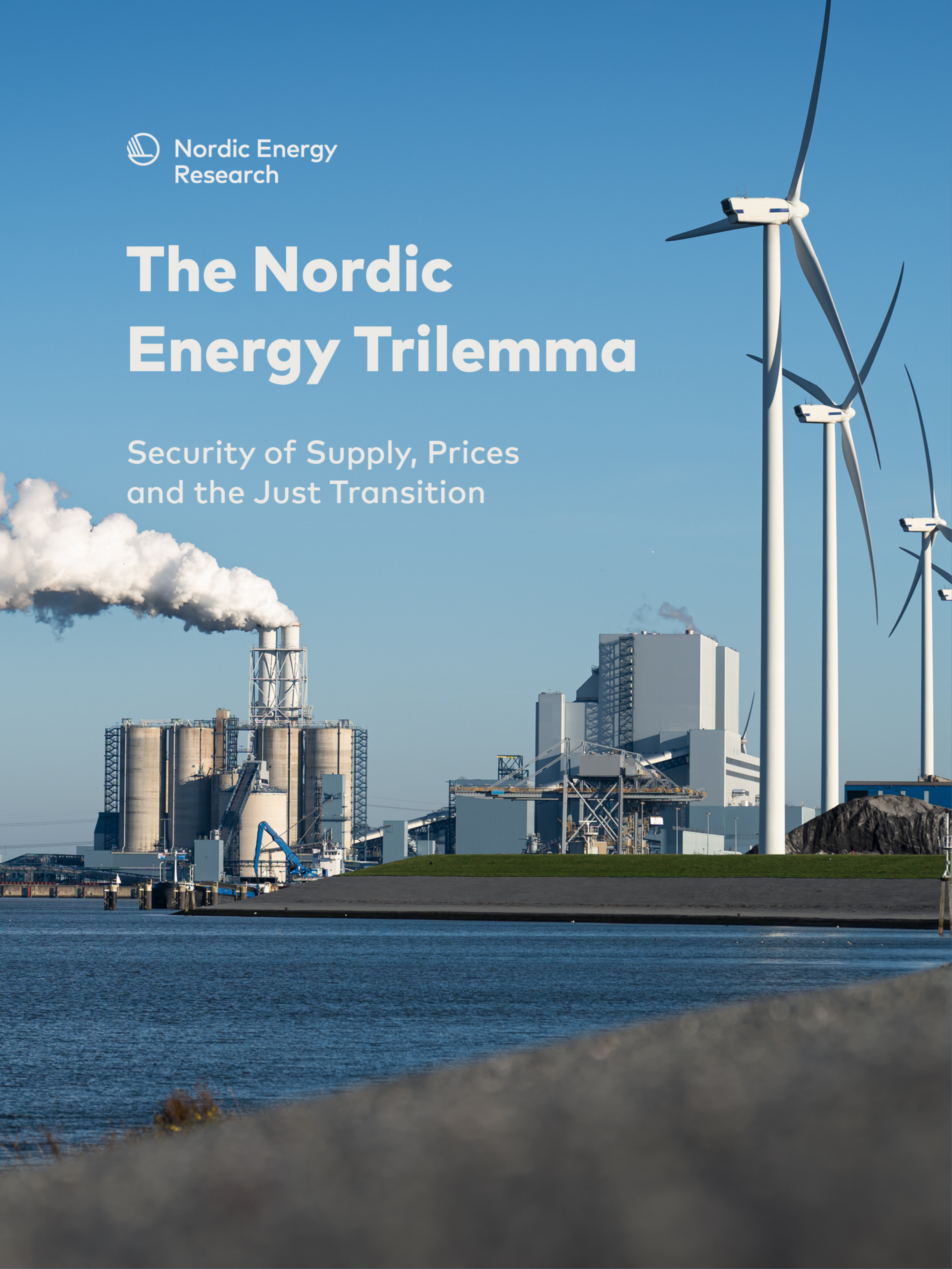
Nordic Energy Research

The Nordic Energy Trilemma

Security of Supply, Prices and the Just Transition



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FOREWORD

The Nordic region has a vision to become the most sustainable and integrated region in the world. Secure, affordable and clean energy is fundamental to realising this. Yet, in view of unprecedented energy prices and geopolitical risk, it remains unclear whether energy supply chains, power grids, raw materials, or enabling technologies can be secured to meet the demands of an electrified society in the long term.

Today, the Nordic region faces an energy trilemma – three conflicting challenges to delivering a secure, affordable, and sustainable energy transition. We must meet energy demand reliably, withstand system shocks, and prepare for a sharp increase in electrification, all while providing equitable access to abundant energy, and delivering a positive climate and environmental impact.

Recently, a confluence of factors led energy and commodity prices to surge in the Nordics and exposed the need for resilient energy infrastructure. As countries exited COVID-19 lockdown, energy demand exceeded fossil fuel supplies. The Russian invasion of Ukraine exacerbated supply disruptions. Energy annual inflation in Europe rose throughout 2022, pushing overall inflation to record levels. Meanwhile, rising prices of critical raw materials increased the cost of technologies enabling the energy transition.

In response, the European Commission created the Just Energy Transition Fund and a toolbox for action and support aimed at consumers and industry. The Nordic countries offered varying levels of support to households most affected by the high electricity prices. These actions demonstrate that energy security must be viewed in an economic, social, and sustainability context. Energy prices and infrastructure investment have societal consequences, for affordability, public acceptance, economic distribution, job creation, climate and environment.

Energy security is a prerequisite for national security and industry competitiveness, with strategic, political and economic implications for countries and individuals, as well as for Nordic and international cooperation. If the Nordic countries are to meet their ambitious electrification goals, policymakers must consider the vulnerabilities of a decarbonising energy system, and ensure our interlinked systems remain resilient.

This report reviews factors that drove the most severe energy crisis in recent memory, with an emphasis on electricity markets, the preparedness of the Nordic countries, and how they responded. Risks to the Nordic energy transition are identified, and measures in place to mitigate these risks are assessed. Where no such measures exist, actions are proposed to address the gaps. The recommendations herein define national, Nordic, and international actions to increase energy security and emergency preparedness, such that our societies are ready for the energy crises of the future.

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CEO, Nordic Energy Research

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The opinions expressed in this publication are those of the consultants. They do not necessarily reflect the views of the Nordic Council of Ministers, Nordic Energy Research, or any entities they represent. The individuals and organizations that contributed to this publication are not responsible for any judgements herein.

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1. EXECUTIVE SUMMARY

The Nordic countries are experiencing an unprecedented energy crisis, characterised by dramatic increases in energy prices caused by a significant reduction in the primary energy supply. High electricity prices for end-consumers is one of the major spill-over effects from continental Europe, along with a reduction in natural gas supplies from Russia. The energy supply crisis has also prompted some regulators to warn of planned outages in winter 2022–2023. Faced with these interrelated problems, both the EU and individual member states, including the Nordic countries, have rolled out a raft of crisis management schemes to help consumers weather the situation financially. Energy cost increases have been felt across the Nordics, although the resulting negative socio-economic impacts such as energy poverty[1] among the poorest income groups, have been felt less in the Nordic countries than in other European economies. In effect, the Nordic economies have shown a degree of socio-economic resilience in the face of the energy crisis.

In addition, recent underlying structural developments (e.g. decommissioning of controllable economic capacity, lack of infrastructure, inflexible demand, energy import dependency) have played a key role in the crisis, as described in the eight drivers of the crisis highlighted later in the report. The problems in energy markets in general, and electricity markets specifically, could impact security of supply in the years ahead.

This report aims to provide recommendations, at national, Nordic, EU, and international level to enable policymakers to ensure that energy systems can strike the desired balance between the elements of the Energy Trilemma of sustainability, affordability and security of supply. Critically, bearing in mind that factors relating to security of supply and electricity markets are the primary focus of the report, the report is structured as follows: identification and analysis of the drivers responsible for the electricity supply crisis, evaluation of individual Nordic countries' exposure, preparedness and responses to these drivers, identification of the future risks that Nordic electricity systems will be exposed to, and an assessment of whether appropriate and effective risk-mitigation measures are in place. The report is subject to a number of delimitations, including relating to geopolitical threats, and is based on data collected up to 30 September 2022. The report had a submission deadline of the end of November 2022. This was followed by a review process involving Nordic Energy Research and the Nordic Council of Ministers and the report was finalised in January 2023.

1. [1] The EU Commission defines energy poverty as follows: Energy poverty occurs when energy bills represent a high percentage of consumers' income, or when they must reduce their household's energy consumption to a degree that negatively impacts their health and well-being.

Furthermore, although the Nordic energy systems are heterogeneous, the systems' many shared characteristics mean that the recommendations formulated in this report can be used to inform national decision-making processes across the Nordics, and to strengthen inter-Nordic collaboration. Nonetheless, it should be noted that further analysis, i.e., in the form of detailed impact assessments, is needed to determine how each recommendation can, or should, be implemented in each country. This report makes 17 recommendations, at respectively national, Nordic and EU/International level, as listed below.

Recommendations:

National

- **Implement fixed timelines and shorten permitting processes** for generation and infrastructure assets while considering the relevant perspectives of local communities.
- **Ensure a high-quality labour supply for the energy sector by developing long-term national roadmaps**, including to determine whether and how the sector should be prioritised.
- **Apply goal-oriented impact assessments as a basis for decision-making**, addressing short- and long-term system-wide perspectives. The goals and assessments should balance all aspects of the Energy Trilemma and consider the benefits that a reliable energy supply can create for other sectors of society. In this context, the number of scenarios in national energy planning should be increased to encompass multiple energy system changes.
- **Increase system capacity and flexibility through existing energy assets** that are currently not fully utilised, e.g., by prolonging lifetimes or other means, in order to maintain affordable prices and security of supply. This should not overly delay the green energy transition.
- **Reinforce electricity crisis management so that it is properly dimensioned and well-planned** at local, national and Nordic level. It should be borne in mind that since electricity is both a traded commodity and a basic societal need, adopting a cautious approach during crisis situations remains pivotal. This is because both inaction and suboptimal policy decisions could result in market disruptions and risk creating future, even more acute crises.
- **Strengthen the energy industry's long-term attractiveness and competitiveness** within important sectors such as energy asset manufacturing, electricity generation, heat production, extraction of critical raw materials, energy service companies and grid infrastructure.

Nordics

- **Diversify sources of energy generation, carriers, and storage** in line with national climate targets, including hydrogen and biofuel infrastructure. Leverage the respective strengths of different technologies and energy carriers and opportunities to develop local energy systems while limiting excessive dependence on any single technology, facility or supply route.
- **Review ways of continuously adapting the electricity market model** to meet society's needs and desires to deliver a green and just energy transition, while maintaining a high security of supply. Based on developments in 2022, markets have not been able to balance the various elements of the Energy Trilemma. In this context, adequate roles, responsibilities for market actors, governments and the number of market interconnections should be considered.
- **Formulate shared plans and set requirements for yearly and multi-year long-term energy storage** to replace fossil-fuel storage. This could involve different energy carriers, e.g., hydrogen, methanol, ammonia, pumped hydro storage and biogas.
- **Strengthen and share the knowledge foundation for addressing public opposition to energy infrastructure**, e.g., through various forms of financial compensation and enhanced stakeholder dialogue in project design and development.
- **Support a flexible demand-side response** by utilising existing knowledge and developing new technologies and infrastructure to facilitate energy efficiency, system flexibility and ancillary services.
- **Strengthen Nordic electricity grid infrastructure** to avoid bottlenecks and renewable energy curtailment in connection with the increased electrification of society.
- **Re-emphasise the importance of Nordic collaboration across energy markets and systems** while highlighting each country's responsibility for positively contributing to regional, national and Nordic security of supply.
- **Share findings from nationally applied financial support schemes** to help consumers weather the current crisis and thereby safeguard future policymaking against undesired distributional effects relating to both energy poverty and long-term market developments.
- **Limit import dependency on the metals and minerals required for the green energy transition** by promoting sustainable mining in the Nordics. Consider making the region a global leader in mining on the back of high environmental and ethical standards.

EU and international

- **Coordinate policy responses between Nordic countries around EU initiatives**, thus making them increasingly applicable to the specific nature of the Nordic markets.
- **Assess the need for setting up a comprehensive stockholding system for various types of fuels and energy carriers to improve security of supply** through EU-wide regulations. This should be achieved by leveraging existing knowledge, including in relation to oil and international processes, in order to alleviate the current situation and prevent similar scenarios arising in the future.

A perfect storm – eight drivers impacting the Nordic energy crisis

The crisis is complex and not caused by a single event or scenario. The study has identified eight drivers that collectively have played a key role in triggering the current electricity crisis, and jointly created a perfect storm of compounding problems. These eight drivers would therefore have been likely to impact the electricity system and led to long-term security of supply challenges, even if Russia had not reduced its supply of natural gas to Europe. The drivers are listed and described below, though the extent to which each driver has impacted the current situation is not quantified.

Electricity market structure
The structure of the electricity markets in the Nordic countries and Europe has produced a set of derivative effects that were not foreseen at their inception, for example in relation to the decommissioning of thermal capacity. Thus, some of the subsequent drivers of the crisis are a direct result of the electricity market structure.

Decommissioned controllable electric capacity
The decommissioning of thermal power plants due to price competition, and nuclear power plants due to political opposition, have resulted in a lack of baseload capacity in the electricity system during periods of unfavourable weather conditions.

Balancing electricity supply and demand
Decarbonisation targets and the resulting focus on the development of renewable energy have heightened the requirements for balancing supply and demand in the electricity system. Going forward, electricity prices are expected to be increasingly volatile, necessitating long-term energy storage.

Lack of electric transmission infrastructure
Underinvestment in both electrical grid infrastructure capable of handling intermittent flows of energy and in cross-border interconnectors has created bottlenecks in Sweden and Norway, which in turn have led to asymmetric pricing trends in the Nordics.

Inflexible electricity demand
Nordic electricity systems have historically been characterised by a high security of supply at low electricity prices and electricity is perceived as a public good throughout the region. Furthermore, the fact that demand in wholesale electricity markets is inflexible means that prices can dramatically increase, since decreases in consumer consumption are not enough to reduce demand and stabilise electricity prices. This has led to significant cost increases for consumers.

Increasing energy-import dependency
Reduced exports of Russian oil, gas and coal have had a major impact on electricity prices in Europe. Energy supply disruptions are not unlikely for the winters of 2022–2023 and 2023–2024. While the Nordic countries are well prepared, connections to Europe make the region as a whole vulnerable.

Reduced supply of natural gas
Reduced extraction of natural gas within the European Union, in combination with a gradual reduction in the foreign supply of natural gas, has created high sourcing prices for LNG and natural gas. Increasing production costs and costs of buying natural gas and electricity for end-consumers are some of the consequences of this development.

Weather-dependent electricity generation
The Nordic countries are exposed to a weather-dependent electricity supply as baseload generation via hydro power and peak capacity are contingent on weather conditions. Other energy sources that will increasingly be utilised going forward such as wind and solar are naturally also dependent on weather conditions.

Risks influencing the Nordic security of electricity supply

The risk screening identified 22 risks which were ranked based on their likelihood and their impact on security of supply. This resulted in the identification of ten high-risk factors (shown below in Table 1), nine medium-risk, and three low-risk factors. The ranking of risk factors was based on a qualitative assessment of the data foundation and has been subject to a validation process (see Section 3.9.1).

RISK	POTENTIAL IMPACT ON THE VALUE CHAIN
Long approval processes	Long approval processes can hinder society's ability to build enough renewable capacity and electric grid infrastructure at a quick enough pace to transmit electricity from the generation site to load centres to meet customer demand. Given the significant requirements for electrification associated with the green energy transition and the desire for energy independence, continued long approval processes could reduce the ability of the Nordic societies to meet these challenges.
Modest public infrastructure acceptance	This risk may impact the whole electricity value chain depending on the extent of public opposition to the installation of the infrastructure. Moreover, the problem is likely to increase over time as renewable electricity generation and additional electric grid infrastructure become more visible in the landscape. Renewable energy sources require more land per energy produced than traditional types of energy generation.
Inadequate electricity market design	There is a risk that the current electricity market is not designed to facilitate a smooth green energy transition while balancing the two other dimensions of the Energy Trilemma. Potential intervention from regulators has created insecurities in the market and affected market operations. For example, reduced controllable electricity generation capacity in the market could lead to load-shedding and price increases for consumers. Therefore, the existing market design should be developed to facilitate a suitable balance between the various dimensions of the Energy Trilemma.
High mineral and fossil energy supply dependencies	Supply dependencies could impact the ability of society to deliver the green energy transition at a sufficient pace, while creating security of supply issues around fossil fuels and minerals in the event of supply disruptions. This could impact consumers through high prices and the availability of electricity.
Lack of electric grid infrastructure	Appropriate and adequate electrical grid infrastructure is the foundation of a well-functioning energy system and electricity market. Transmission problems caused by lack of electrical infrastructure could therefore negatively impact the system's entire value chain.
Lack of sustainable long-term energy storage	The potential lack of sustainable long-term energy storage as a means for supplying peak electricity demand during periods of unfavourable weather conditions could negatively impact overall security of supply and the resulting prices consumers pay.
Unchanged consumer behaviour	The inability of consumers to exercise demand-side response during peak hours, and change their behaviour impacts overall security of supply.
Increased weather dependence	A significant scarcity of generation capacity, i.e. as the result of limited availability of different energy sources (hydro and renewables), could impact the ability of society to meet electricity demand.
Insufficient energy crisis management	Energy-crisis management that does not consider the system-wide effects of initiatives at Nordic and EU levels could impact the entire electricity value chain.
Labour shortages	Any labour shortages in the energy sector have consequences throughout the value chain since assets cannot be developed and maintained. This makes labour shortages a system-wide risk.

Table 1: Potential impacts of the ten highest risk factors on the energy sector value chain.

Mitigation measures and gap analysis on responses to the crisis

Following the risk screening, selected mitigation measures applied during the ongoing energy crisis were mapped against the identified high-risk factors. The main purpose was to identify whether the applied mitigation measures were an adequate and efficient response to the identified risks, or whether a risk-mitigation gap existed. The results of the gap analysis established that significant gaps are associated with one risk ("gap exists"), that gaps are partially addressed ("gap remains") for eight risks and that gaps are fully addressed for one risk ("no gap"). The findings are based on a qualitative assessment of the data foundation for this report and have been subject to the report's validation process (see Section 3.9.1).

The mitigation measures presented in Table 2 below demonstrate that the mitigation measures and cases discussed may not be the most appropriate options to implement in all the Nordic countries. They are merely examples of the applied mitigation measures, presented with the aim of assessing how well the Nordic electricity market is equipped to ensure supply security going forward.

RISK	MEASURE	
Long approval processes	Accelerated permitting for electricity generation and grid infrastructure	GAP REMAINS
Modest public infrastructure acceptance	Public inclusion in electricity infrastructure	GAP REMAINS
Inadequate electricity market design	Analyse adaptation measures for electricity market design	GAP REMAINS
High mineral and fossil energy supply dependencies	Strategic sourcing of metals	GAP EXISTS
High mineral and fossil energy supply dependencies*	Strategic sourcing of fuels	GAP REMAINS
Lack of electric grid infrastructure	Electric grid infrastructure	GAP REMAINS
Lack of sustainable long-term energy storage	Energy infrastructure integration	GAP REMAINS
Unchanged consumer behaviour	Information campaigns and digital applications	NO GAP
Increased weather dependence	Electricity generation diversification	GAP REMAINS
Inadequate energy crisis management	Energy crisis management	GAP REMAINS
Low workforce availability	Tripartite negotiations	GAP EXISTS

*Separate mitigating measures are applied for the "high mineral and fossil energy supply dependencies". The risk is addressed collectively as it relates to both dependencies.

Table 2: Mitigation measures and gap analysis.

2. INTRODUCTION

Secure access to abundant and affordable energy is critical for societies and a cornerstone of well-functioning economies. The Nordic governments' participation in the Paris Agreement's goal of limiting the global temperature increase to well below 2°C compared with pre-industrial levels has created a desire to accelerate the pace of the green energy transition. Governments are consequently being challenged to balance the three dimensions of the Energy Trilemma of security, affordability and sustainability, which, while often conflicting, do offer some synergies.

The current energy crisis in the Nordic region is the result of the decisions society has made regarding how energy systems are designed and has essentially been underway for some time. The crisis originated in the summer of 2021 following the European Union's rapid economic recovery after the COVID-19 lockdowns, and the war in Ukraine has resulted in substantial energy price rises across Europe and the Nordic countries. (Prices in Iceland have remained stable.) Low water levels in Norwegian reservoirs, warm weather in Europe during the summer of 2022, reduced availability of French nuclear power, and a weakened energy infrastructure are other factors that have contributed to the crisis.

The energy crisis has raised concerns about the ability of Nordic societies to maintain secure access to abundant and affordable energy. This makes securing an appropriate balance within the Energy Trilemma a key priority for policymakers going forward.

This report aims to provide recommendations to enable policymakers to achieve the desired balance in the Energy Trilemma and to provide a basis for an affordable, secure energy transition. We have adopted the following approach to achieve this: (1) analyse the drivers of the crisis, (2) evaluate the Nordic countries' exposure to the crisis, preparedness and responses to these drivers, (3) identify the future risks the Nordic electricity systems are exposed to and (4) determine whether appropriate and effective mitigation measures are in place to manage the identified risks. Based on this assessment, this report presents several national, regional and international policy recommendations. In light of current crisis, this report has been tasked with providing recommendations with an emphasis on how to achieve energy security, with affordability and sustainability as important second priorities.

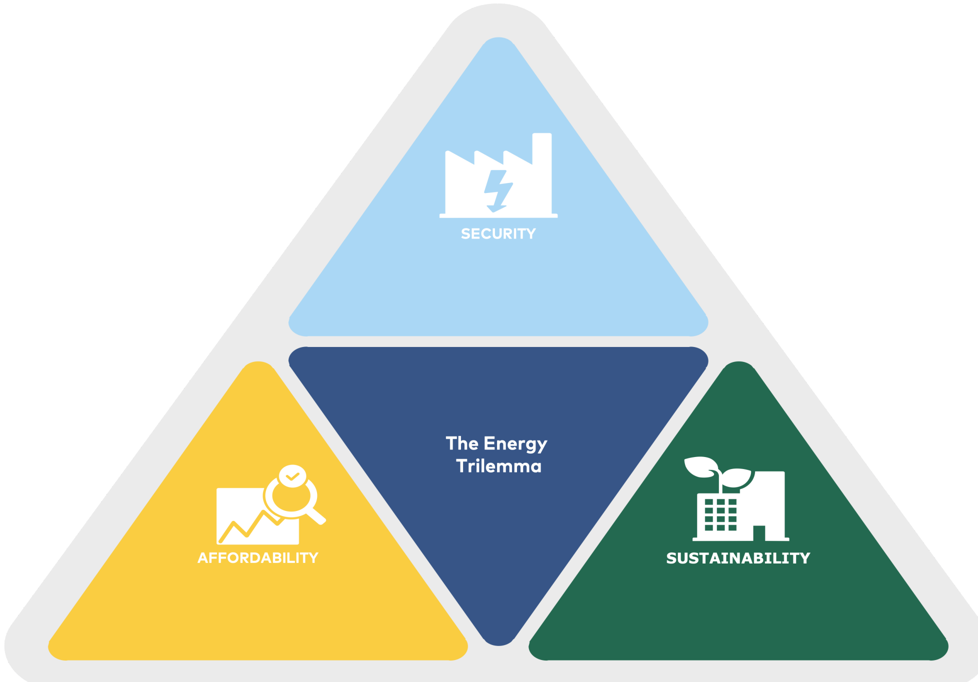


Figure 1: The Energy Trilemma.


3. METHODOLOGY

3.1 The Energy Trilemma

This report focuses on the Energy Trilemma as defined by the World Energy Council, which consists of three interconnected elements: security, affordability and sustainability[2]. All three elements of the Energy Trilemma are interrelated, which means there can be trade-offs associated with focusing on a single dimension. However, synergies can also be derived from some initiatives. In this report, we will emphasise both synergies and trade-offs associated with these initiatives.

1. Security is the ability to supply current and future energy demand reliably and withstand and recover from system shocks through effective crisis management.

2. Affordability is the ability to provide universal access to reliable, affordable and abundant energy for residential and industrial consumers. This dimension also encompasses job creation in relation to expanding renewable energy and transmission infrastructure. Finally, it covers public acceptance of the implemented mitigation initiatives in general.

3. Sustainability is the extent to which the green energy transition mitigates potential climate impacts by transitioning from fossil-based to renewable energy systems. This dimension focuses on the effectiveness of the decarbonisation process and the efficiency of energy generation, transmission and distribution.

The current situation, characterised by high energy prices and a low supply of natural gas via traditional supply routes, entails a number of security of supply risks for the Nordic (but especially European) energy systems. The main primary energy source needed to balance the energy system due to unfavourable weather conditions is, to some extent, missing. Consequently, this report focuses on security of supply and how to achieve this while balancing it with the two other dimensions in the Energy Trilemma: affordability and sustainability.

2. World Energy Council, World Energy Trilemma Index, 2022. Website reference: https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-index.

3.2 The energy crisis and security of supply

We define an energy crisis as a sudden rise in energy prices caused by a significant decrease in the primary energy supply. Several underlying factors should be considered when determining the causes of the current energy crisis. We will touch more upon these in Section 5 when we examine the drivers causing the crisis.

A secure energy supply is primarily maintained through well-functioning energy markets and effective targeted regulation, i.e., ensuring that the markets can meet society and businesses' needs for energy in accordance with the desired energy policy. The goal of a secure energy supply is, balanced against other social goals, (which depending on the incumbent government, could be e.g. high-quality healthcare, affordable public transport and good schools), to prevent and alleviate negative impacts for society and energy users due to disruptions and interruptions in the energy supply. This is achieved through robust supply chains and a well-planned and practised crisis management mechanism that can be rolled out in the event of a crisis.

3.3 The energy value chain

In addition to the Energy Trilemma, the energy value chain is also a critical analysis tool used in this report for two main reasons. Firstly, focusing on the energy value chain to identify existing drivers, risks and mitigation measures ensures that the different stages of the energy value chain are covered in the analysis. Secondly, identifying gaps and potential improvement areas in the value chain enables more tangible policy recommendations to address the energy crisis. A generic energy market value chain is presented in Figure 2.

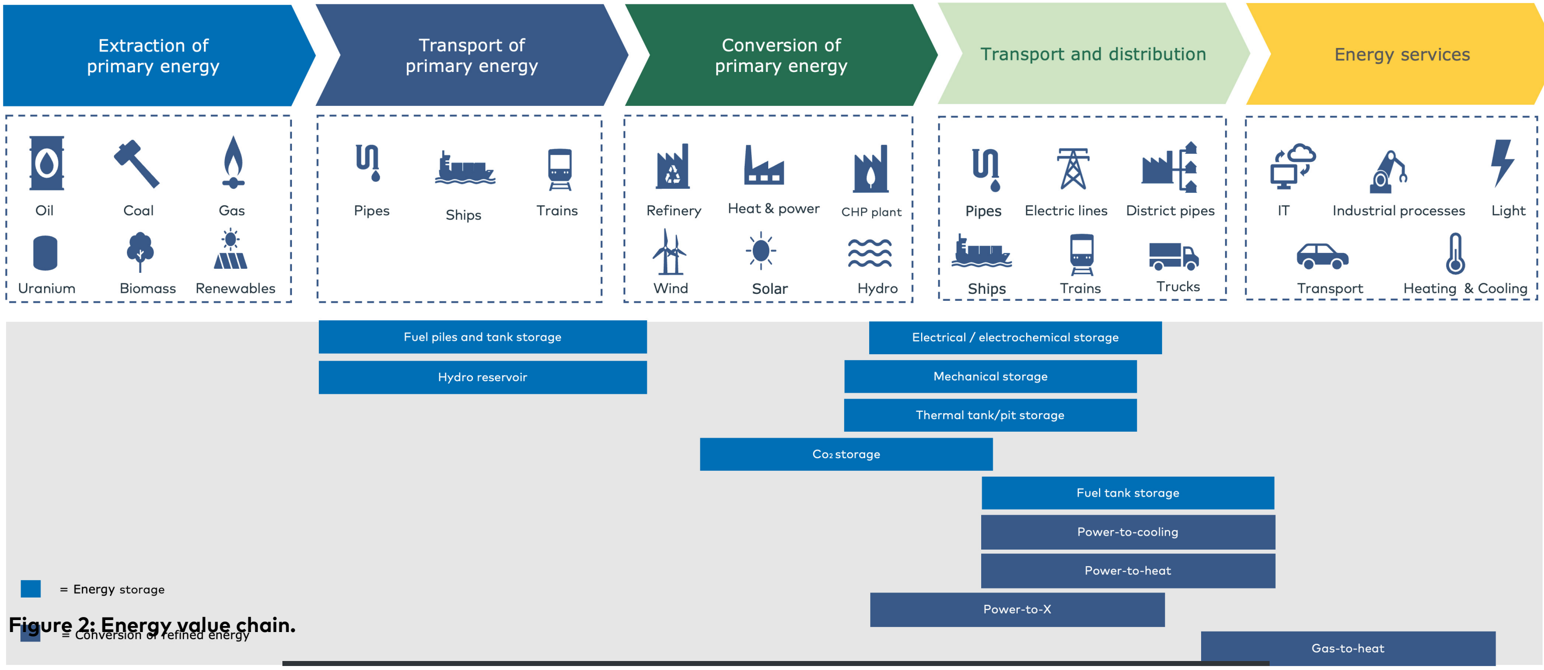


Figure 2: Energy value chain.

3.4 Scope of the study

Electricity and gas markets

Electricity and gas markets are this report's primary unit of analysis in terms of identifying drivers of the current energy crisis. This is because electricity and gas markets are connected markets through cables and pipelines. This means that the markets influence one another internally within the Nordics and Europe. Primary energy sources other than renewables (oil, coal etc.) used for electricity and heat production are considered, but in less detail, since these markets depend on global market movements. District heating systems, which are interconnected between cities but not between the Nordic countries, are less relevant as a unit of analysis from a Nordic and European perspective. Nonetheless, from a national perspective, district heating systems are relevant in terms of mitigation solutions for the energy crisis.

Affordability

As already mentioned, in broad terms affordability refers to universal access to affordable electricity for all citizens and industrial consumers. It also encompasses the topics of job creation and public acceptance. Thus, affordability is closely related to economic income, i.e. ensuring citizens can afford electricity. The strong welfare states in the Nordic countries ensure citizens' access to affordable electricity through universal social assistance targeted at various low-income groups (e.g., students, pensioners, the unemployed and similar). Therefore, this analysis does not include mitigation measures that existed prior to the energy crisis as these were not designed to address the current situation, but instead to ensure a minimum threshold of acceptable poverty in each of the Nordic countries. In addition, the energy crisis has coincided with a period of rising prices due to inflation. Some of the Nordic countries have implemented mitigation measures for inflation in general (food, transport etc.). These measures are also not included in this analysis as their purpose is to make specific services affordable. However, if a package of initiatives targeted at inflation includes a separate mitigation measure that also targets electricity bills, such measures are included here.

Sustainability

This report recognises the EU Taxonomy's definition of environmental objectives when considering environmental sustainability. Nevertheless, when evaluating electricity system risks and exposure to sustainability, the sole focus will be on climate change mitigation through reduction of greenhouse gas emissions. Other environmental objectives will not be covered in the drivers, risk, mitigation and policy recommendations sections. While it could be argued that this is a narrow focus on sustainability and related issues, this analytical choice has been taken to limit the scope.

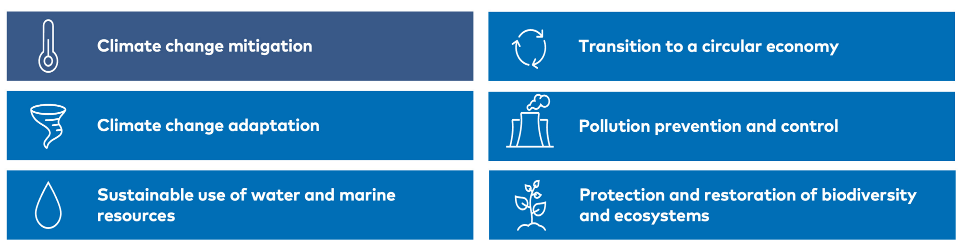


Figure 3: The EU Taxonomy's environmental objectives.

3.5 Delimitations

There are several topics that, while relevant in terms of security of supply, do not fall within the scope of this report. These topics, which could have serious implications for security of supply, include:

- **Cybersecurity:** Applying novel digital solutions is a key element of many aspects relating to security of supply, for example, demand-side management and automated grid balancing. However, increasing digitalisation of critical electricity infrastructure presents a significant risk of cyberattacks that could potentially jeopardise electricity supply security.

- **Geopolitics:** An increasingly changed world order with energy as a central element of geopolitics could potentially affect the perceived credibility of various national trading partners. Moreover, geopolitical movements could also make electricity infrastructure vulnerable to sabotage or similar, potentially requiring increased operational security from asset owners.

- **Inflation:** Inflation effects from initiatives to address affordability concerns among Nordic households and corporates are not considered, although potentially relevant as these could further contribute to economy-wide inflation, and hence the ability to pay for electricity-related goods.

The proposed policy recommendations increase society's ability to ensure a resilient and robust electricity supply, thereby facilitating efforts to tackle problems arising from cybercrime, geopolitics and inflation. However, specific recommendations should be developed targeting the above-listed topics.

3.6 Data collection

Period for data collection

The period for collection of quantitative data ended on 1 September 2022. Qualitative data collection started at the beginning of August and was scheduled to finish on 30 September 2022. However, additional data has been collected beyond the planned deadline in relation to mitigation measures implemented by Nordic governments and the EU. The primary analysis period is, however, up to September. Therefore, the significant decreases in natural gas and electricity prices experienced in October and November 2022 have not been included.

It was necessary to set a deadline for the data collection from the beginning of this project because the electricity markets are highly debated in the Nordic countries and Europe in general. Therefore, it was expected that the Nordic countries would implement several mitigation measures or that other external factors would influence electricity market developments throughout the autumn/winter period, potentially postponing the project plan.

Focus on the Energy Trilemma

The analytical focus on the Energy Trilemma and the energy market value chain necessitates the collection of data to be able to analyse across the dimensions of the trilemma and the value chain. Information has therefore been screened and collected based on the step in the value chain and the part of the Energy Trilemma it relates to. This was achieved in practice by developing an evaluation matrix applied in connection with literature research and selecting interview candidates. (See list of interviewees in Table 3).

3.7 Description of data sources

This report relies on both qualitative and quantitative data. Qualitative data consists of information gained from reviewing existing literature on energy security in the Nordics and EU, as well as interviews with relevant market stakeholders. This report builds on the literature published by international institutions, EU institutions, national energy agencies, think tanks, TSOs and news agencies. To support data collected through existing reports, we have consulted several stakeholders in the energy value chain to obtain a more detailed perspective on the electricity crisis. Consequently, the combination of national expert interviews and reports provides us with a better understanding of the current electricity crisis and of the risks and potential mitigation measures that can be applied to alleviate the situation.

Quantitative data has mainly been sourced from the European Network of Transmission System Operators for Electricity (ENTSO-E), the European Network of Transmission System Operators for Gas (ENTSO-G) and Eurostat, before being processed for the purpose of this analysis.

To the extent possible, the triangulation approach has been applied in connection with data collection in order to ensure that the analysis in this report is based on valid data. However, given that the analysis concerns five different countries, it is to be expected that some stakeholders possess information that is impossible to confirm with other market participants. Moreover, given the current electricity crisis, authorities and TSOs might be reluctant to share sensitive information relating to electricity security. The stakeholders included in the data collection are shown in Figure 4.

Figure 4: Stakeholders included in data collection.

3.8 Interviews

Based on the identified relevant stakeholders, Ramboll sent 60+ interview requests to various organisations in the countries covered by this report. In September 2022, 25 interviews were conducted with relevant individuals spanning organisations across the energy landscape. Due to the exploratory nature of this report, the semi-structured interview method has been applied as it is deemed the most appropriate in that it allows both structure and flexibility. Hence, the interviews followed an interview guide to cover specific topics but also allowed for follow-up questions and deviation from the guide to explore topics that were not initially a part of the interview guide. The focus of the interviews varies depending on the specialism of the various interviewees. The list of interviewed organisations is presented in Table 3 below.

NO.	ORGANISATION	COUNTRY FOCUS	ENERGY TRILEMMA FOCUS	VALUE CHAIN FOCUS
1	Ramboll Energy	Nordics general	The full Energy Trilemma	Full value chain
2	Svenska Kraftnät	Sweden	Security & Sustainability	Transmission
3	Energinet	Denmark	Security & Sustainability	Transmission
4	Ramboll Resilience	Nordics general	Security & Sustainability	Full value chain
5	Fingrid	Finland	Security & Sustainability	Transmission
6	Energia	Finland	Security & Sustainability	Full value chain
7	The National Energy Authority of Iceland	Iceland	Security & Sustainability	Consumers
8	Statnett	Norway	Security & Sustainability	Transmission
9	The Danish Utility Regulator	Denmark	Security	Generation; Consumption
10	The Nordic Council of Ministers	Nordics general	Affordability	Consumption
11	Mandag Morgen	Denmark	Affordability	Consumption
12	The Danish Energy Agency	Denmark	Security & Sustainability	Generation; Transmission
13	The Finnish Energy Authority	Finland	Security & Sustainability	Generation; Consumption
14	Samfunnsbedriftene	Norway	Affordability	Consumption
15	Concito	Nordics general	Affordability	Consumption
16	The Finnish Trade Unions	Finland	The full Energy Trilemma	Consumption
17	Landsnet	Iceland	Security & Sustainability	Full value chain
18	The Norwegian Energy Regulation Authority	Norway	Security	Generation; Transmission
19	Landsvirkjun	Iceland	Security & Sustainability	Generation; Transmission
20	Ørsted	Nordics general	Security & Sustainability	Full value chain
21	CPH Infrastructure Partners	Nordics general	Security & Sustainability	Generation; Transmission
22	Siemens Energy	Nordics general	Security & Sustainability	Transmission
23	DTU Wind And Energy Systems	Nordics general	Security & Sustainability	Full value chain
24	The Danish Trade Union Confederation	Denmark	Affordability	Consumers
25	The Swedish Energy Agency	Sweden	Affordability	Consumers

Table 3: List of interviewed organisation.

3.9 Assessment of the data used

As already mentioned, our analytical focus on the Energy Trilemma and the energy market value chain requires data to be collected from different sources, adopting a data triangulation approach to obtain reliable and nuanced data. However, the data hierarchies of the included sources are not of equal value because some data sources rely on systematic evidence-based studies, while other sources rely on observed experiences that render impacts and consequences probable.

Qualitative interviews are, by their nature, observations that cannot prove the effect, e.g., of a mitigation measure, even though the interviews are collected systematically. Instead, qualitative interviews can be used to gather in-depth insights into a problem or provide perspectives on potential problems around issues relating to the Energy Trilemma. The evidence level of the reviewed reports depends on the individual report's data sources. As already mentioned, some of the reviewed reports on electricity market developments have essentially been published by recognised international institutions. These reports are based on relevant and valid data and build on solid analyses of quality, which increases the reports' reliability. Reports can, with higher probability, be relied upon to map drivers with a reasonable documented effect. However, as society is developing a new electricity system, the effect of various new initiatives is not proven or documented, meaning that the findings and recommendations of this report are built on data with seeming effect.

Consequently, this report relies on data with a 'documented effect' to map drivers and a 'seeming effect' for risks, mitigation initiatives and recommendations (see Figure 5). Specifically, data analysed from one source, has been compared with conclusions from other sources, ensuring the validity of the arguments despite the relative lack of proven effects of the data.

With this data foundation, the report mixes top-down and bottom-up analysis approaches. While reports considered from international institutions and regulatory interventions from the EU and at national level apply a top-down approach, insights from relevant stakeholders are considered through interviews that leverage bottom-up approaches.

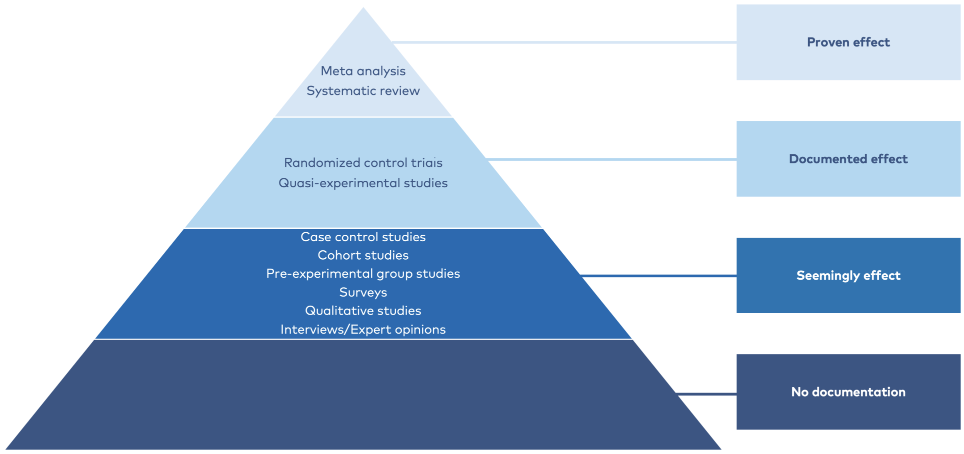


Figure 5: Evidence steps and effects.

3.9.1 Validation

Identified drivers, risks and mitigation initiatives have been subject to quality validation internally in the project group and from selected Ramboll and external stakeholders. Moreover, Nordic Energy Research and Nordic Energy Ministry representatives have been continuously involved in the validation and review process. Although the results of the report have been subject to wider stakeholder involvement and feedback, the findings and conclusions represent the full data foundation (desktop research and interviews) and are Ramboll's independent conclusions. The validation process is shown in Figure 6.

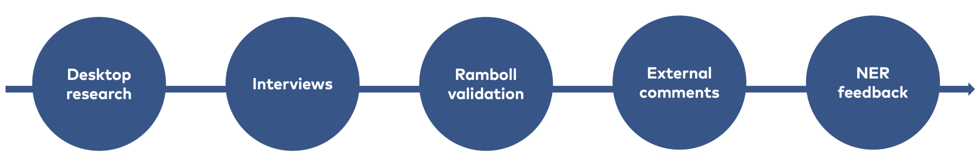


Figure 6: Validation process.

3.10 Report structure

The report consists of five sections designed to deliver sound and tangible policy recommendations to the Nordic Council of Ministers, which can be considered in connection with future electricity planning and decision-making by national policymakers. The recommendations can also serve as a source of inspiration for cross-border discussions on electricity planning. The report adopts a funnel structure, as shown in Figure 7. Each of the five sections is presented in more detail below.

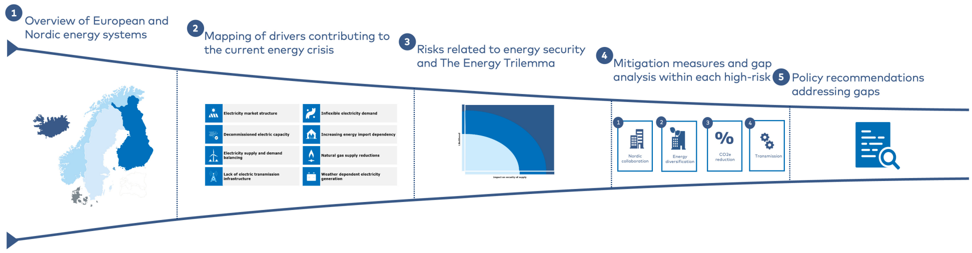


Figure 7. Analysis model and structure of the report

3.10.1 The European and Nordic energy systems

In Section 1, we present the European and Nordic energy systems. The purpose is to enable an analysis of the drivers (causes) of the energy crisis in Section 2. The section describes the international electricity and natural gas systems, as these cause spill-over effects between countries.

3.10.2 Mapping of drivers

In Section 2, we discuss the main drivers of the current electricity crisis. Each driver is described with the following structure: 1) impact on the electricity crisis, 2) context, 3) consequences and 4) impact on the value chain. The purpose is to understand the nature of the driver, the consequences for security of supply and to identify where the impact on the value chain occurs. The analysis structure is applied across identified drivers. The main drivers are identified through interviews with stakeholders in the energy market and literature research.

3.10.3 Identifying and assessing key risks

In Section 3, we analyse the key risks that the Nordic electricity market is exposed to in the short, medium, and long term. The first step was to develop a list outlining the specific risk and potential consequences for the value chain. This assessment forms the basis for an evaluation of the likelihood of the risk materialising and its impact on security of supply.

As discussed previously, this report does not consider the changing geopolitical environment, which could potentially give rise to sabotage and cybersecurity concerns. These risk categories could potentially have disastrous consequences for security of supply and should be analysed in a separate report. The list developed for this report consisted of approximately 25 risks spanning the short, medium and long term. Each of the risks is plotted in a risk matrix, enabling the identification of high-risk factors, for which we will subsequently suggest several mitigation measures. The applied risk matrix is shown below in Figure 8.

High-risk elements, which appear in the top right-hand corner in dark blue, are important to consider in order to maintain security of supply in the short to medium term. Mitigation initiatives are identified for high-risk elements, which form the basis for further country-specific analysis and serve as a foundation for policymaking relating to national electricity planning.

Medium-risk elements appear in the lighter blue area. These risks are recognised and briefly described in Appendix 3; however, mitigation measures are not identified. They should, however, be flagged for monitoring in case the risk materialises.

Low-risk elements will appear in the bottom left-hand corner in the lightest blue colour. These risks are also described in Appendix 3 but not considered relevant due to their low likelihood of materialising and/or their low impact on security of supply.

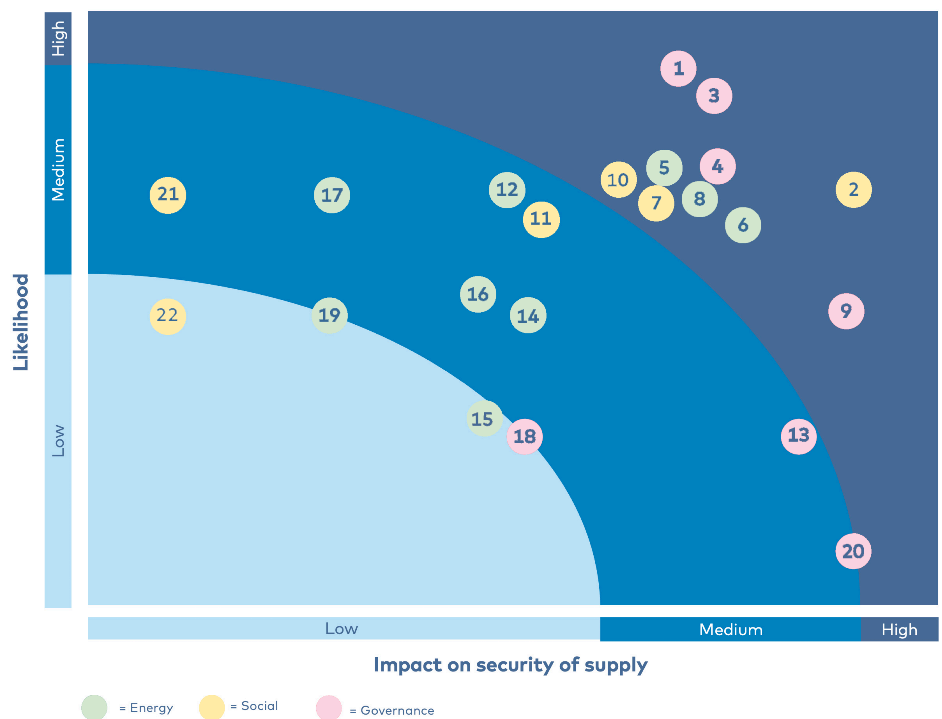


Figure 8: Applied risk matrix.

3.10.4 Mapping mitigation measuremitigation measures and gap analyseis

In Section 4, we identify some of the currently applied mitigation measuremitigation measures applied to respond to each of the high risks factors are identified. These measures have are either been implemented, adopteddecided, or considered in policymaking, often in 2022. Once againAgain, a long list was drawn up eveloped describing where measures were described in terms of the likely materialisation of the effect, their impact effect in time horizon and whether there is any documented effect of the initiative. Hence, mitigation initiatives are analysed based on their ability to respond effectively and adequately to the identified risk.

This is achieved done by evaluating whether there are any is a documented effects of implementing the initiative, i.e., "No experience", "Mixed experience", "Experience" or "Positive experience". By evaluating the relevance of each identified mitigation initiative and mapping it against towards the high-risk factors items identified in Section 3, gaps that where the Nordic energy ministries should focus on going forward, are identifiedfound. This in turn us, provides ing the foundation for recommendations to the Nordic Council of Ministers.

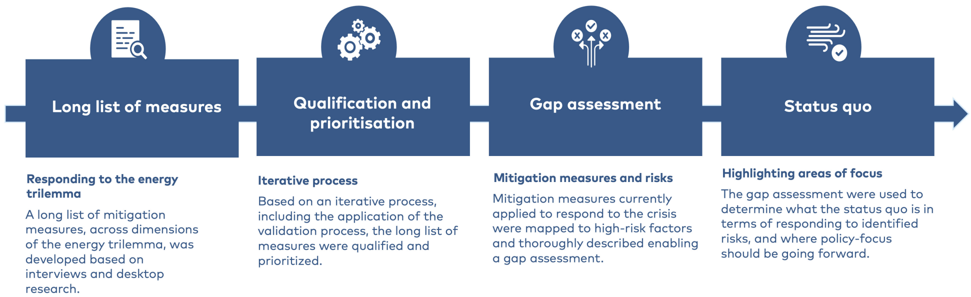
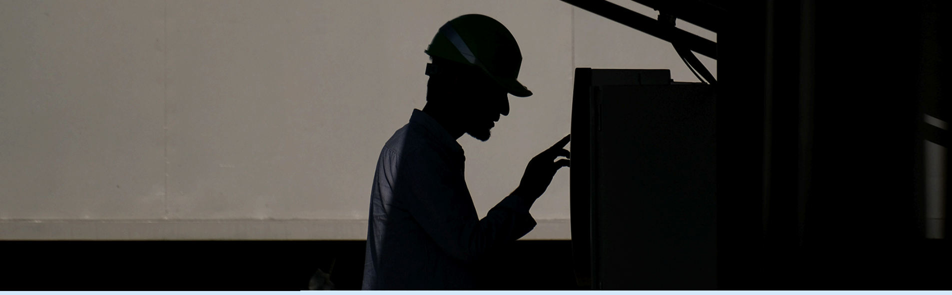


Figure 9: Process of identifying mitigation measures and gap analyses.

3.10.5 Policy recommendations

In Section 5, we present several policy recommendations for the Nordic Council of Ministers, which the Nordic countries can consider in connection with national electricity planning. In this context, it is important to note that the recommendations should be viewed as standard measures which need to be adapted to the situation in each of the Nordic countries. If recommendations are incorporated in national electricity planning, further analysis will be required to determine how the specific recommendation should be implemented in or adapted to the local context. The main purpose of the recommendations is to address security of supply concerns, with affordability and sustainability aspects as important second priorities, ultimately balancing all three dimensions of the Energy Trilemma, if necessary through trade-offs. Policy recommendations are made at national (although not country-specific), regional (Nordic) and international (EU) level.




4. INTERNATIONAL ENERGY SYSTEMS AND MARKETS

This section provides an overview of the European electricity and natural gas systems. We assess Iceland separately due to the fact that it is not experiencing the electricity crisis to the same extent as the rest of Europe. We present the existing systems rather than future scenarios, as the current electricity crisis is impacting the existing systems. Another important reason to focus on the European electricity and natural gas systems is that the underlying drivers causing the electricity crisis discussed in the subsequent chapter are propagated across European borders. Therefore what happens in Europe affects the Nordic countries.

Local energy systems such as district heating and cooling networks are not described, since these have not negatively impacted the current electricity crisis. District heating networks are significantly more expensive for long-distance energy transmission than gas and electricity, which is why the district heating zones are divided into geographically isolated areas. High heating prices in one area do not spread to adjoining areas as in the case of electricity and gas. While district heating and cooling systems could be part of a future solution to balance the Energy Trilemma, they have not negatively impacted the current electricity crisis.

Although we examine the Nordic countries as one, there are several differences between the individual countries' energy supply systems worth highlighting:

Finland has historically relied on imports of energy. The primary energy production has been nuclear and renewables (mainly hydro and solid biomass). Importing oil from Russia for further refinement and exporting to the world market, with Sweden as the main customer, has been a profitable industry. Electricity is mainly imported from Sweden and Russia.
Sweden has historically relied on imports of energy. The primary energy production has been nuclear and renewables (mainly hydro and solid biomass). In most years Sweden is a net exporter of electricity but a net importer of oil and natural gas.
Norway's large hydrocarbon production capacity makes it a net exporter of energy. The main export product from oil and gas production has changed from oil to natural gas. In most years, Norway is also a net exporter of electricity from its hydropower plants – albeit at a comparatively much lower level than oil and natural gas.
Denmark has oscillated between being a net importer and exporter of energy depending on its oil and gas production in the North Sea. The main energy import has generally been coal for the large central power plants and oil for onward export. In recent years, electricity has also been net imported from neighbouring countries.
Iceland is in a unique situation compared to the other Nordic countries as it is nearly self-sufficient in energy, and its energy prices have remained stable. The competitive situation is also different as Landsvirkjun (the national energy company) is the majority shareholder in the TSO. Moreover, there is a lack of transparency in the market regarding pricing. Lack of rainfall has created supply issues for a few energy-intensive industries.

Table 4: Country overview of energy system

In the following section we present the European electricity and natural gas system. The European electricity system is interconnected, and electricity is shared across borders. We also present the electricity market structure. Finally, we present an overview of the European natural gas system and the market. In Appendix 1, the primary energy supply, total energy balance and net energy import are shown for each of the Nordic countries.

4.1 The electricity system

The Nordic electricity system (excl. Iceland) is closely linked to the European electricity system, with interconnectors permitting trading across borders. The uniqueness of the Nordic countries lies in the availability of relatively cheap and abundant hydro, nuclear and wind power resources. The interconnections with the European electricity system have been gradually developed. The Nordic electricity system has, to a large extent, been based on electricity production from combustible fuels (coal, natural gas, etc.), nuclear and hydro. In recent years, production from uncontrollable renewables has been introduced (mainly wind power but also solar PV and biomass). See Figure 10 below.

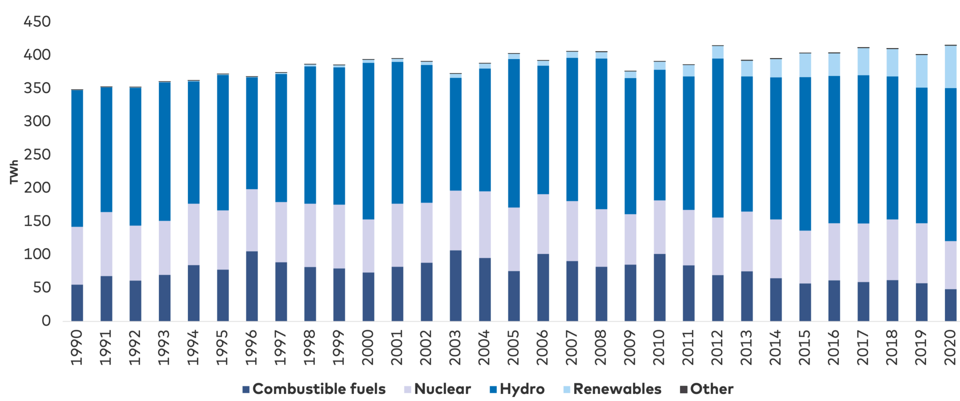


Figure 10: Gross electricity production (1990–2020) in the Nordic countries (excl. Iceland). (Source: Eurostat).

Due to the heightened focus on decarbonisation, the current electricity system is expected to change in the years to come. For example, new interconnectors will be built to ensure high supply security when domestic power plant capacity is reduced, and to develop a common European electricity market. Furthermore, a number of central power plants have been decommissioned, mothballed or converted to biomass with reduced capacity. Biomass-based power plants are expected to be gradually replaced by wind turbines and solar cells. The development of uncontrollable renewables like wind and solar will create a need for intermediate energy storage or alternative backup production. Controllable power generation (reservoir hydro, thermal power plants, nuclear) does not present the same problems.

Thermal power plants in Europe

Historically, the European electricity system has largely relied on electricity production from power plants. With the exception of hydropower, the electricity produced has come from nuclear and fossil-fuelled power plants. With increasing renewable energy production, the requirement for power plants will switch from energy production to system-bearing properties. Today 73% of power plant capacity in Europe is based on fossil fuels, and 23% on nuclear. The remaining 4% is based on other energy sources. Figure 11 presents thermal power plant capacity per country in Europe, and Figure 12 shows the total installed capacity per fuel type shown.

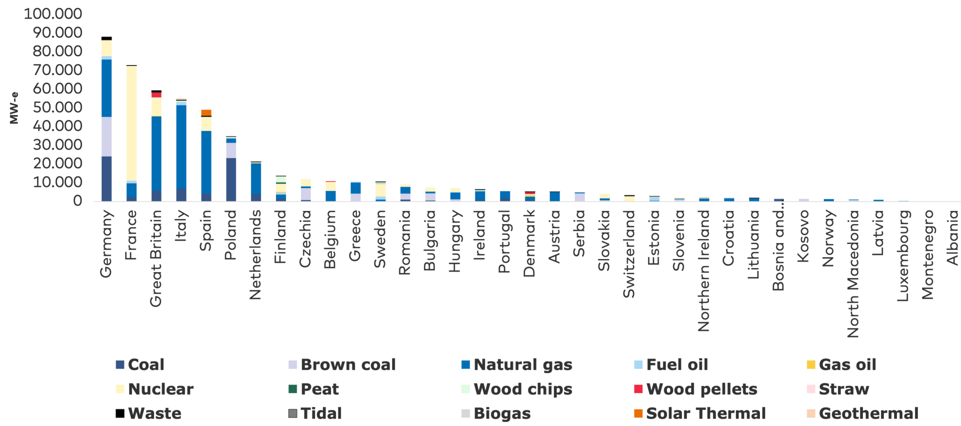


Figure 11: Thermal power plant capacity in Europe, 2022.

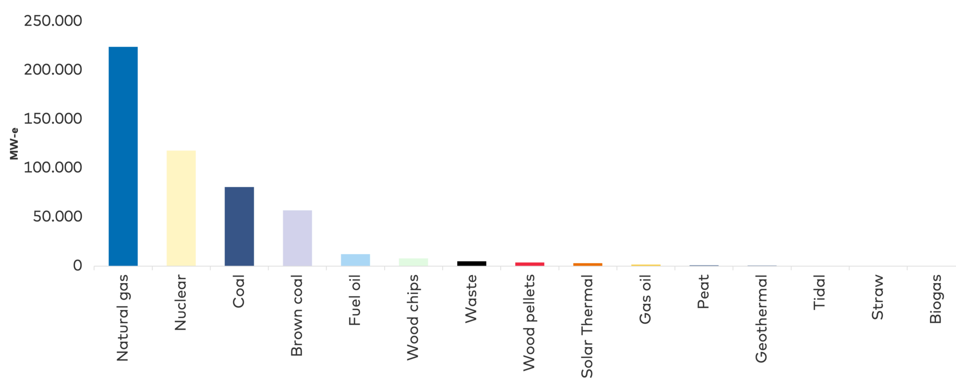


Figure 12: Thermal power plant capacity in Europe per fuel type, 2022.

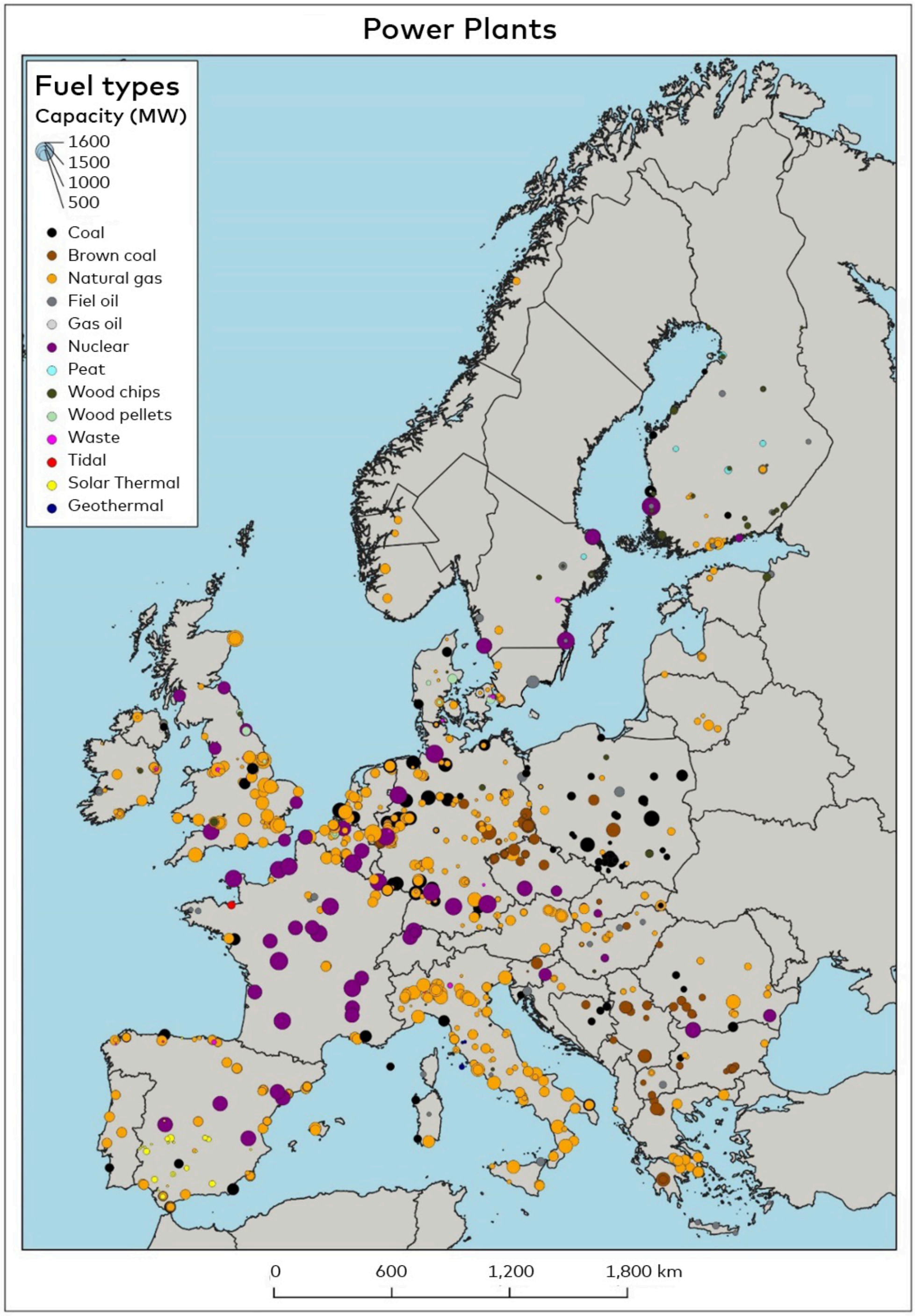


Figure 13: Thermal power plants in Europe, 2022. The map shows power plants with a capacity of more than 50 MW at block level. Some power plant groupings exceed 1.6 GW in total capacity.

4.1.1 Hydropower plants in Europe

The largest carbon-neutral energy source in Europe has for many years been hydropower. With the development of wind and solar, this is set to change. In future, more renewable energy, and hence more fluctuating electricity production, especially reservoir hydropower, will play an important role in system stabilisation. The water can be dammed, as in the case of reservoir plants, or it can flow, as in run-of-river plants. The former method offers greater production flexibility. Irrespective of flexibility, hydropower relies on weather conditions in the form of precipitation. Dry, wet, and normal years occur.

To some degree, the potential of hydropower has been almost fully exploited in Europe. However, further pumped hydro could be developed by upgrading existing generators or by damming new areas. Nonetheless, the future growth potential of hydropower is negligible compared with wind and solar. Hydropower is being developed in Scandinavia, the Alps, the Iberian Peninsula and eastern Europe.

Norway in particular is in a fortunate position, as it can base its entire electricity production on hydropower and export to other countries. The country will also be able to increase its wind power production in the future. Excluding pumped hydro, Norway is responsible for 23% of total installed hydropower capacity and 25% of total energy generated from hydropower in Europe. Figure 14 presents hydropower plant capacity by type (reservoir, run-of-river and pumped) for each country in Europe.

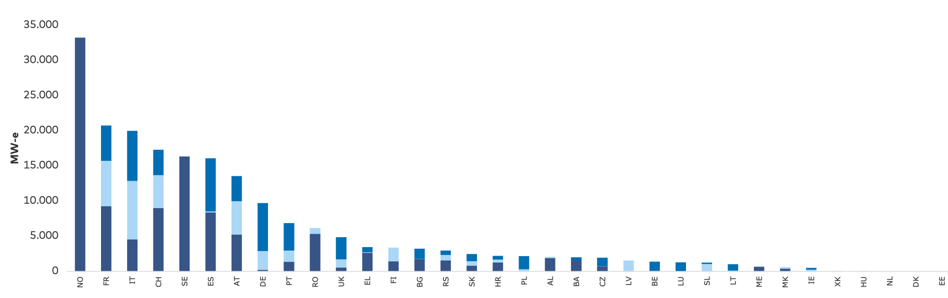


Figure 14: Hydropower plant capacity in Europe, January 2022. The pumped hydro plants can only be used to store electricity. Some reservoir plants in Norway can operate in reverse pump mode.

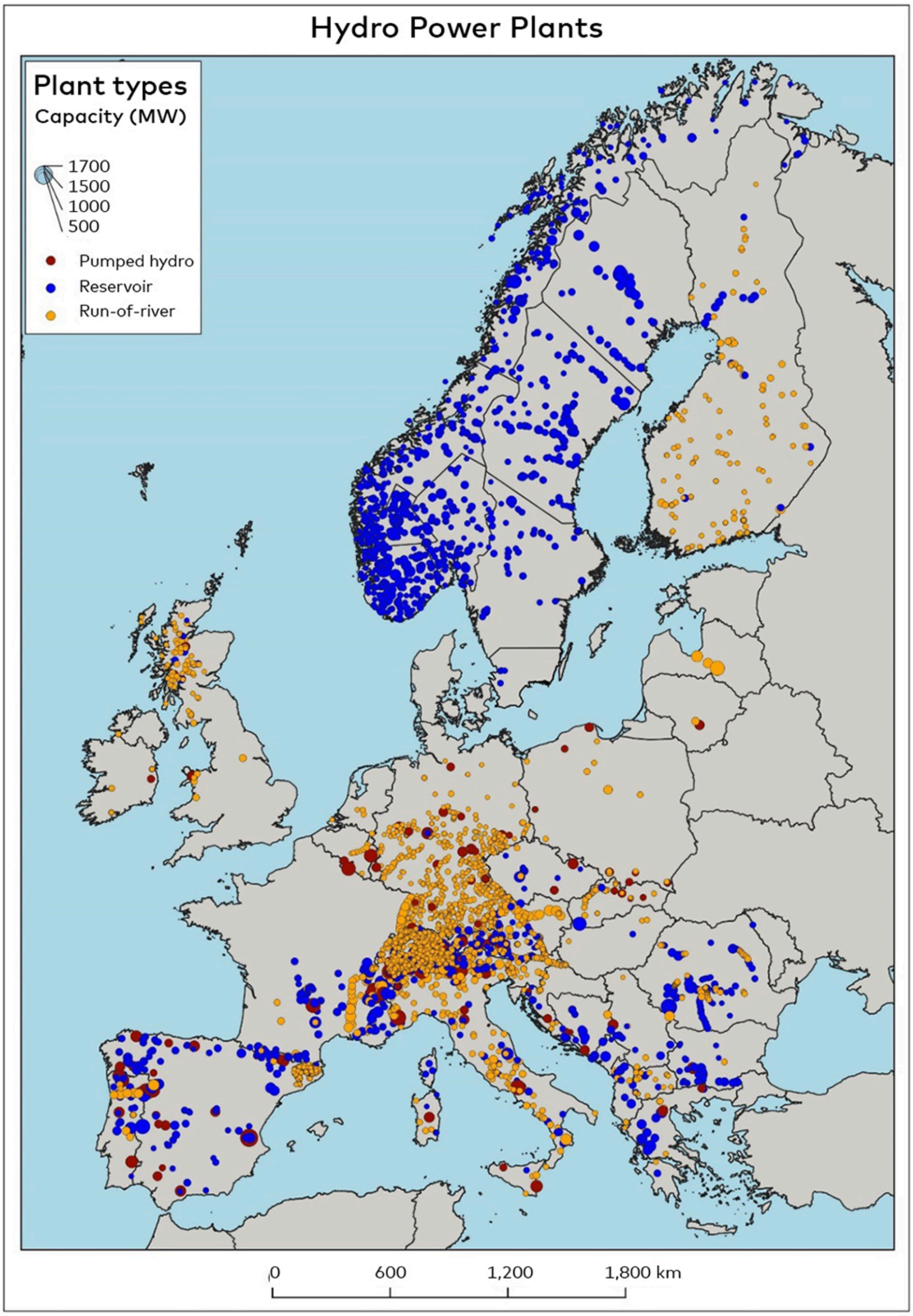


Figure 15: Hydropower plants in Europe, 2022. Note: The map shows all hydropower plants in Europe. Some rivers can supply multiple hydropower plants.

4.1.2 Renewable energy in Europe

Since the first onshore wind turbines appeared in Denmark in the early 1980s followed by offshore wind turbines in the 1990s, technological developments have resulted in significant cost reductions. The increase in wind power capacity has mainly been driven by onshore wind. Germany is currently Europe's largest producer of wind and solar-generated electricity – mostly onshore wind. Figure 16 and Figure 17 show the wind and solar PV plant capacities per country in Europe, while the map (Figure 18) shows the wind power plants in Europe. Several offshore wind farms will be built in the period leading up to 2030, as indicated by the blue dots. However, plans for offshore wind change almost daily. The offshore wind farms will likely be built in northern Europe. High, low and normal wind years occur.

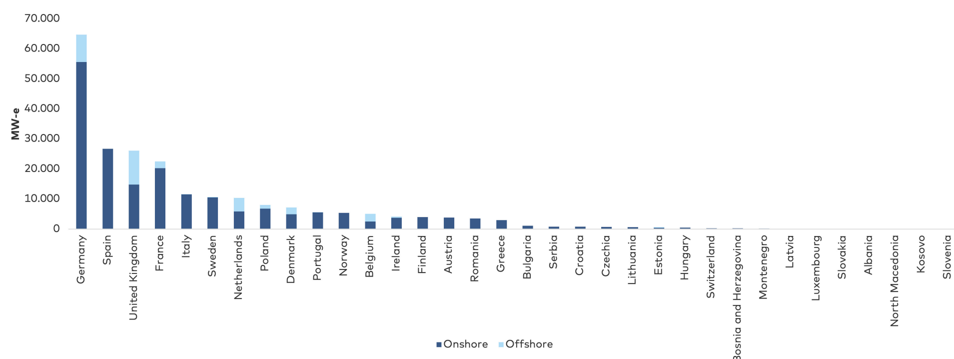


Figure 16: Wind power plant capacity in Europe, 2022.

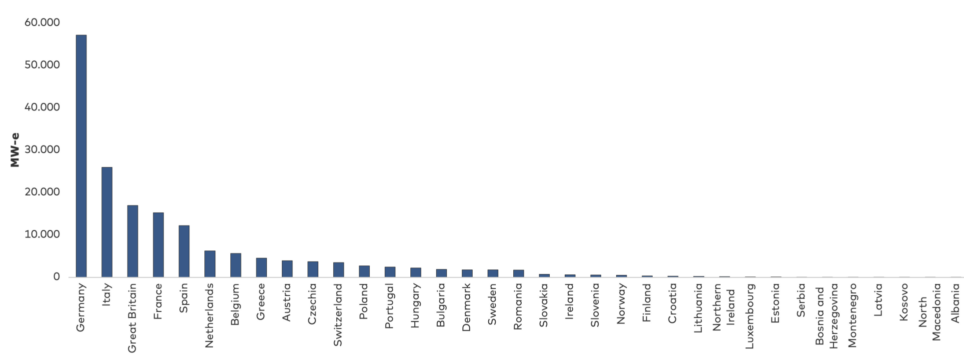


Figure 17: Solar PV capacity in Europe, 2022.

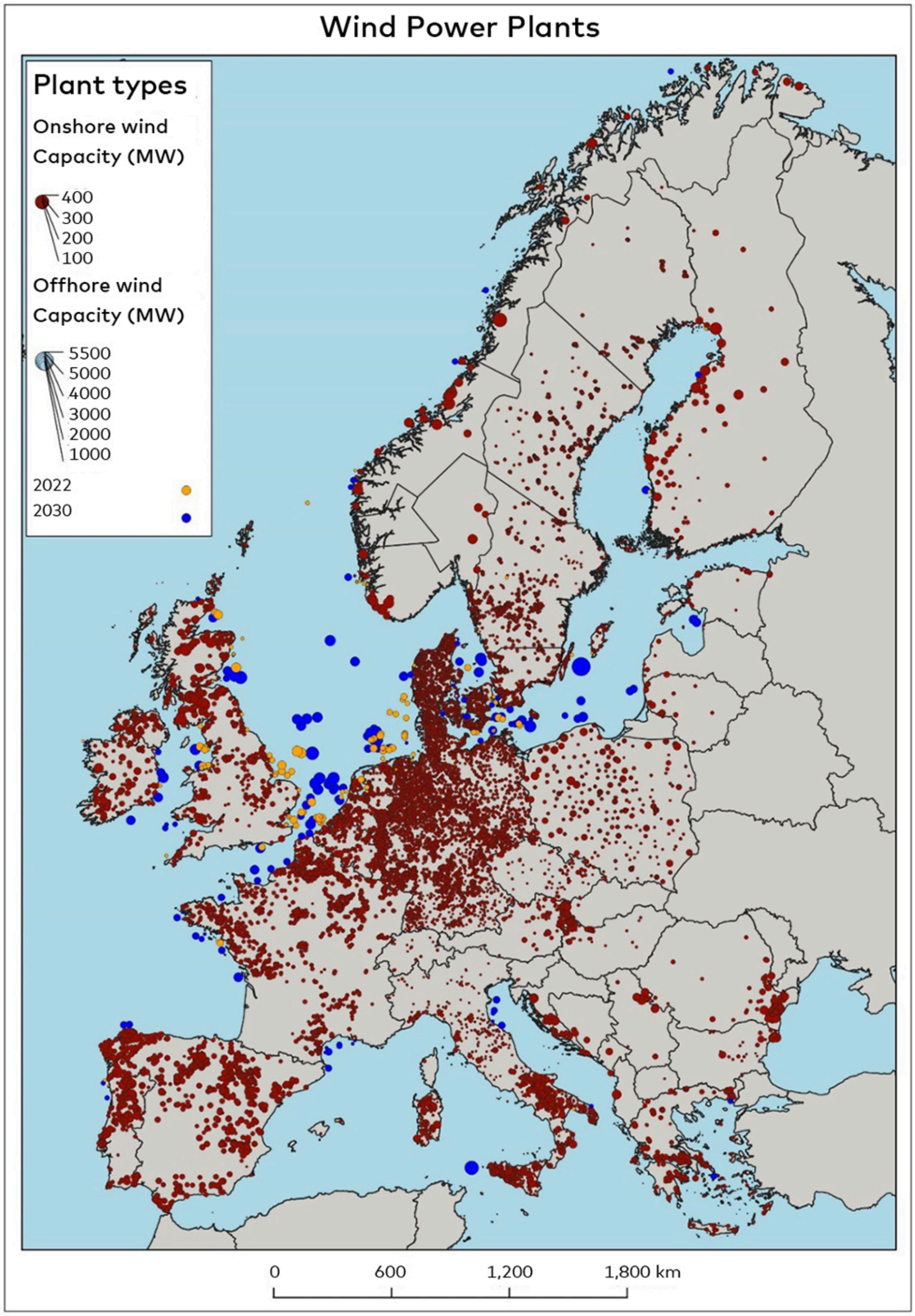


Figure 18: Wind Power Plants in Europe, January 2022. Existing wind power plants are shown in red and orange. New offshore wind power plants expected to be established by 2030 are shown in blue. Data availability differs between countries. Some countries provide information per wind turbine, some per wind farm and some only provide regional coordinates in areas where wind farms are located.

4.1.3 Interconnectors and electric transmission in Europe

The electricity market zones with interconnectors within Europe are shown on the map in Figure 20, while the interconnection export and import capacity for each country are shown in Figure 19.

The transmission system in Europe is shown on the map in Figure 21. The connections to Ukraine and Russia are also shown here. Electricity exchange between Russia and Europe has been reduced as a result of the conflict between the two countries.

The development of cross-border energy infrastructure (electric, natural gas, hydrogen, etc.) is, to some extent, governed by the Projects of Common Interest (PCI) in the European Union.

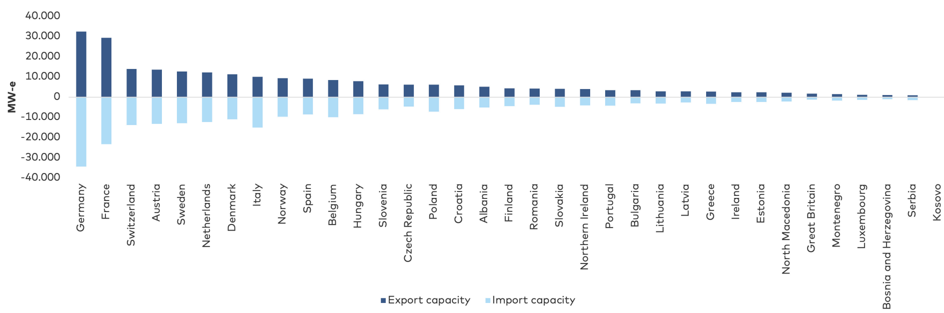


Figure 19: Import and export capacity by country, 2022. Some countries are split into multiple zones (e.g., Sweden, etc.). Internal transmission capacity within country electricity market zones is not shown.

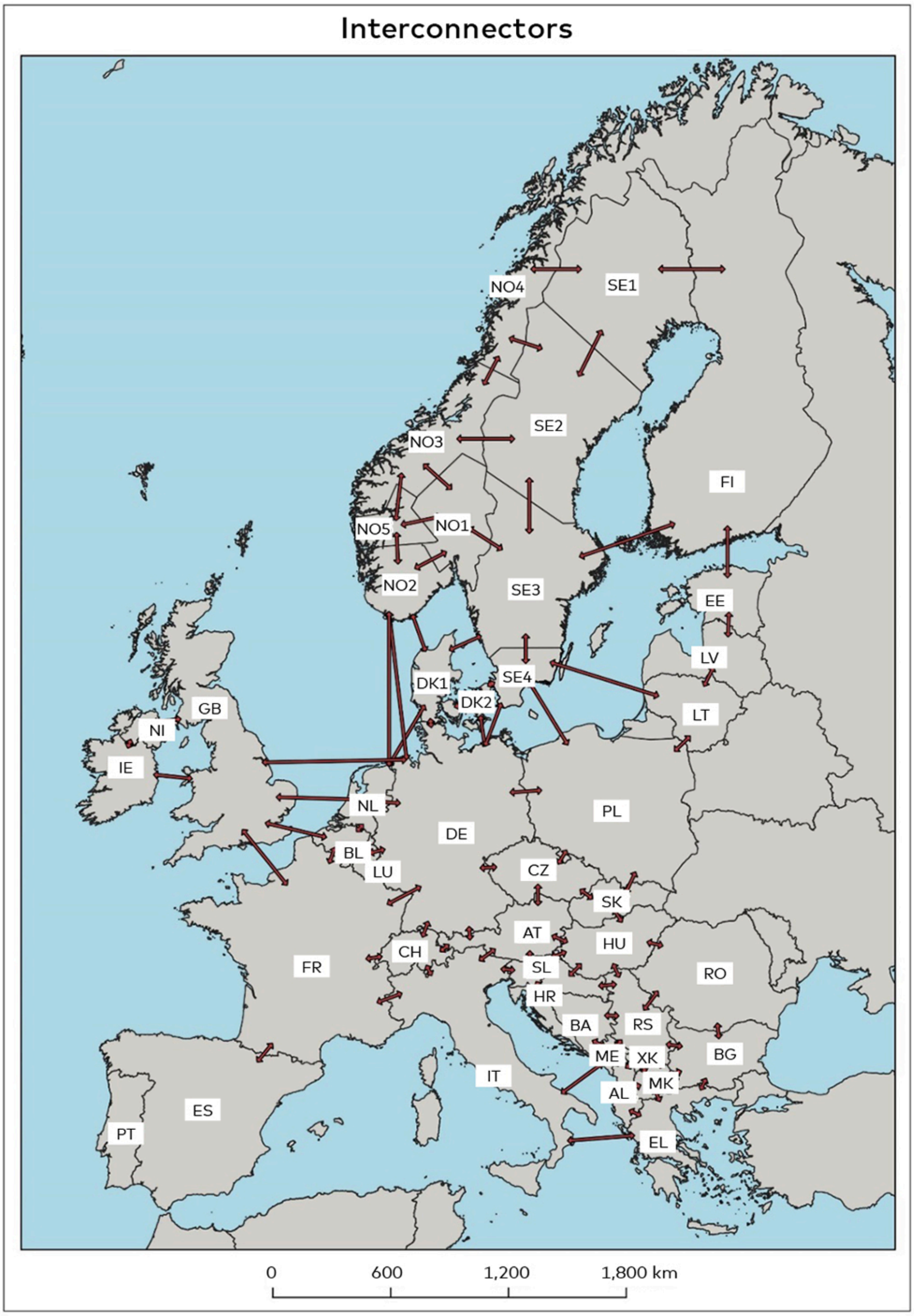


Figure 20: Electricity market zones and internal interconnectors, 2022. Not all countries have a deregulated electricity market. In addition, different trading platforms (exchanges) are available in some market areas.

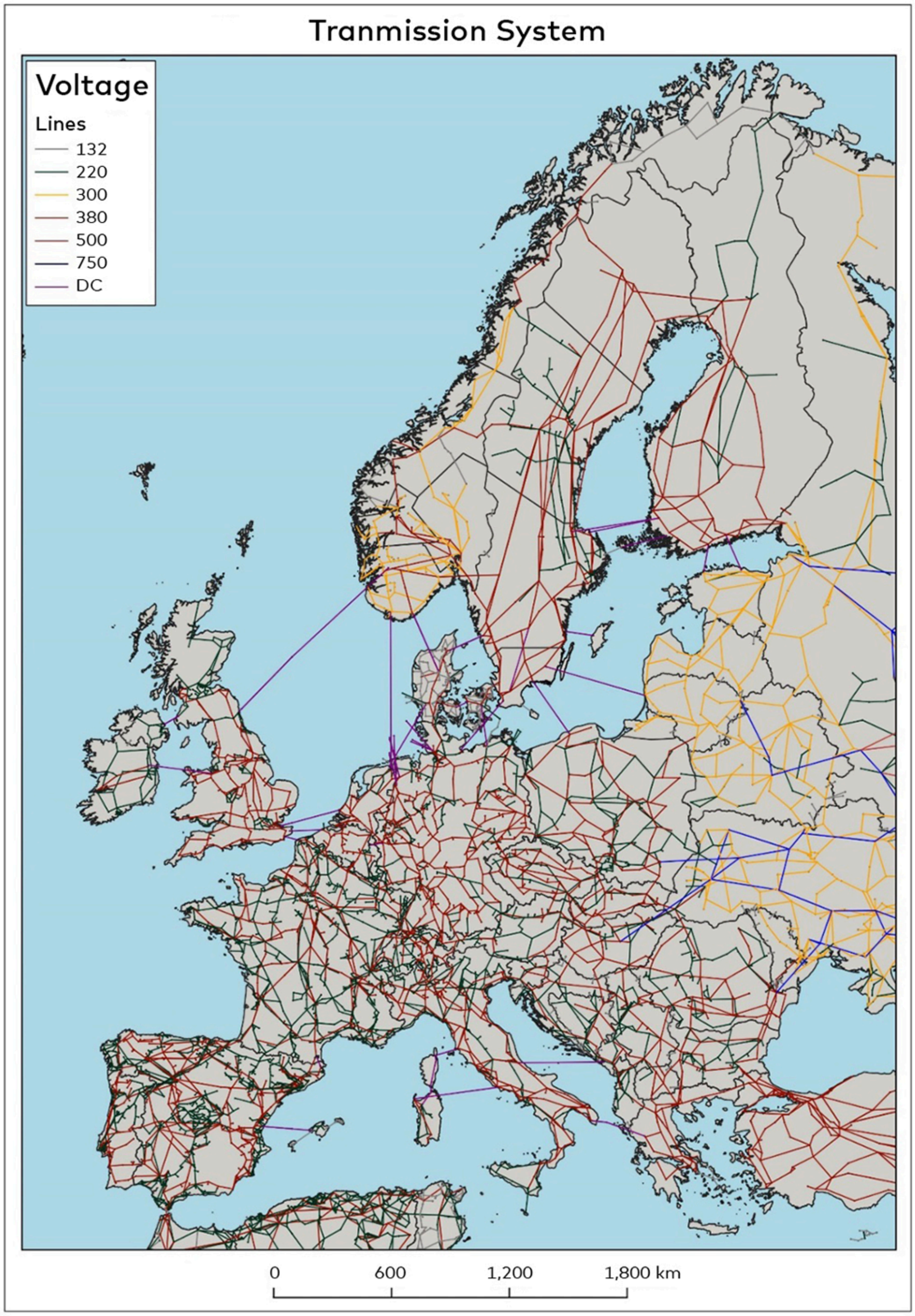


Figure 21: Cross-border electricity transmission system in Europe, 2022.

4.1.4 The electricity market structure in the Nordic countries

In the electricity system, an entity is required to ensure overall stability of the network – which means that both import and export, as well as frequency and voltages, must remain within agreed limits. This task is performed by the Transmission System Operator (TSO). To ensure a constant balance between the purchase and sale of electricity, selected players in the electricity market are assigned the status of balance responsible parties. All electricity production, consumption and trading must be assigned to a balance-responsible party. In practice, this role can be transferred to other balancing actors. For example, if the electricity producer is not responsible for balancing, the balance is guaranteed through a purchase agreement with a balance-responsible market player.

The reform of the electricity sector introduced competition between producers and suppliers. These players act together in the wholesale market. Due to fact that the TSO administers a natural monopoly, the transmission network is not competitive. The TSO owns the transmission network, while the distribution networks are owned by local distribution companies (DSOs). Advantages of a deregulated electricity market include the fact that electricity is produced at the lowest cost, transmission capacity between market areas is implicitly allocated and that electricity flows from high-price areas to low-price areas. The wholesale market is the market where producers sell their production through balance-responsible parties and where the latter also buy electricity on behalf of the retail suppliers who sell the electricity to consumers. The general electricity market structure is presented in Figure 22 below.

The futures market is active from the day before operations until years ahead. On the day before operation, trading takes place on the day-ahead market. By noon 12.00 – after the market has closed – the balance-responsible parties submit binding action plans for consumption, production and trading for the following day. Operator plans are subsequently approved by the system operator but can be changed up to 45 minutes prior to operation via trading on the intraday market, which is open from 2 p.m. and up to one hour before operating hours. From this point, responsibility for balancing the system lies solely with the system operator, which can adapt production through several system services. The system operator maintains the balance by buying electricity (up-regulation) or selling electricity (down-regulation) in the regulation market. At the same time, the frequency of the network is stabilised by operating automatic reserves. The structure of the wholesale market is presented in Figure 23.

In addition to being responsible for the electricity markets as shown in Figure 22 and Figure 23, TSOs also pay explicitly for a number of system-bearing properties, such as frequency stabilisation, system inertia, emergency capacity and special regulation, typically applying bilateral agreements.

Figure 22: Market structure for electricity

Figure 23: Structure of the wholesale market

The natural gas system in Europe

The European natural gas system is shown on the map in Figure 24. Natural gas is mainly supplied along three corridors: the North Sea via Norway, Russia, and North Africa and the Caspian Sea. LNG is also imported, in particular from the USA.

From a Nordic perspective, natural gas distribution systems are in place in Denmark, southern Sweden and southern Finland. The existing natural gas markets in the Nordics are small and cannot be compared with the scale of the Nordpool electricity market, which covers the entire region. Nonetheless, an increasing price influence between Europe's electricity and natural gas markets has been observed.

The natural gas system in Finland has historically been supplied by Russian gas, which was recently cut off due to the conflict in Ukraine. Natural gas supplies can be replaced by supplies through the Baltic connector and LNG imports; however, supply disruptions are expected due to the fact that not enough gas can be transferred to Finland. With the commissioning of the Baltic Pipe, more gas will flow from Norway through Denmark, mainly towards Poland, but the pipeline will also help supply Denmark and Sweden. Denmark has historically been self-sufficient with natural gas from the North Sea, but imports of natural gas from other countries are now necessary due to country's dwindling reserves and ongoing redevelopment of the Tyra field.

4.1.5 Natural gas market

The natural gas market model is constructed around an entry/exit model. Like the electricity market, it consists of wholesale and retail markets. The wholesale market is responsible for the transmission of gas from producers to the distribution network and the wholesale gas market. The following players are involved:

- **Shippers** are commercial actors engaging in wholesale gas transport in the transmission system. The shippers purchase transport rights to deliver the gas to one or more gas suppliers in the distribution systems. The shipper is responsible for balancing deliveries into the transmission system and despatches out of the transmission system.
- **Gas suppliers** supply consumers with gas and invoice them for the gas received.
- **The storage customer** owns the gas that has been transferred by the shipper for

storage in the gas storage facilities. The storage customer can sell the gas from the storage facility to a shipping company or another storage customer.

The remaining parts of the natural gas market consist of the following:

- **The retail market** is responsible for the distribution of gas from the transmission system to consumers and retail trade in gas to the end consumer.
- **The gas transmission system** is operated and owned by the TSO, who is responsible for volume balancing and the management of gas supply in the event of emergencies.
- **The gas distribution systems** are owned by the distribution companies.
- **The gas storage facilities** are owned and operated by GSOs or commercial actors. The storage facilities are operated on commercial terms. The storage facilities sell a product that allows the storage customer to store, inject and extract gas. This means that the storage facilities both compete with each other and are providers of other flexibility services.

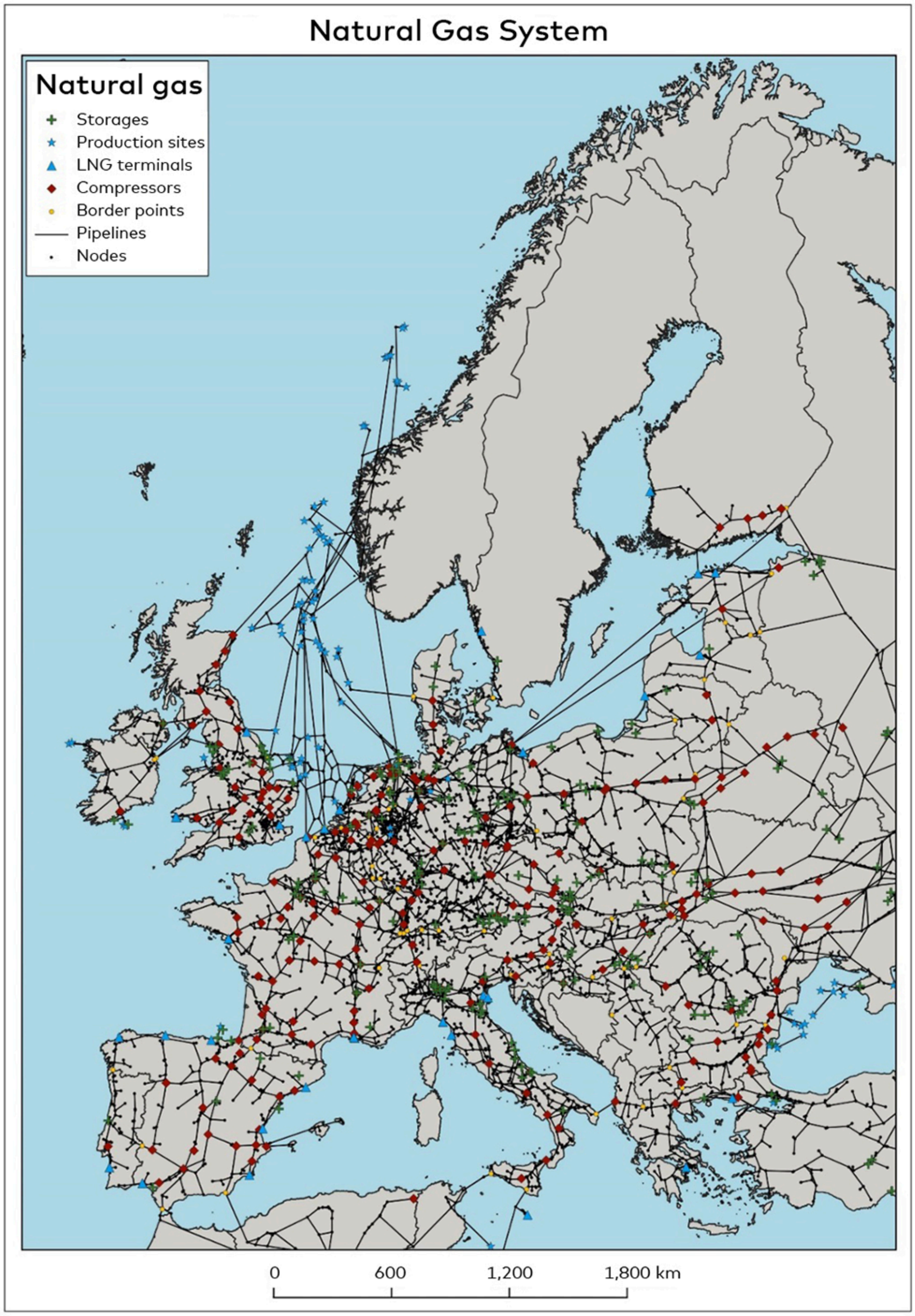


Figure 24: Natural gas system in Europe, 2022.

4.2. Natural gas and electricity prices in Europe

The energy crisis is generally manifesting in high natural gas and electricity prices increases. As shown in Figure 25, the natural gas price is more than four times higher than any previous peak price. The same can be said of the electricity price in Figure 26 albeit depending on the country. Sweden, Norway and Finland have, in general, experienced lower electricity prices than central Europe.

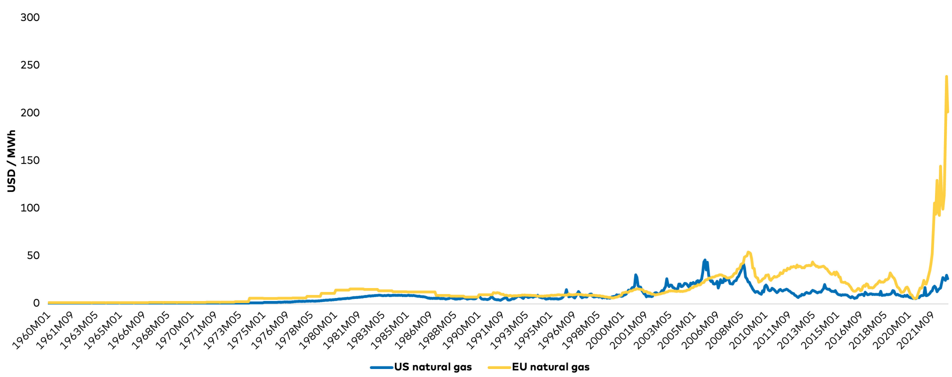


Figure 25: Natural gas monthly price development in the USA and Europe

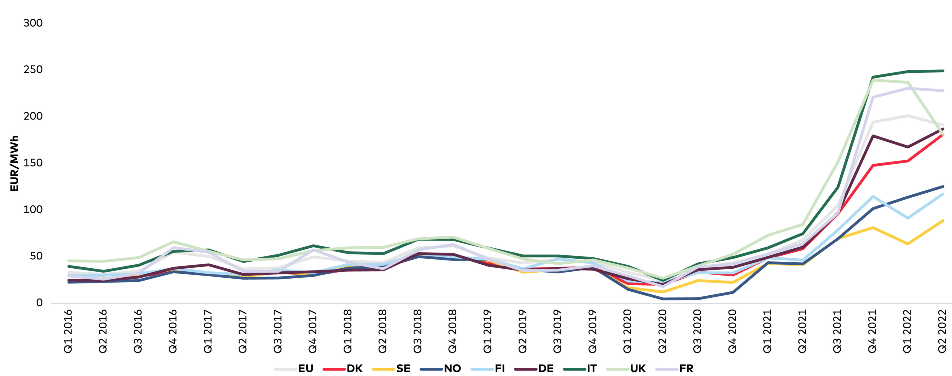


Figure 26: Average wholesale baseload electricity prices in selected European countries

4.3 The energy system in Iceland

The Icelandic energy system is, in many ways, unique. The country is geographically isolated with an independent transmission network. The location provides a potential for both hydro and geothermal power. Consequently, almost all Iceland's electricity is generated from carbon-neutral energy sources (70% hydro and 30% geothermal power), and 90% of the country's primary energy derives from domestically produced energy. Oil supplies 10% of the primary energy demand in Iceland and is mainly used to operate the country's fishing fleet and motorised vehicles. Iceland has no nuclear, coal or gas infrastructure. On the islands of Grimsey and Flatey, which are not connected to the national grid, diesel generators are used to produce electricity.

Electricity production in Iceland, which is almost entirely based on hydro and geothermal (renewable) sources, is shown in Figure 27.

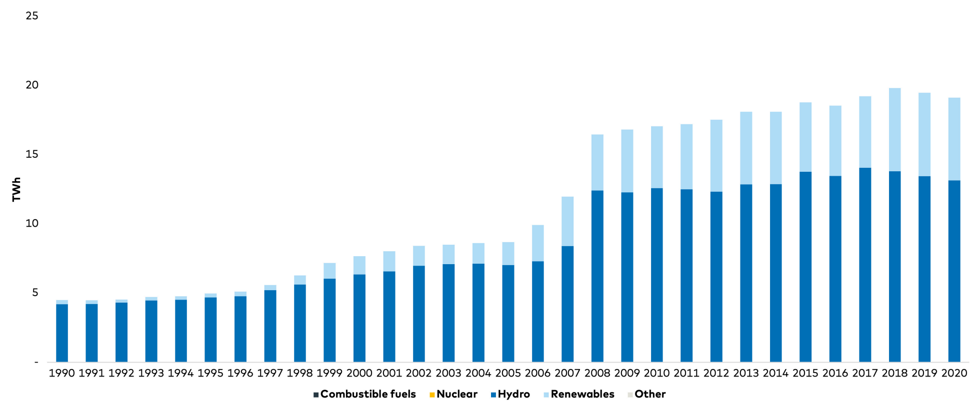


Figure 27: Gross electricity production and net demand in Iceland

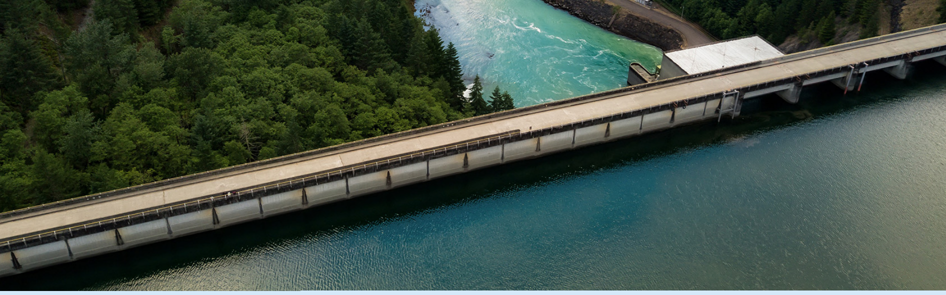
Power-intensive industries, mainly aluminium smelters, use around 80% of all electricity produced in Iceland, while other businesses use around 15% and homes 5%. A number of energy-intensive industries, combined with high heating demand, a small population and low-cost electricity production, make Iceland the largest per capita producer of electricity in the world.

One distinguishing feature of the electricity market in Iceland is the dominant size of the publicly owned generator Landsvirkjun. Today, most of the hydropower plants in Iceland are owned by Landsvirkjun, and the company generates about 73% of all electricity in Iceland. The company's dominant position among energy producers in Iceland results in limited direct competition in the wholesale market. The largest share of Landsvirkjun's energy generation goes to large industrial consumers (minimum of 80 GWh annual consumption), with most of the energy locked up in long-term power purchase agreements (PPAs).

The electricity transmission system is operated by Landsnet, and the company's majority shareholder is the power producer Landsvirkjun (65%). While local distributors distribute energy to the retail market, large users are connected directly to the transmission network and contract with the TSO, Landsnet and Landsvirkjun on supply.

Due to its isolated energy system and limited import of fuels, Iceland is not directly affected by the current energy crisis in Europe. However, the effects can be felt indirectly through increased oil and petroleum prices, and air travel prices. Energy prices in Europe will also indirectly affect Iceland through higher goods prices as production costs rise in Europe.

While electricity prices have risen in Europe over the past year, they have remained stable in Iceland. This has resulted in growing demand for energy from industries in Iceland and increased interest from international industrial companies in relocating to Iceland. While Iceland has historically produced an energy surplus, growing demand from a diverse group of actors is putting pressure on the market. In recent years, a number of data centres have relocated to Iceland, and energy-intensive industries, such as food producers and the biotechnology industry, have also shown an interest in joining them. The increasing demand from larger consumers for renewable electricity, combined with a need for decarbonisation in the transport and the fishing industry, could affect the country's energy security.



5. DRIVERS, PREPAREDNESS AND RESPONSES

This section of the report analyses the drivers behind the crisis, the preparedness of each of the Nordic countries and their respective responses to the crisis. Before taking a closer look at each of these aspects, we briefly describe the drivers, preparedness and responses.

Drivers

The current energy crisis is ultimately the result of the decisions societies have made in planning their energy systems. The drivers described below could perhaps have been avoided if other technological visions and different energy infrastructure projects had been adopted. Discourse around our future energy supply is essential to ensure a successful green energy transition while balancing the three pillars of the Energy Trilemma of security, affordability and sustainability.

The drivers we have identified are shown in Figure 28. Due to the analytical focus of the report, namely security of supply in the Energy Trilemma, drivers have been identified in accordance with their influence hereupon. The drivers have been identified through a literature review and a series of interviews with relevant stakeholders in the energy market. Each driver is described in more detail in this section based on the overarching conditions in the integrated electricity markets in the Nordics. Due to its unique situation as an independent market, Iceland is described separately within each driver.

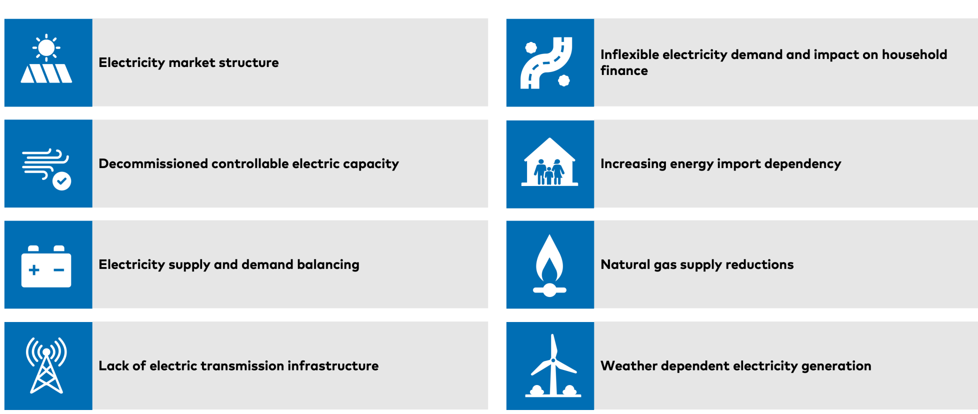


Figure 28: Drivers impacting the current energy crisis

This report argues that the current energy crisis has not been caused by a single incident or driver. Instead, it is a complex problem with several underlying causes triggered by the reduction in Russian fuel supplies, the unavailability of nuclear capacity in France, the drought in Europe and a speedy economic recovery following the COVID-19 lockdowns etc.

Even if Russia had not reduced its natural gas supply to Europe, the drivers we describe in the following would still have been present, creating issues for the energy system in terms of long-term security of supply. The drivers should not be viewed as standalone factors, since they are interdependent and consequently impact each other. While some of the drivers are already known to impact security of supply and energy prices, the manifestation of all drivers simultaneously has created a *perfect storm*, resulting in potential supply disruptions and high prices. In reality, it is the underlying risk factors, triggered by reduced fuel supplies from Russia, that have created the current energy crisis.

The extent to which each driver has impacted the current situation is not quantified. Such calculations are reserved for any subsequent report. For the time-being, we simply argue that there are a series of underlying causes that have contributed to the current energy crisis and that it is the manifestation of all the drivers simultaneously that has caused a perfect storm in the energy markets.

Preparedness

The energy system in each of the five Nordic countries is unique, even though the product consumers receive is the same – electricity, gas, heat, etc. The system each nation has built to generate and distribute electricity is different. These differences are attributable to natural conditions, organisational structures and investment in different technological visions.

Moreover, the relevance of security of supply, affordability and sustainability would essentially appear to change depending on current societal trends. There is generally a focus on one or two of these elements, which skews decision-making towards one of the three dimensions in the Energy Trilemma. With the advent of the energy crisis, we have recently gone from a situation with economic growth and low-interest rates and a focus on sustainability to a situation with a focus on security of supply and affordability of energy. Adopting a narrow focus on one of these factors generally appears to trigger a set of unintended effects with implications for security of supply.

The impact of the drivers in terms of security of supply at national level is analyzed by assessing each country's exposure and comparing it to other countries. The Nordic countries have been impacted differently by each of the drivers, mainly as a consequence of the composition of each country's energy system (mix of supply sources, infrastructure, degree of policy interventions and dependency on imports). This has resulted in different preparedness levels among the Nordic countries. The analysis also shows that each of the Nordic countries' electricity systems offers its own distinct advantages, which can be leveraged in a common Nordic market.

Responses

The Nordic governments have applied different initiatives to respond to the energy crisis with a view to mitigating energy poverty. While the increase in energy costs unleashed by the crisis have been felt by consumers, the Nordic countries have shown a degree of resilience and have been less affected by changes in energy poverty than other countries. Here it should be borne in mind that an increase in energy costs generally has a greater impact on the poorest households, and that this has also been the case in the Nordics, but to a substantially lesser degree than in the rest of Europe.

5.1 Electricity market structure

Influence on the energy crisises

The electricity market structure in the Nordic countries and Europe has produced had a number of unintended effects not envisioned anticipated at the its inception of the marketonset. We will touch upon thesem separately in the following when as we discuss the decommissioning of power plants and the introduction of subsidiszed renewable energy. The reason why that some power plants were decommissioned is reflected can be seen in the dynamics of the marginal pricing principle applied in energy-only markets. The structure of the electricity market structure has been a direct cause of is viewed as a prerequisite for some of the subsequent drivers.

Context

The Nordic countries (excluding . Iceland) were the first to reform electricity markets in Europe together with England and Wales. The Nord Pool electricity market has been in operation since Starting in Norway with the deregulation of electricity marketss in Norway in 1991, the Nord Pool electricity market has been operated since, followed by with neighbouring Scandinavian surrounding countries in Scandinavia (S: Sweweden (1996), Finland (1998) and , Denmark (1999),) and then the Baltics being added. New transmission lines are better at linking market areas. The electricity markets in the Nordic countries are closely connected to the rest of Europe, with an ultimate goal of orking towards creating an internal energy market that connecting s aall EU member states into a single deregulated liberalised electricity market. The idea is based on the agenda of the free movement of capital, goods and people. The planning of energy infrastructure is mostly agreed upon at a national level. In contrast, the development of new Projects of Common Interest (PCI), such as like interconnectors, is agreed upon at the EU level and between countries.

The reformed electricity markets in most western European countries are increasingly being coupled. Electricity is sold between the Nord Pool countries and the north-westnorth-western European markets through market coupling price mechanisms. In the event of In cases with no bottlenecks in the European electricity system, hydropower in Norway can, in principle, compete with nuclear power in France.

The electricity markets in Europe are developed as zonal markets. This means that the market operator has defined an area (market zone) where the electricity price is uniform. Any congestion within that zone is settled in the real-time markets or through bilateral contracts with the TSO. An internally congested zone will be expensive to operate, which calling s for either grid reinforcements or splitting of the zone into more zones. Such a situation can, for example, be seen in Germany, where there is only one one market zone is operated. Due to grid constraints, the wind farms in northern Germany cannot supply the electricity demand in the south of the country during periods of high windwindy periods, which causes wind production to be curtailed and conventional generators to be put into operation.

By reforming the electricity markets, vertically integrated monopolies were gradually dissolved with the aim of building a more competitive and flexible electricity market with competitive prices. As a result, companies could no longer generate, transport, trade and supply electricity while managing the transmission and distribution networks. Although there are national differences, today the effect of the reform today is a market that which operates based on the marginal pricing principle in energy-only market structures in which where new entrants can participate. The general reform of the operation of the electricity market is illustrated in Figure 29.

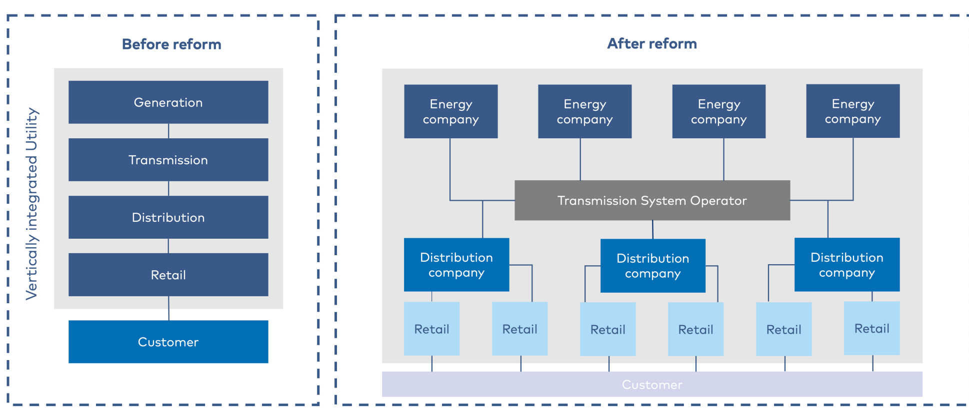


Figure 29: Reform of the electricity market

Consequences

The principle of the energy-only market is that each supplier and consumer bid their marginal cost (excluding capital and fixed costs) of production and consumption into a market pool. Any profit made by the generators makes a contribution to capital and fixed costs. The demand curve reflects consumers' willingness to pay for electricity. The intersection between the supply and demand curve sets the market price for electricity. Baseload generators with a low marginal cost recover their capital and fixed costs when more expensive generators are setting the market price. Peak load generators, with the highest marginal cost in the system, will only recover their capital and fixed costs when the market price is above the marginal cost of any generator – demand sets the price. Such price spikes occur when the total available generation capacity cannot supply demand. Peak-load generators hence only recover their capital and fixed costs when there is insufficient generation to supply demand, which in turn results in load-shedding and price spikes. The principle should, in theory, lead to investment incentives in new generation and an optimal mix of technologies.

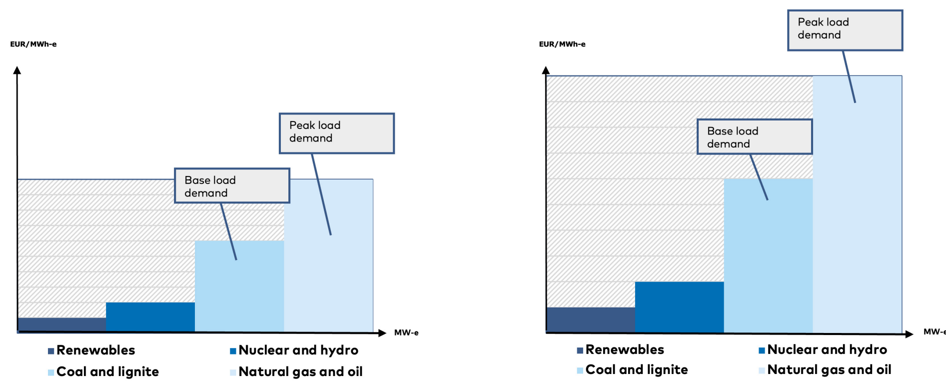


Figure 30: Marginal price principle and the impact of rising fossil fuel prices

Because price-setting in the European electricity markets is based on the last dispatched marginal unit (the most expensive unit required during operation), the electricity price is typically determined by gas- and sometimes oil-fired power plants – ultimately depending on the fossil fuel and CO2 prices and the renewable energy production.

The principle of the influence of increasing fossil fuel prices on market-wide electricity prices, as witnessed during the energy crisis, is outlined in Figure 30. In our example, the gas-fired power plants are at the top of the merit-order curve, which sets the electricity price. When comparing the total cost of generating electricity before and during the energy crisis, we see no significant difference. It is the fossil-fuelled plants that become more expensive to operate. Consumers pay a high premium, as the marginal unit sets the electricity price.

Figure 31 shows the bidding prices for various power plant types on the Iberian Peninsula. While the same data is not available for the Nordpool electricity market, the curve would likely be similar. The principle of high bidding prices from natural gas plants is visible, as well as how the hydropower plants influence the market through bidding between nuclear and natural gas plants

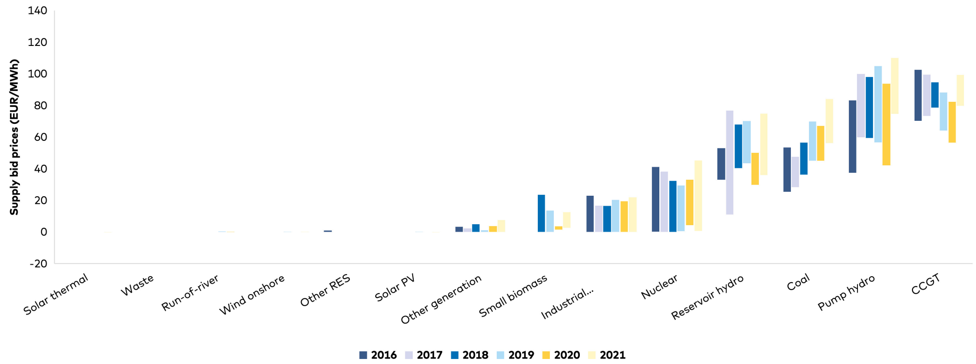


Figure 31: Electricity supply bid prices in the Iberian Peninsula electricity market. Equivalent data is not available for the Nordpool electricity market.

During the energy crisis, a price cap of 40 €/MWh was imposed on natural gas in the Iberian market. Direct payments to the gas-fired power plants cover the difference between the wholesale gas price and the cap, meaning that in practice the peak electricity price is capped. Consumers pay a lower price for the electricity provided that the government provides a direct payment. The net result is lower costs of energy for consumers.

Impact on the value chain

The impact of the marginal pricing principle in energy-only markets is primarily that generators must make the necessary revenue during peak price hours to cover capital and fixed costs and that consumers, in situations of bottlenecks between market zones, will be exposed to significant price increases. The following market drivers are a direct result of the operating principle of the energy-only market.

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The Icelandic parliament adopted the European Union Directive on competition and unbundling of the internal energy market in 2003 through The Electricity Act (no. 65/ 2003). With the new energy law, Landsvirkjun was no longer obligated to supply users in the country with an adequate supply of electricity; instead, the supply of electricity was to be determined by market dynamics. No public authority has responsibility for security of supply. Nonetheless, the Icelandic electricity market has a different structure to that of the other Nordic countries, as there are fewer actors throughout the value chain.

A long HVDC cable connecting Iceland and the United Kingdom, Icelink, has been proposed. Were the cable be built, the Icelandic electricity system would be connected to Europe.

5.2 Decommissioned controllable electric capacity

Impact on the energy crisis

The decommissioning of thermal power plants due to price competition, initiated by the energy-only market structure and the introduction of renewable energy, has resulted in a lack of baseload capacity in the electricity system to supply demand during unfavourable weather conditions. The closure of nuclear power plants in Sweden and Germany has been a political decision and is not attributable to reduced revenues from electricity sales. Nonetheless, their impact on system operation is similar since controllable electric capacity is withdrawn from the market in both cases.

Context

Marginal pricing theory for the electricity market states that when there is overcapacity in the market, peak-load electricity prices will be too low, and power plants will therefore be decommissioned as they cannot recover their operating costs. Conversely, the theory also states that when peak-load electricity prices are very high (or electricity prices in general are high), this will provide an incentive to invest in new power plants. However, one limitation of the theory is that while it does not take long to decommission a power plant, it can take a long time (10+ years) to commission a new power plant. Furthermore, the costs of developing new electricity production technologies are high. The closing and opening of power plants are not like other economic markets, since the decision-making processes and complexity of projects are different. In situations with falling electricity prices (as experienced before the energy crisis) and insufficient accompanying price spikes, power plants have increasingly been decommissioned or mothballed.

Consequences

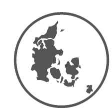
The reform and integration of the electricity markets in the Nordic countries have been implemented taking account of the national differences in energy supply in the Nordic countries: Norway is primarily supplied by hydropower, Sweden and Finland by nuclear and hydropower and Denmark by an increasing share of wind turbines supported by power plants. It is also important to remember that the majority of the largest power producers have been, and remain, state-owned energy companies

Furthermore, since each market area and country designed their energy system with different optimisation parameters from the inception of their respective electricity markets, it could be argued that surplus power generation capacity was made available. Therefore, closure of power plant capacity could be seen as predictable due to marginal price competition caused by an oversupplied market. Consequently, the advent of subsidised renewable energy generation has contributed to lower electricity prices and decommissioning of power plants.

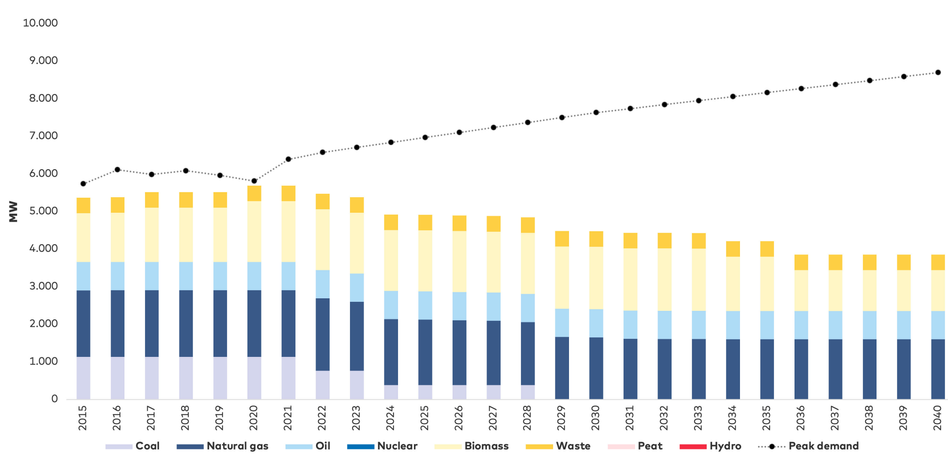
Decommissioning power plant capacity has led to an imbalance in production capacity between countries, which is expected to increase in the coming years, potentially impacting both electricity prices and security of supply. Expected power plant development in relation to peak demand in in the Nordic countries can be seen in Figure 32. The trend is most pronounced in Denmark, Sweden and Finland, as Norway relies on hydropower for its electricity production. The availability of hydropower depends on rainfall, which is why full capacity cannot always be expected to be available in peak demand periods, as shown. Electrification of heavy industry and transport, and reindustrialisation (e.g., battery factories and data centres) points to a very large deficit in controllable electricity production capacity moving forward.

The development of nuclear power plant capacity in Finland, Sweden and Germany is shown in Figure 33. Germany had planned to close all its nuclear reactors by 2023, but has decided to keep the remaining plants in operation due to the energy crisis. Sweden has also closed some reactors, whereas Finland has increased capacity with the addition of the Olkiluoto 3 reactor. Overall, the total nuclear capacity in central/northern Europe has decreased significantly over the last decade.

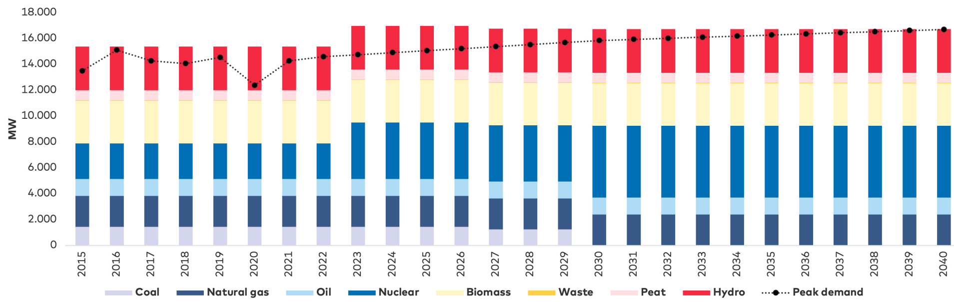
Figure 32: Power plant capacity development in the Nordic countries compared to peak demand. The demand projection is based on the expectations outlined in the Nordic Grid Development Perspective 2021. All power plants including expected closures and mothballings are included. Changes in expected capacity may have occurred, e.g. with respect to nuclear in Finland.



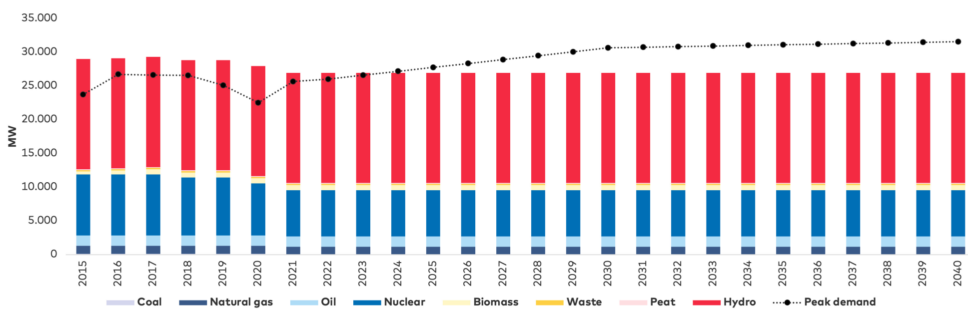
Denmark



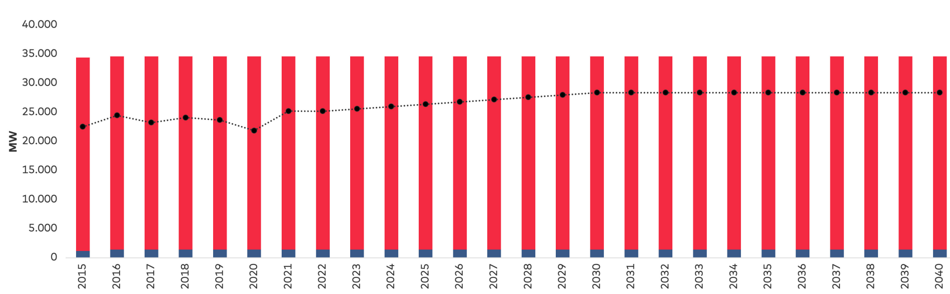
Finland



Sweden



Norway



The development of nuclear power plant capacity in Finland, Sweden and Germany is shown in Figure 33. Germany had planned to close all its nuclear reactors by 2023, but has decided to keep the remaining plants in operation due to the energy crisis. Sweden has also closed some reactors, whereas Finland has increased capacity with the addition of the Olkiluoto 3 reactor. Overall, the total nuclear capacity in central/northern Europe has decreased significantly over the last decade.

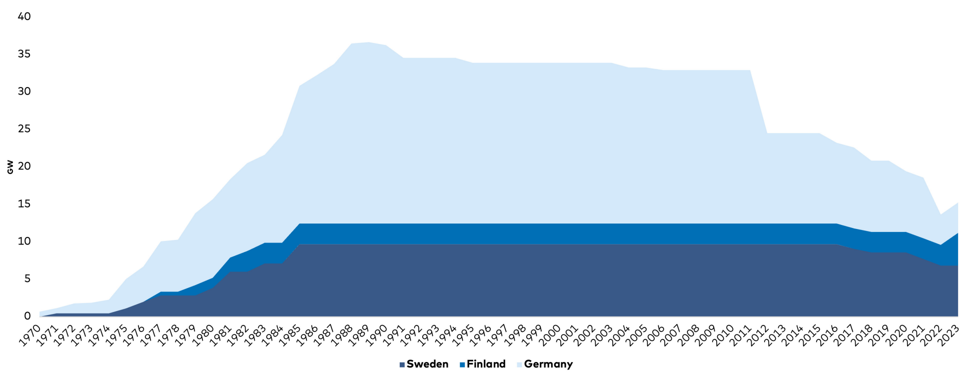


Figure 33: Nuclear power plant development in Finland, Sweden, and Germany.

High electricity prices throughout the day usually indicate a lack of baseload capacity, since peak plants dictate the price even at low demand. This development is most prevalent in countries where the majority of electricity production comes from thermal power plants. Although the Nordic countries generally appear to be safeguarded against a significant reduction in security of supply due to their reliance on hydro and nuclear power, a reduction in security of supply may be experienced, as power plants are decommissioned and electrification of society increases. Additionally, grid interconnectors from the Nordics to central Europe increase the likelihood of spill-over effects, thereby challenging generation capacity, security of supply and low electricity prices in the Nordics. Despite this, electricity demand in the Nordic countries is expected to increase due to the need for the electrification of society in order to fulfil national climate targets, although it is expected that much of this demand will be supplied by renewable energy. However, supply disruptions can occur during unfavourable conditions for wind and solar.

Nuclear power in France is an important part of the electricity mix in Europe and provides most of the country's electricity production. However, only 30 out of 56 nuclear reactors are currently operating. This exposes France to potential electricity supply disruptions and increases in electricity prices in the rest of Europe. During 2022, nuclear reactors have been out of operation due to a mix of technical and environmental issues. The latter included biodiversity concerns in connection with increased water temperatures in rivers due to discharge of water from the reactors. Nuclear power plants in the Nordics are nonetheless located by the sea, making the risk exposure to environmental standards less than those experienced by France in 2022. However, technical issues are also present, including in the Nordics, as reflected in the delay in the start-up of the Olkiluoto 3 reactor.

Figure 34 shows electricity production from French nuclear power plants since 2015. Electricity production in 2022 is clearly lower than in previous years.

Impact on the value chain

The main impact on the value chain is a lack of generation capacity in countries relying on power plants to supply electricity demand. The closure of nuclear power plants or decreased capacity due to a mix of technical and/or environmental issues also play a role here. Electricity exchange via interconnectors creates spill-over effects between countries. The security of supply is hence reduced in all countries. Furthermore, the lack of baseload capacity allows more expensive power plants, such as gas-fired power plants, to set the electricity price during many hours in line with the marginal pricing theory.

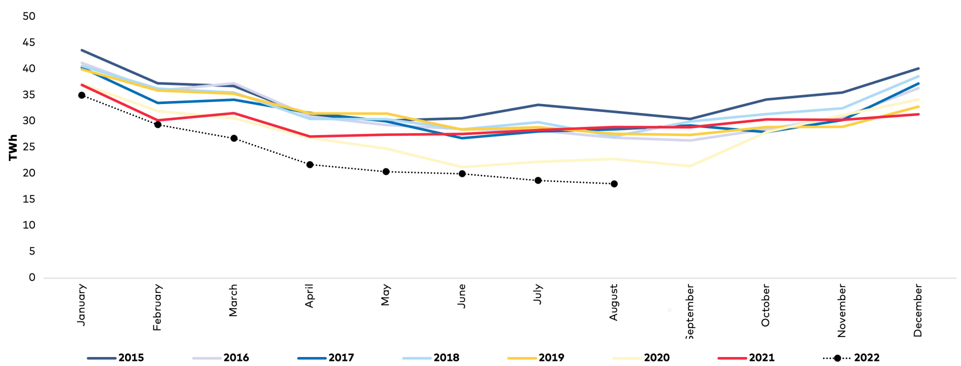


Figure 34: Operation of French nuclear plants (2015 – 1 September 2022) (ENTSO-E TP).

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There has been no significant decommissioning of controllable electric capacity in Iceland.

5.3 Balancing electricity supply and demand

Impact on the energy crisis

Decarbonisation targets and an associated focus on renewable energy development have heightened the requirements for balancing supply and demand in the electricity system. Going forward, electricity prices are expected to become increasingly volatile and hence impact security of supply.

Context

Awareness of global warming and its expected impacts have fuelled widespread public support for ambitious decarbonisation targets across the Nordic countries. This has crystallised in specific greenhouse gas reduction targets, as shown in Table 5.

Given the importance of the energy sector for reaching these decarbonisation targets across society, the integration of renewable energy has become a key policy priority. Historically, the Nordic countries have led the way in integrating renewables into the energy mix. The high reliance on hydro and nuclear power has also ensured very low CO_2 emissions from the electricity sector in comparison with other regions. Further development of wind and solar will increase the volume of renewables. The historical and projected development of low-carbon electric capacity in the Nordic countries are shown in Figure 35. Most of the wind and solar development will take place in Sweden and Denmark. However, the plans for offshore wind development seem to be continuously changing with an emphasis on further build-out of capacity in both the North Sea and Baltic Sea.

	Denmark	Finland	Iceland	Norway	Sweden
Carbon neutrality	2050	2035	2040	2030	2045
Application of carbon sinks (offsetting)	Yes	Yes	Yes	Yes	Yes
2030 CO_2 reduction target	70%	60%	40%	50-55%	63%* 70%**
2050 CO_2 reduction target	No	90-95%	No	90-95%	85%
Legally binding	Yes	Yes	Yes	Yes	Yes

*Emission reduction covered by the EU Effort Sharing regulation
** Domestic transport excluding aviation

Table 5: National decarbonisation targets in the Nordic countries

Figure 35: Renewable electric capacity development in the Nordic countries (Nordic Grid Development Perspective 2021, Eurostat, incl. energy islands. All elements other than wind and solar are maintained at 2020 levels).

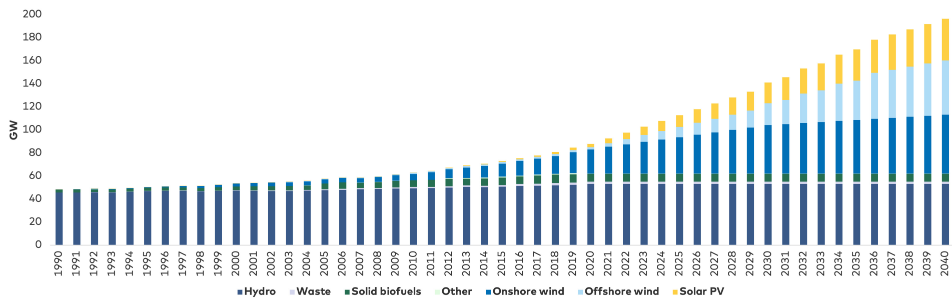

Figure 35 A: Low-carbon energy capacity

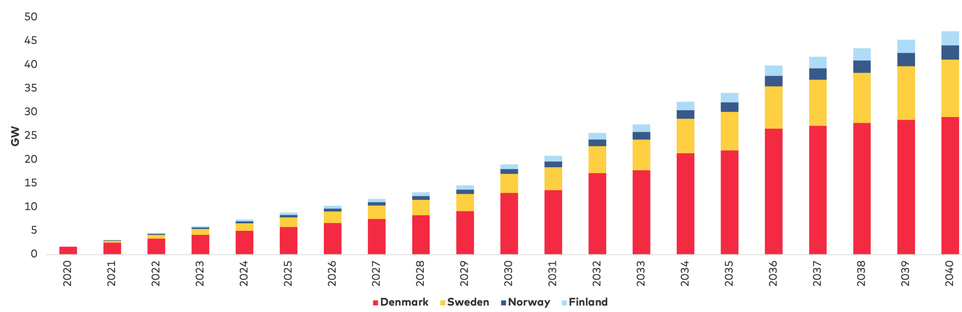

Figure 35 B: Onshore wind

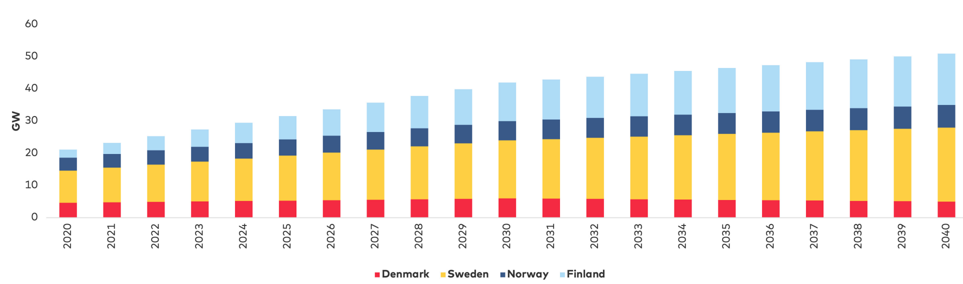

Figure 35 C: Offshore wind

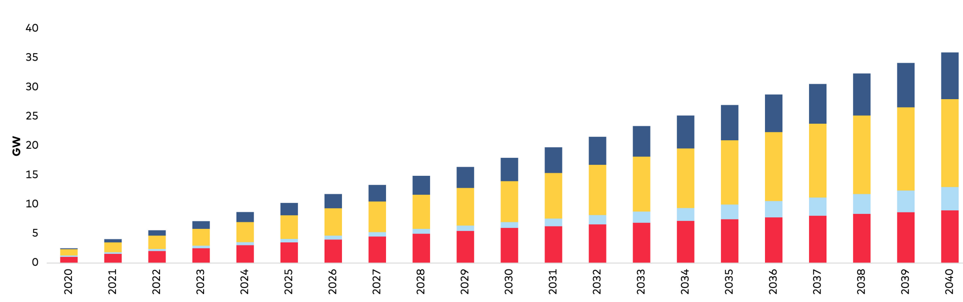

Figure 35 D: Solar PV

Consequences

One consequence of the increased integration of renewables in the electricity generation mix is a weather-dependent electricity system. This in turn necessitates a heightened focus on forecasting supply and demand to balance the system. The fact that demand from consumers does not coincide with renewable electricity production gives rise to a need for dispatchable energy resources to supply demand during these hours. The use of energy storage to reschedule production or a combination of energy storage and dispatchable energy is also possible. The Nordic countries have historically relied on conventional power plants and hydropower to provide this flexibility. Given the reduction in power plant capacity, there is a need to identify other sources that can reliably produce electricity during these periods.

The use of subsidies to stimulate interest in developing renewables has created a situation in the electricity market where renewable energy generators are able to bid at a very low (even negative) marginal price. This has increased the number of hours with negative electricity prices. Other issues relating to the integration of renewable energy include higher regulation costs and the creation of bottlenecks between electricity market zones as well as internally within countries due to major price variations caused by the lack of electric transmission infrastructure .

Impact on the value chain

Renewable energy integration impacts producers, grid operators and consumers throughout the value chain. Grid operators need to invest in balancing measures to avoid outages and strengthen electric transmission infrastructure in order to decrease the risk of congestion between the generation site and load centres. Consumers are required to deliver demand-side flexibility to reduce the price paid for electricity by spreading out the demand to match supply.

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Due to the isolated nature of the energy market in Iceland, production capacity must be higher than demand. This excess capacity has decreased in recent years and, according to Landsnet's predictions, may fall below the threshold in the coming years. In 2021, electricity demand was approaching the power plants' total installed capacity, complicating the balancing of electricity generation. Demand for electricity, combined with a dry year in 2021 and bottlenecks in the transmission system, led the National Power Company of Iceland to reduce the electricity supply to, among others, fishmeal factories. This meant that fishmeal factories had to burn oil to power their buildings. Electricity prices, however, remain stable.

Since variable renewable energy sources such as wind and solar have not been significantly developed in Iceland, the problems relating to shorter-term balancing are not relevant.

5.4 Lack of electric grid infrastructure

Impact on the energy crisis

Insufficient investment in electric grid infrastructure to meet the requirements of a renewables-based energy system and changed power flows caused by new interconnectors have created bottlenecks in Sweden and Norway. This has led to asymmetric electricity price formation in the Nordic electricity market bidding zones, as reflected in the electricity price differences between northern and southern Norway and northern and southern Sweden.

Context

Electric transmission infrastructure plays an important role in maintaining a high level of security of supply. An electricity system based on renewable energy requires a strong electric transmission infrastructure. The introduction of more renewable energy will result in more volatile electricity exchanges and electricity prices moving forward. The lead time for establishing new electric transmission infrastructure and strengthening the existing system is long, requiring grid operators to plan with an appropriately +10-year time horizon. The electricity price differences shown in Figure 36 reflect bottlenecks between market zones in the Nordic countries.

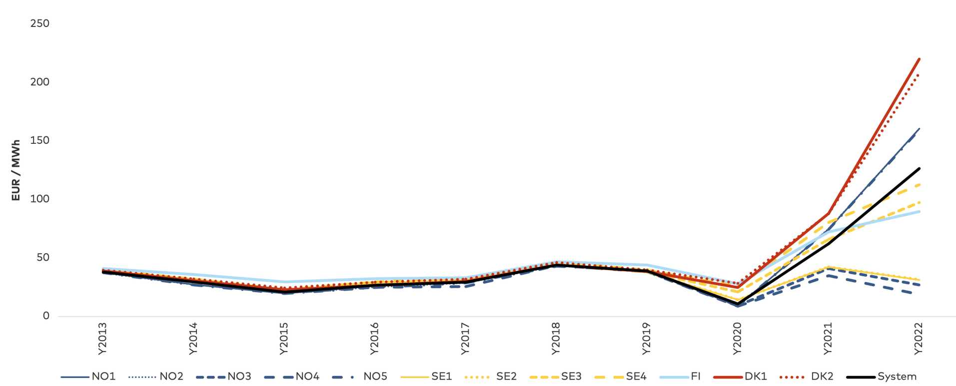


Figure 36: Annual electricity price average in the Nordic price zones.

Improvements in the electric transmission network are mainly necessitated by imbalances between the regions where production and consumption take place, for example, northern Sweden, which has high production and southern Sweden, which has high demand. Improvements in the electric distribution networks (local networks) are required to reduce local/regional bottlenecks that create local capacity shortages. One challenge is that most renewable energy capacity has been connected at a low-voltage distribution level.

Another sometimes forgotten challenge with renewable energy development is that it requires more electrical infrastructure to transmit the energy from production sites to load centres compared to fossil-based generation. This is because the capacity factors for wind and solar are lower than fossil sources by nature. The fact that the energy crisis is partially attributable to the lack of electric grid infrastructure to handle fluctuating renewable electricity production leaves Europe highly vulnerable to changes in weather conditions and disruptions in fuel supply.

Consequences

Figure 37 shows the net exchanges of electricity in the Nordic countries. The general picture is that Sweden and Norway are exporters of electricity, whereas Denmark and Finland are importers of electricity. The variations in electricity exchanges depend on whether it is a wet, dry, or normal year for hydropower and in the future whether it is a windy, still, or normal year for wind power. We show the electricity exchanges on an annual basis to be able to discount the effects of any system problems. Capacity shortages are prevalent in situations at a lower time resolution e.g. in situations with high wind power generation but low demand or outages on central power plants.

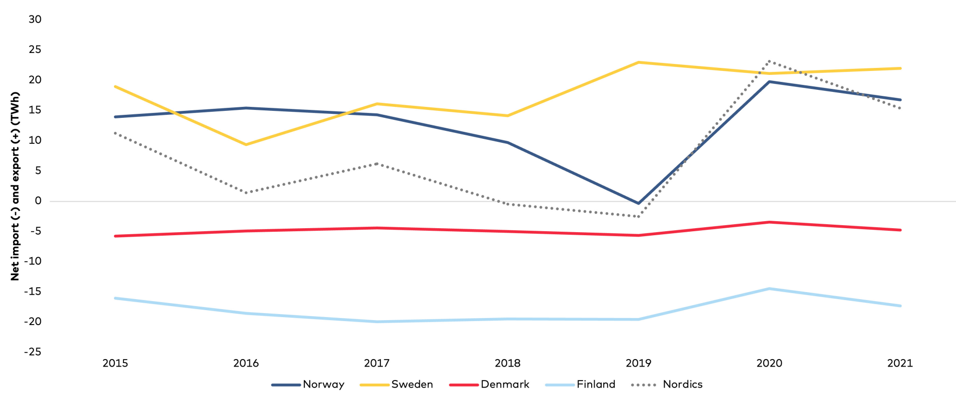


Figure 37: Net import and export of electricity in the Nordic countries (excl. Iceland).

Sweden's central location means that other Nordic countries will be impacted by the resilience and stability of the Swedish transmission grid. Three significant changes have driven new electricity exchange patterns during the energy crisis: (1) decommissioning of nuclear power plants in Sweden, (2) increased wind power in northern Sweden and (3) new interconnectors between Norway and Germany and between Norway and the United Kingdom. These changes have increased electricity flows from Finland to SE3 and onwards to NO1 as well as from SE2 to SE3, resulting in congestion between SE2 and SE3 and reduced capacity between SE3 and NO1 to safeguard operational security. These flow patterns are expected to increase following the commissioning of Olkiluoto 3.

The reduced capacity in the corridor between NO1 and SE3, as well as between SE2 and SE3, affects power prices in the whole Nordic system by impacting the ability to trade energy east–west and north–south. This has created price differences between electricity market bidding zones, especially in the southern and northern parts of Norway and Sweden. Long lead times on the infrastructure between SE2 and SE3 have also contributed to this development.

Impact on the value chain

Underinvestment in electric grid infrastructure primarily impacts the ability to transport energy from production sites to load centres. Furthermore, the long lead times associated with developing infrastructure projects can impact the ability to respond to physical infrastructure challenges caused by the relatively rapid roll-out of renewable energy generation capacity. Both elements result in increased price differences between electricity market bidding zones.

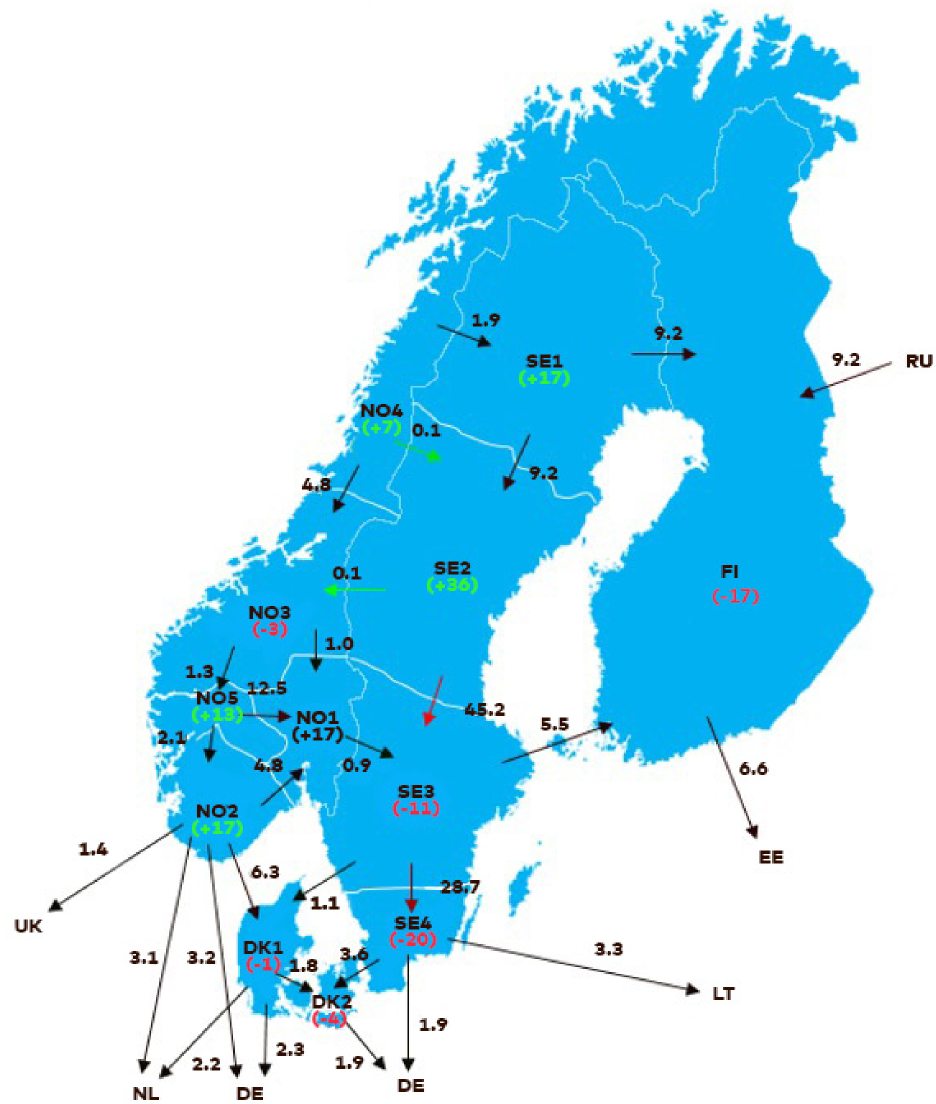


Figure 38: Net electricity flows in the Nordic countries in 2021.

FOCUS ON ICELAND

The transmission system in Iceland is ageing, and there are problems with expanding transmission capacity. Delays in the maintenance of the transmission system, lack of investment and increased electricity demand have caused tolerance limits of the network to be reached, and there are also transmission constraints between different parts of Iceland.

The average age of transmission lines (per km) in Iceland is 44 years, where the designated lifetime of lines is 50 years. System bottlenecks mean that many parts of Iceland are affected by transmission capacity constraints, which cause energy insecurity and hinder the development of industry in certain areas.

A storm in 2019 represented one of the most extreme weather events experienced by the Icelandic power system, causing major damage to transmission lines. As a result, a decision was made to speed up the construction of new transmission system lines. The development of a new transmission network started in 2019, and is due to be completed in 2030. The development has met some opposition, and approval procedures such as obtaining construction permits from municipalities and environmental impact assessments have made the process slower than expected.

5.5 Inflexible electricity demand

Impact on the energy crisis

High security of supply at low electricity prices and the perception of electricity as a public good has been the norm in the Nordic countries. In the past, consumers have had no economic incentive to actively engage in the electricity market. The inflexible demand on the wholesale electricity market is one reason why electricity prices can increase to such high levels, as the demand side is not capable of sufficiently decreasing consumption to stabilise electricity prices. This has, among other things, led to an increase in energy costs as a percentage of total spending, and increased awareness of potential brownouts in winter 2022–2023 in the Nordics.

Context

Electricity demand is generally inflexible. Historically low and stable electricity prices have meant that consumers have become accustomed to using as much electricity as and when they want without this significantly affecting their bills. The opening of the electricity market to competition in connection with energy market reform of the 1990s was intended to provide end-users with the ability to act flexibly. Figure 39 shows that for 90% of the electricity demand, consumers are willing to pay a maximum price of 4,000 EUR/MWh-e, and that only 10% of demand is price-flexible. Consequently, consumers are not participating in the wholesale electricity market. Therefore, within the Nord Pool, consumers' willingness to pay for electricity appears to be very high, indicating that demand for electricity is inelastic. Figure 39 shows the demand and supply curves on the Nord Pool electricity exchange at midday on the last day in September 2022.

However, this does not necessarily mean that end-users do not reduce their electricity consumption during peak hours if electricity prices are high. Consumers are increasingly being exposed to real-time electricity prices, and are moving from fixed price to variable price contracts with electricity distributors in order to align consumption with periods of low electricity prices.

Realised Nordic electricity demand per month for the period 2015–2022 can also be seen in Figure 40, which clearly shows that there have been no significant electricity demand reductions due to the energy crisis. The rapid increases in electricity demand predicted by experts due to expected growth in the number of electric vehicles, data centres, heat pumps, etc. in the Nordics, have also not materialised. Consequently, it is likely that the seemingly stable annual electricity demand does not necessarily indicate that there is lower demand or long-term price elasticity, but rather that price rises have counteracted the expected demand increases.

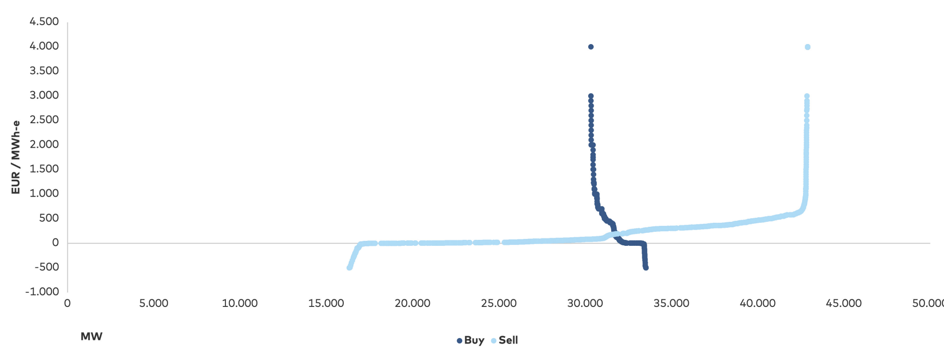


Figure 39: Nord Pool bid curves (30 September 2022   00:00:00 – 01:00:00).

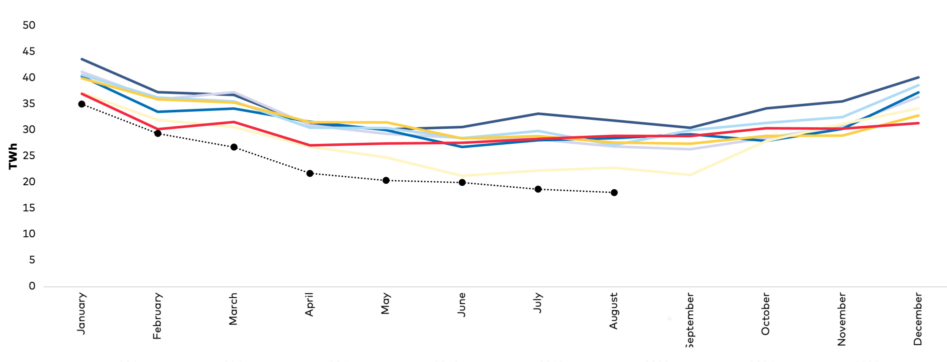


Figure 40: Electricity demand in the Nordic countries from 1 January 2015 to 1 September 2022. Electricity demand is not adjusted for weather-related factors.

Consequences

The inflexible demand and the decrease in baseload capacity from hydro and nuclear power has led to concerns about potential brownouts in the Nordic countries during hours of peak demand. A risk of power shortages for winter 2022–2023 has been highlighted in some of the Nordic countries, see Figure 41 below. Governments have therefore prolonged the operation of existing power plants to reduce the likelihood of brownouts, which could prove an effective tool in periods of low supply during peak-demand hours. Information campaigns and collaboration with electricity-intensive consumers have also been widely rolled out.

Given the potential heightened risk of brownouts in the Nordics, prices have increased significantly for both businesses and retail consumers, raising the spectre of energy poverty, an issue not previously prevalent in the Nordic countries. The International Monetary Fund (IMF) estimates that the surge in international fossil-fuel prices raised European households' cost of living in 2022 by 7%. The increase in energy prices has also contributed to consumer price inflation of around 5% in Finland, Sweden and Denmark. Initiatives to mitigate effects on household finances are discussed later in this report.

Impact on the value chain

The impact on the value chain primarily relates to insecurity around the availability of sufficient electricity, where subsequent price increases could potentially lead to energy poverty among Nordic retail consumers and lower profitability for businesses. However, since electricity demand in the wholesale electricity market will likely remain inflexible, the current high electricity prices may not decrease as a result of long-term demand response. We are yet to see the large-scale involvement in the electricity market regarded as necessary to integrate future increased volumes of renewable energy.

	DENMARK	SWEDEN	NORWAY	FINLAND	ICELAND
Risk reported publicly	!	!	!	√	X

√ = Risk reported   X = Risk not reported.   ! = Heightened awareness

Figure 41: Risk of brownouts reported

FOCUS ON ICELAND

Around 80% of all electricity production in Iceland is used by a few large energy-intensive companies, with most of the energy locked up in long-term power-purchase agreements (PPAs). For example, the largest and longest PPA in Iceland is a 4.9 TWh/year contract between Landsvirkjun and Alcoa, with a duration of 40 years.

Historically, energy-intensive companies have shown an interest in relocating their operations to Iceland. For a long time, the majority of companies interested in Icelandic energy were aluminium smelters. However, in recent years more high-intensive electricity industries have joined this group, including data centres.

Iceland has enjoyed very stable electricity prices, and the government has not been required to intervene to support affordability. An inflexible demand side is not a problem if the production of electricity is controllable.

5.6 Weather-dependent energy supply

Impact on the energy crisis

In contrast to the previous market drivers examined, it is not only renewable energy generation and hydropower energy generation that are weather-dependent. Energy demand is also highly dependent on seasonal temperature fluctuations since these can affect demand for heating and cooling. This poses a risk, given that it is likely that global warming will cause a rapid rise in temperatures in the near future which could lead to situations with low wind speeds and extreme heat. Such scenarios could leave both renewables and conventional power plants vulnerable to rapid increases in demand.

Context

Hydropower exports from Norway to Europe were high in winter 2021–2022. In combination with the driest 12-month period in 26 years in southern Norway, this saw hydro reservoirs reach their lowest level in 20 years in spring 2022. This prompted the Norwegian government to warn of potential restrictions in electricity exports during winter 2022–2023. However, the Norwegian TSO has argued against restricting exports as Norway may well need to rely on electricity imports in the future. Both developments are shown in Figure 42.

Figure 42: Hydro reservoir levels and electricity production from hydropower in Norway.

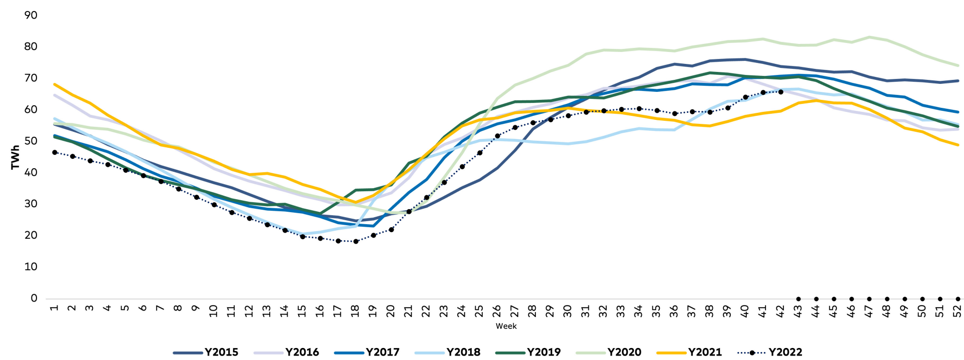


Figure 42 A: Reservoir level in Norway

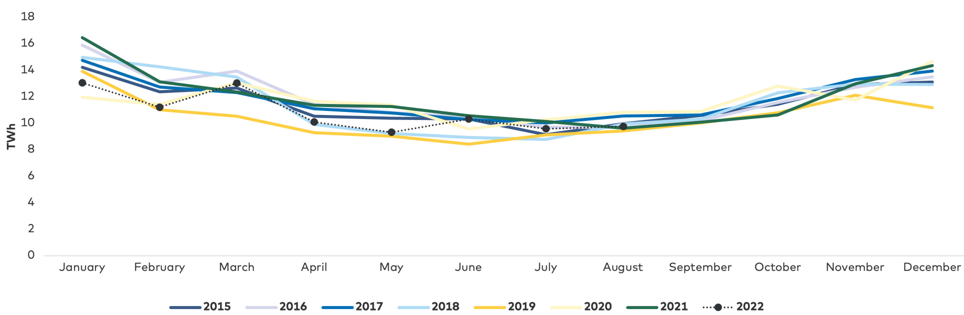


Figure 42 B: Hydro power production i Norway

Consequences

Norwegian hydropower has generally benefitted from high electricity prices. However, low reservoir levels have resulted in calls to reduce Norway's electricity exchange with other countries in order to conserve supplies. This illustrates that the weather has an influence not only on renewable energy production but also on other types of generation. However, the need to supply demand during periods of low wind and peak demand remains. For example, Denmark relies on power plants and electricity imports to meet demand when there is a lack of production from renewable energy. Going forward there is therefore a need for sustainable annual and multi-year long-term energy storage possibilities.

The general impact of wind energy on electricity prices and electricity flows is shown in Figure 43 and Figure 44. High power production e.g. via wind or solar lead to lower electricity prices and vice versa. The general trend of net imports at high electricity prices and net exports at low electricity prices is also evident. Denmark has been selected as an example due to its higher level of integration of wind energy and can be applied as a case for other Nordic countries considering the regional trend of building out renewable capacity. Furthermore, the weather has a visible impact on electricity prices and electricity flows.

Impact on the value chain

Security of supply can be weakened when there is low availability of multiple energy supply options at the same time due to unfavourable weather conditions. Reduced availability of conventional power plants (as explained in Section 5.2) and hydropower generally result in higher electricity prices during the day, especially during peak hours, impacting end-consumers. In practice, this makes taking account of weather considerations during energy planning increasingly important for both renewables and hydro.

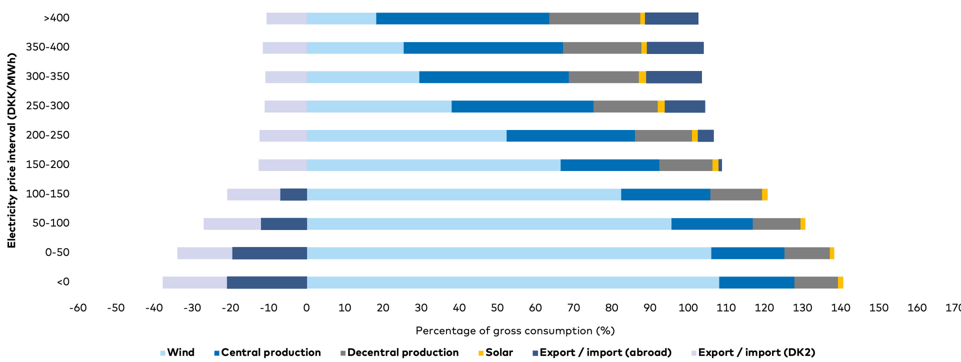


Figure 43: Average production distribution in DK1 at varying electricity price ranges (2010–2020).

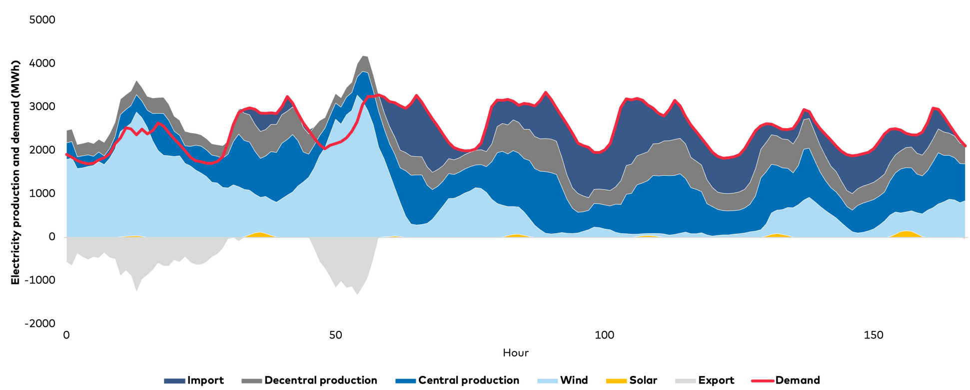


Figure 44: Electricity production distribution in the first week of 2018 in DK1, which is representative of the principle being illustrated.

FOCUS ON ICELAND

Hydropower accounts for 70% of total electricity generation in Iceland. Since hydropower depends on weather conditions, power generation is likely to vary accordingly. Glaciers play an important role in the hydropower system in Iceland and glacier melt during warm and dry summer periods is likely to cause a variation in hydropower electricity generation. Wet, dry and normal years occur in Iceland, and in dry years, hydro facilities are at risk of water shortages. Conversely, extra power generation opportunities can be wasted in wet years due to a lack of buyers, i.e., demand, or transmission problems. Critically, as previously mentioned, there was a lack of water inflow in 2021, which led to the curtailment of the national electricity supply.

5.7 Increasing energy-import dependency

Impact on the energy crisis

Europe is an energy import-dependent region. Reduced exports of Russian oil, gas, coal and electricity have impacted European energy prices. Energy supply disruptions are not unlikely for the winters of 2022–2023 and 2023–2024. In the long run, domestic energy resources such as renewables may be able to provide additional energy production, but not in the near future. Although the Nordic countries are in a strong position, its connectors to Europe make the region vulnerable to developments in Europe.

Context

Figure 45 shows the European Union's dependence on energy imports. More than half of the EU's gross available energy has been supplied by net imports, and in 2019 the energy import dependency rate reached more than 60%. It should be noted that Norway is not a member of the European Union, which is why imports from Norway are included under energy import dependency. The energy import dependency for oil and natural gas is high, whereas it is lower for solid fossil fuels, since there are coal and lignite mines in Central Europe.

The markets for coal, oil and, to some extent, natural gas via LNG are global energy markets. Since 1990, Russia has been the largest single exporter of coal, oil and gas to the EU. Consequently, it was no surprise that energy prices rose in Europe when Russia disrupted this supply. The import of solid fossil fuels and oil and petroleum products by EU partner countries is shown in Figure 46 and Figure 47. The figures for natural gas are presented in Figure 50.

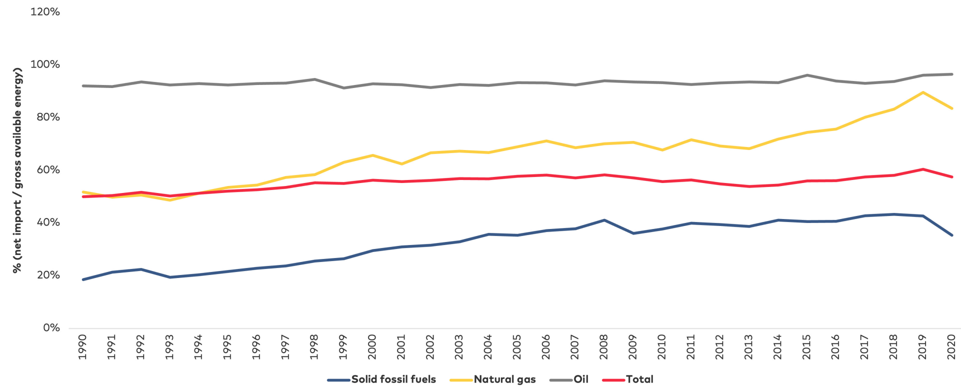


Figure 45: Energy import dependency in the European Union. (Source: Eurostat).

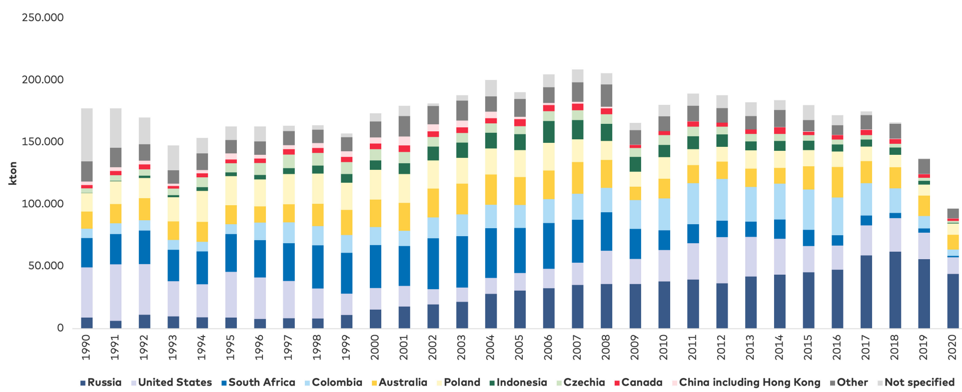


Figure 46: Import of solid fossil fuels and oil and petroleum products by European Union partner countries.

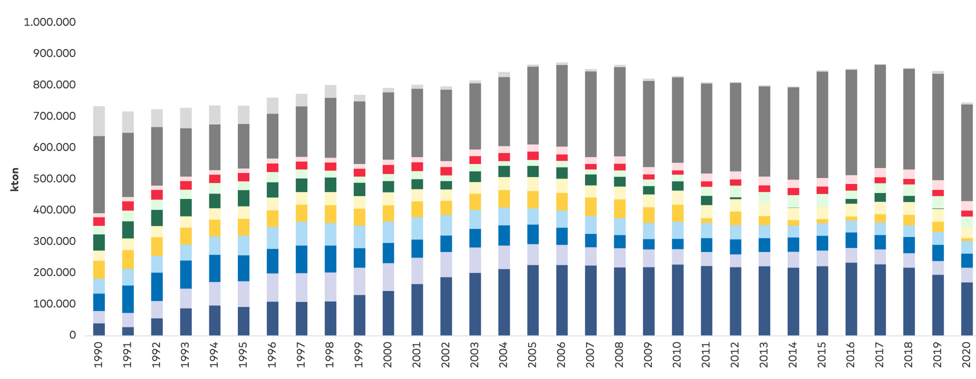


Figure 47: Import of oil and petroleum products by partner country.

Consequences

Europe's import dependency and reliance on Russian supply as its main source of energy imports is an important driver of the current energy crisis. Following the 1970's oil crisis, most countries started to diversify their fuel purchases across countries to avoid becoming dependent on a single energy supplier. The problem then was reliance on oil supplies from OPEC; today, it is reliance on supplies from Russia. However, the two situations are comparable. Since Europe's dependency on imports of Russian natural gas has been very high, energy supply disruptions cannot be disregarded for the coming winters before other energy supply chains are available at the same level as before the conflict with Russia. Connection to Europe via interconnectors and gas pipelines from the Nordic countries and the general global nature of fuel markets have created a spill-over effect for high energy prices. The energy supply challenges in Europe have been transplanted to the Nordic countries.

Impact on the value chain

The lack of diversification of energy resources and dependency on imports from Russia impact the value chain across primary energy sources. Mitigating the current situation will require diversification of energy resources and suppliers in order to provide the necessary level of security for the energy supply.

FOCUS ON ICELAND

The driver is not relevant to Iceland since 90% of primary energy use comes from domestic low-carbon energy sources. The other 10% mainly derives from oil imported from Norway.

5.8 Reductions in natural gas supply

Impact on the energy crisis

Reduced extraction of natural gas within the European Union, in connection with a gradual reduction in the foreign supply of natural gas, has created high sourcing prices for LNG and natural gas. This has led to increasing production costs and natural gas prices for end-consumers.

Context

The EU is dependent on imports for approximately 80% of its natural gas, making it vulnerable to import disruptions, as natural gas makes up approximately 20% of the EU's total energy demand. The largest suppliers of natural gas to the EU have been Russia, Norway, Algeria and the Netherlands, as shown in Figure 48. The closure of gas fields in the Netherlands has reduced internal natural gas production in the EU. One of the main causes of the increased dependency on natural gas imports has been a decrease in internal production, which has diverse causes, including a desire to achieve decarbonisation targets, public opposition, and less favourable conditions for natural gas production in new fields.

Norway is the largest producer of hydrocarbons within the Nordics. Denmark also produces hydrocarbons, albeit on a much smaller scale. A more comprehensive overview of the Nordic countries hydrocarbon activities based on data from 1990 to 2020 can be found in Appendix 1.

Consequences

One consequence of underinvestment in natural gas production in the EU and a significant reduction in gas supplies from Russia is that power plants based on natural gas have been exposed to the historically high production costs impacting the electricity market. For example, in 2019 the decision was taken to close Europe's largest natural gas field near Groningen in the Netherlands. Production was expected to cease in mid-2022, though this closure has since been postponed to 2023. Moreover, Denmark's largest gas field, Tyra, will remain closed for redevelopment until 2023. Nonetheless, crisis management measures designed to increase the security of the natural gas supply have been implemented, including a requirement that natural gas storage facilities through LNG out-sourcing be filled to 80% capacity before the winter.

Following the reduction in natural gas supplies from Russia and within the EU, ENTSO-G concluded that the gas storage situation may well be worse in winter 2023–2024: "*Without preparedness for Winter 2023–2024, the situation could deteriorate over the next gas year 2022–2023: storage facilities would be depleted in April 2023 and sites in Central and South-Eastern Europe would be less than 15% full on 1 October 2023, leaving the EU more exposed to risks of SoS in winter 2023–2024*".

Impact on the value chain

Lower natural gas production in the EU and a reduction in the supply of natural gas supplies from Russia have impacted the value chain through a lack of available natural gas as a primary energy source for storage and generation. This in turn has significantly affected both the natural gas and electricity price for end-consumers. Natural gas-fired power plants have been setting high electricity prices for many hours.

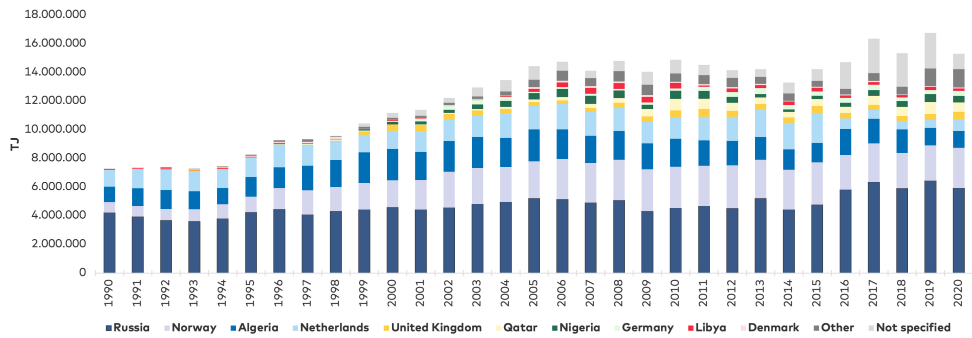


Figure 48: Import of natural gas by partner country to the European Union and primary energy production in the Nordic countries in 2020. (Source: Eurostat).

FOCUS ON ICELAND

Not relevant as Iceland does not use natural gas.

5.9 Preparedness of the Nordic countries

As mentioned, while the Nordic countries have integrated electricity markets, each country has its own distinct characteristics, putting each country in a unique situation with respect to the current energy crisis and their preparedness level. One country might be exposed to a specific driver but the same driver may not be relevant for another country. Table 7 provides an overview of each country's exposure – along with any positive effects – to the identified drivers impacting the energy crisis. One finding of the analysis is that each of the Nordic countries has its own distinct advantages that can be leveraged across the common Nordic market.

	NO EFFECT	LOW	MEDIUM	HIGH	
DRIVER	DENMARK	FINLAND	ICELAND	NORWAY	SWEDEN
Electricity market structure	Several power plants have been decommissioned or mothballed. Profit margins on electricity sales were significantly reduced before the energy crisis, leading to a greater focus on district heating (CHP plants) as revenue-providers. Peak demand can no longer be supplied domestically.	Additional nuclear capacity and wind will improve the capacity balance. No significant closure of baseload plants such as hydro and nuclear has been observed. Spill-over effects from neighbouring countries and electricity import reliance have affected prices and domestic security of supply.	The electricity market structure is different from the other Nordic countries with fewer market players. No actor is legally responsible for security of supply. One company produces 73% of all energy in Iceland and is also the country's majority shareholder in the TSO.	The first Nordic country to deregulate its electricity market was Norway. No hydropower plants have been closed, and trade across borders has been profitable. Spill-over effects of high electricity prices from central Europe during the energy crisis have been observed.	The structure of the electricity market zones in Sweden splits the country into high and low-price zones. Production is concentrated in the north and demand in the south. Strategic reserves are deployed as peak load plants. Re-drawing of the market zones has been discussed. Price signals indicate a lack of baseload and electric grid infrastructure.
Decommissioned controllable electric capacity	The decommissioning of power plants has already had and will continue to have an impact on the capacity balance due to the expected increase in electricity demand. Demand response, energy storage and sector coupling are currently not delivering the equivalent services of power plants.	The closure of power plant capacity in other countries and reduced electricity imports from Russia have had an impact. New nuclear capacity will increase security of supply and reduce dependency on electricity imports. Some power plants have been closed, but new nuclear capacity will improve the capacity balance.	No electric capacity has been decommissioned.	No hydropower electric capacity has been decommissioned. Mongstad gas-fired power station has been mothballed. Spill-over effects from other countries in terms of higher electricity prices have been observed.	Decommissioning of nuclear capacity and reduced electricity from CHP has had a negative effect on the capacity balance, reducing security of supply. This has resulted in higher reliance on electricity imports from neighbouring countries. Demand response, energy storage, and sector coupling have so far not been able to replace nuclear power plants.
Electricity supply and demand balancing	Denmark is impacted by the integration of renewables in terms of the	Reliance on nuclear and hydro power for baseload electricity	Excess energy capacity has decreased in recent years due to increased	Norway relies on short-term controllable hydropower. From a longer	The location of renewable energy generation and challenges around

	additional grid balancing services that need to be delivered. Interconnectors are used extensively to integrate renewables. Export during high renewable production and import during low renewable production have been observed.	production and lower development of renewable energy (in 2022) in comparison to the other Nordic countries ensures a generally lower requirement for short-term balancing. Future build-out of renewables is significant.	electricity demand, resulting in occasional shortages of energy supply.	perspective, production is dependent on water inflow. Wet, dry and normal years occur. Seasonal storage is possible if conditions or requirements for this are present.	transportation to loading centres due to bottlenecks in the transmission system has created a need for additional grid balancing services.
Lack of electric grid infrastructure	Low price differentials between the two market zones have been observed. The transmission problems in Germany and Sweden have impacted renewable energy integration. Future challenges are expected to increase.	Electric grid infrastructure is expected to be further developed in the future. Increased build-out of interconnectors to Sweden and Norway is expected. Direct connections to central Europe are not possible.	An ageing transmission network, lack of investment in infrastructure, bottlenecks in the network and increased energy demand have had an impact.	Increasing electricity prices impact Norwegian consumers via interconnectors and a lack of domestic infrastructure. Producers have increased revenues through exports. Price differences exist between northern and southern Norway. Domestic transmission is needed.	Lack of investments in grid infrastructure together with renewable energy development have resulted in electricity price differences between north and south Sweden. Long permitting times for new grid infrastructure have impacted current needs.
Inflexible electricity demand	Energy efficiency measures have been promoted to reduce vulnerability during the energy crisis. A short-term demand response is required to integrate renewable energy. However, the required demand response is not currently available in the wholesale electricity	Electricity production in Finland can cope with inflexible demand more easily as most generation is controllable. The reduction in electricity supplies from Russia is expected to be compensated by the new nuclear power plant, Olkiluoto 3. Demand response is	Inflexible demand has recently impacted Iceland, with a large share of electricity locked up in long-term PPAs, and increased energy demand from energy-intensive industries.	Dry years for hydro power are currently handled through increased electricity imports via interconnectors. Historically, reductions in demand have been necessary. Short-term variations in demand can be supplied by hydropower.	Integration of renewable energy requires a short-term demand response. The price differences across Sweden require a level of demand response to high prices that has not yet been observed. Demand is not sufficiently impacting price setting to substantially reduce electricity prices.

	market.	needed to avoid outages.			
Weather-dependent energy supply	Changing weather conditions in the form of wind and solar radiation have a high short-term impact due to the significant development of renewable energy. More focus on forecasting demand and supply will be required.	Precipitation for the hydropower plants affects the long-term operation of the system. The development of renewable energy is still at a lower comparative level than in other Nordic countries in 2022. Significant build-out of renewables is expected.	70% of total electricity generation comes from hydro power, meaning that low precipitation and glacial runoff have an impact on long-term operations.	Changes in precipitation cause changes in water inflow to the reservoirs. Foreign connections ensure supply during dry years. The system is designed to handle fluctuations in water inflow to the reservoirs.	Changed weather conditions affect both hydropower and renewable energy generation. In practice, short-term and long-term balancing challenges will have to be managed.
Increasing energy import dependency	Reductions in domestic hydrocarbon production have increased reliance on foreign supply, increasing import dependency.	Reductions in energy imports from Russia have made security of supply dependent on the commissioning of Olkiluoto 3. Electricity prices have been affected by imports from the Baltics..	No changes have been observed.	Rising oil and natural gas prices have substantially boosted revenues from hydrocarbon sales.	Higher energy prices have impacted Sweden in general. Import dependency has not changed in recent years.
Natural gas supply reductions	Biogas has been able to supply an increasing share of demand for natural gas. Furthermore, the opening of Baltic Pipe has increased the natural gas supply options. Natural gas prices have been increasing.	Finland has been impacted by its high reliance on natural gas supplies from Russia; Other gas routes can replace Russia e.g. LNG imports or the Baltic-connector.	No demand for natural gas.	Norway has benefitted from natural gas supply disruptions through higher sales volumes and prices.	Sweden is in the same situation as Denmark, as the natural gas system in Sweden is only connected via Denmark.

5.10 Responses to alleviate pressure on household finances

Corporates and retail consumers are experiencing drastic cost increases due to the crisis, which is also impacting industry profitability and highlighting potential issues around energy poverty in the retail segment. Energy poverty has historically not attracted a great deal of public attention in the Nordic countries due to the strong welfare states in these countries. Consequently, it has not been addressed through specific policy objectives in the past. However, rising prices have raised concerns among households that they will not be able to meet their financial obligations, prompting a significant reduction in energy consumption. Governments across the Nordics are adopting various approaches to respond to these concerns. An overview of these responses is presented in Table 8. Descriptions of the intended effect of the various policy initiatives are shown in Appendix 3.

RESPONSE AND INTENDED EFFECT	DENMARK	FINLAND	NORWAY	SWEDEN	ICELAND
Subsidy/ grant/cheque	Implemented	Implemented	Implemented	Implemented	Not adopted
Lower energy tariffs/taxes	Adopted not implemented yet	Adopted not implemented yet	Implemented	Not adopted	Not adopted
Incentivise energy efficiency/ technology	Implemented	Implemented	Implemented	Not adopted	Not adopted
Postponements of bills	Implemented	Not adopted	Not adopted	Not adopted	Not adopted
Information campaigns	Implemented	Implemented	Implemented	Implemented	Not adopted
Public energy savings	Implemented	Not adopted	Not adopted	Implemented	Not adopted
Tripartite negotiations	Not adopted	Not adopted	Implemented	Not adopted	Not adopted
Investment in research	Not adopted	Implemented	Not adopted	Not adopted	Not adopted

● = Implemented initiative

● = Adopted not implemented yet

● = Not adopted

Table 8: Responses to rising energy prices in Nordic countries in 2022. Data collection ceased on 30 September 2022. Updates in national policy responses may have occurred since then. No significant policy responses have been identified in Iceland.

Compared with the other European countries, the responses in Nordic countries have been less extensive in terms of monetary support, as measured as a percentage of GDP (See Figure 49). The responses in Finland and Sweden in particular have been modest compared to in some larger European economies. The same could be argued for Denmark and Norway. One reason could be that there is less need for support, as electricity prices have generally been higher in the larger European economies, e.g. France, Italy and the UK, as shown previously in Figure 26. Secondly, the composition of the energy supply mix in the various countries may also play a role. Thirdly, a general political desire to alleviate pressure on household finances also contributes in this context, though it should be borne in mind that the figure below also includes support for businesses.

Despite government intervention to provide financial help to households, European energy poverty is expected to generally increase as a result of rising energy costs. The EU's Joint Research Centre (Figure 50) predicts that the energy poverty rate in the EU will increase to 8.6% as a result of rising energy costs. At country level, changes in energy poverty rates, expressed as a percentage of the total population, will vary between 1.1% (Germany) and 41.8% (Lithuania). Following the energy crisis, energy poverty is predicted to increase to ≈2% in Finland, ≈4% in Sweden and ≈5% in Denmark, which is significantly lower than other European economies. The Nordic countries therefore appear to be more resilient to price shocks than their European neighbours.

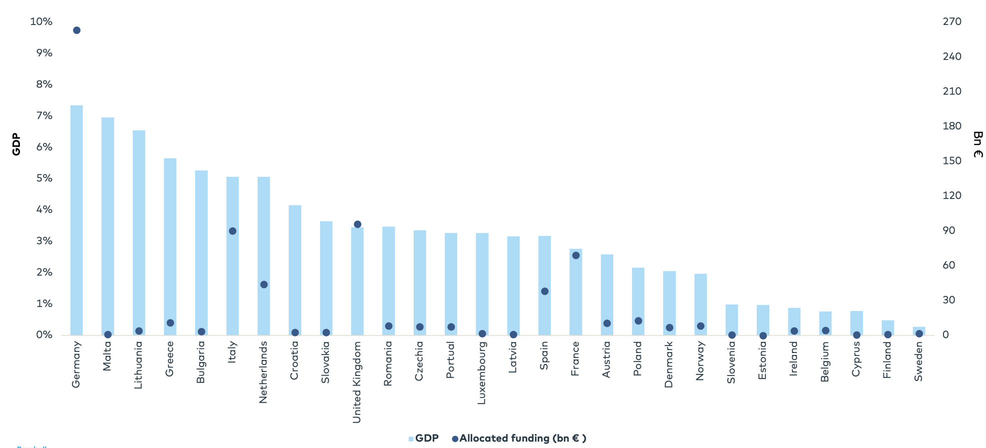


Figure 49: Governments' earmarked and allocated funding (Sep 2021–Nov 2022) to shield households and businesses from the energy crisis. (Source: Bruegel 2022). Iceland was not included in the dataset.

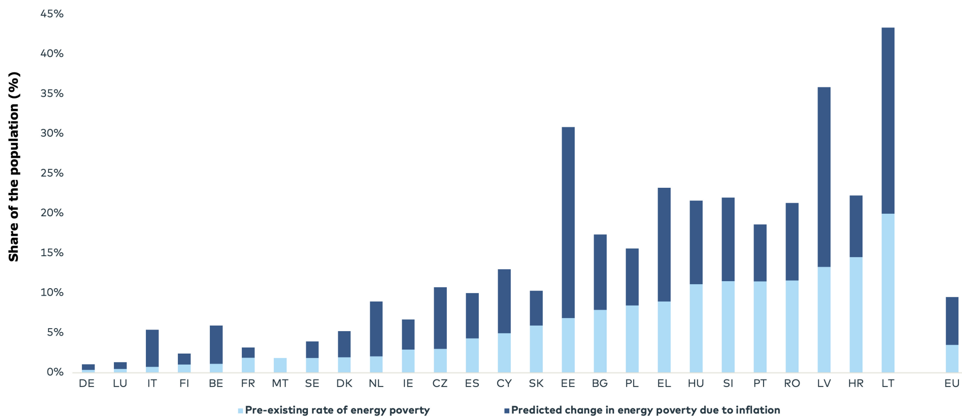


Figure 50: Predicted change (percentage of population) in energy poverty based on a fixed relative expenditure threshold. (Source: EU Commission Joint Research Centre). Norway and Iceland were not included in the dataset.

Energy poverty is generally more prevalent among lower-income groups, since price increases affect these households more as a percentage of income and spending. This can also be seen when analysing the distributional impact of energy prices on high income and low income households in 2022 (Figure 51). Once again, the Nordic countries are less affected by this general trend than other European countries. The heterogeneous distributional impact has barely been noticed in Finland and Sweden, while there is a slight difference in impact (≈1-2%) on the richest and poorest 20% of the population in Denmark. Given the general expectation of more volatile markets, and consequently prices, going forward, it is important to maintain an overview of distributional effects and apply necessary measures to avoid an increase in energy poverty. Given the general economic redistribution in Nordic welfare states, the issue of distributional effects may be less relevant for the Nordic countries. That being said, the Nordic countries do generally enjoy lower electricity prices than other European countries, making lower income groups less vulnerable to price increases since energy costs account for a lower share of their spending.

In this context, it is worth noting that Sweden and Finland both experienced a low heterogeneous impact of energy price increases and low predicted changes in energy poverty and also allocated less funding as a percentage of GDP for counteractive measures. In contrast, Denmark has been hit slightly harder. Therefore, while there has been an increase in the cost of living and energy poverty, the crisis has not impacted Nordic households to the same extent as in other European countries.

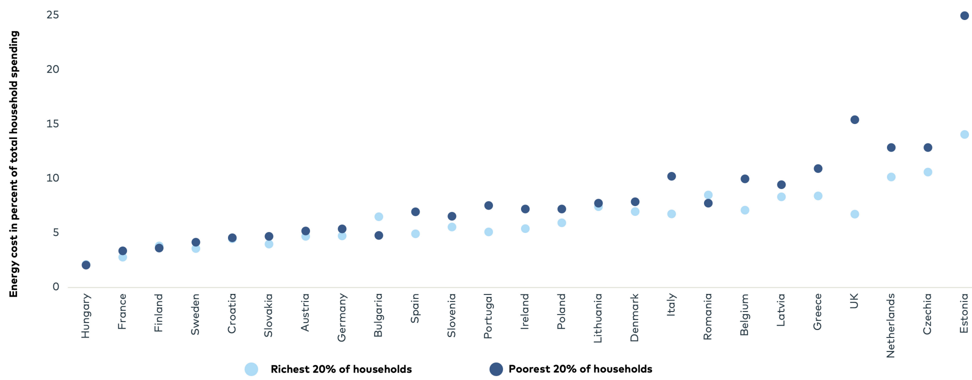


Figure 51: Energy cost as a percentage of total household spending. (Source: IMF). Norway and Iceland were not included in the dataset.

6. RISK SCREENING

This section includes a risk screening of the Nordic electricity market, with the aim of investigating, identifying and evaluating key risk factors for the energy transition in the form of potential supply chain issues and price shocks going forward. The risks have been identified through literature screening and interviews with key stakeholders in the energy market.

Risks are mapped and ranked in terms of their impact on security of supply and the likelihood that they will materialise. This enabled the creation of a risk matrix to obtain an overview of the high-, medium- and low-risk factors affecting the Nordic electricity supply. As already mentioned, delimitations, geopolitical movements potentially leading to sabotage etc. and cybersecurity concerns are not considered in the scope of this report. These risk categories have a relatively low likelihood of materialising, but could have disastrous consequences for security of supply if they did, indicating that these risks – and similar risk factors - should be thoroughly analysed in a separate report. The identified high-risk factors are described applying the analysis structure highlighted in Figure 52. Medium- and low-risk factors are described in Appendix 2. The impact scoring on security of supply (SoS) and likelihood, as well as the evaluation of negative impacts on affordability and sustainability, have been subject to the quality validation process described in Section 3. However, this remains a qualitative assessment. The risks are categorised into three subcategories: Energy, Social and Governance.

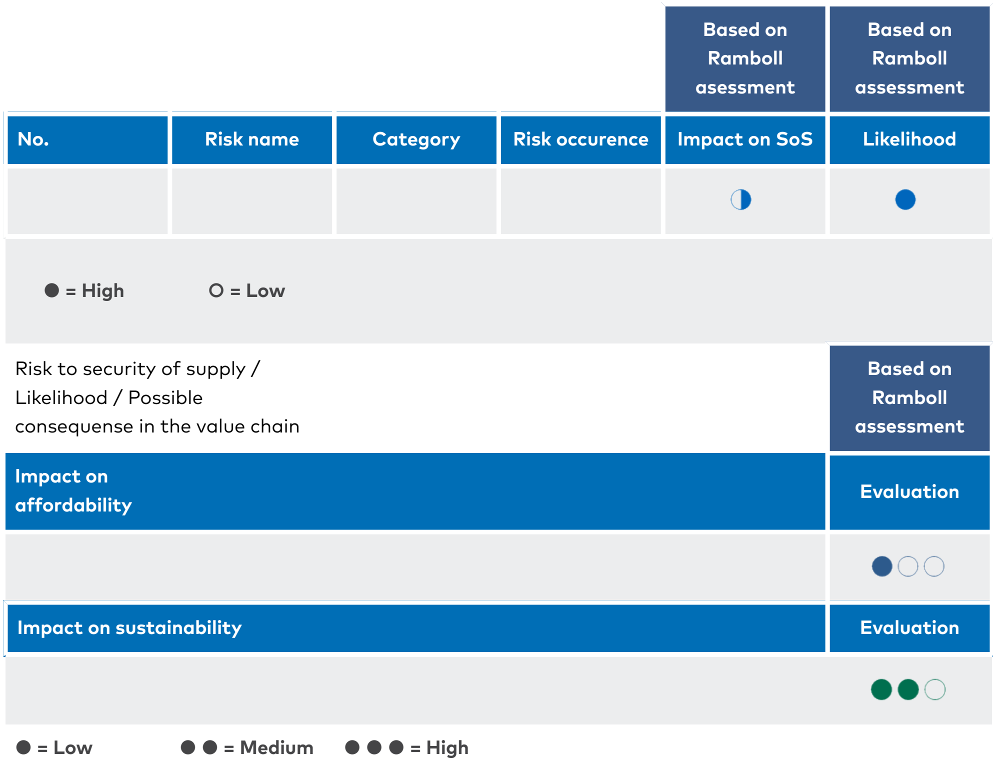


Figure 52: Risk analysis template

The risk screening identified ten high-risk factors, nine medium and three low-risk factors. Four high-risk factors relate to governance issues, three to energy and three to social issues. Of the top five high-risk factors, three relate to governance issues, namely: approval processes for infrastructure projects, market design in terms of ensuring the required capacity at low and stable prices, and country dependence in terms of concentration of where materials and fuels are sourced from to avoid external security of supply concerns. Public acceptance of infrastructure and electricity grid infrastructure is also in the top 5. The results are presented in Figure 53 and Table 8. Each of the top-ten high risk factors are described in further detail in this section. The remaining 12 identified risk factors are briefly outlined in Appendix 2.

Based on identified high-risk factors, Section 7 maps the mitigation measures proposed or discussed in connection with policymaking at respectively EU and national level, and conducts a gap analysis to inform policy recommendations.

NO.	RISK NAME	CATEGORY	OCCURENCE
1	Long approval processes	Governance	Short-term
2	Modest public infrastructure acceptance	Social	Short-term
3	Inadequate electricity market design	Governance	Short-term
4	High mineral and fossil energy supply dependencies	Governance	Medium-term
5	Lack of electric grid infrastructure	Energy	Short-term
6	Absence of sustainable long-term energy storage	Energy	Medium-term
7	Unchanged consumer behaviour	Social	Short-term
8	Increased weather dependence	Energy	Short-term
9	Insufficient energy crisis management	Governance	Short-term
10	Labour shortage	Social	Medium-term
11	GHG goals opposition	Social	Medium-term
12	Material intensity	Energy	Medium-term
13	Decreased collaboration	Governance	Short-term
14	Climate tunnel vision	Energy	Short-term
15	Climate adaptation	Energy	Long-term
16	Electrification	Energy	Long-term
17	Delayed transition	Energy	Medium-term
18	Corporate trading partners	Governance	Medium-term
19	Inertia	Energy	Long-term
20	Energy company default	Governance	Short-term
21	Energy affordability (retail)	Social	Short-term
22	Enegry affordability (corporate)	Social	Short-term

Table 9: Natural gas demand, 2022 vs. 2019–2021 average. (Source: Bruegel based on ENTSO-E and Ember data).

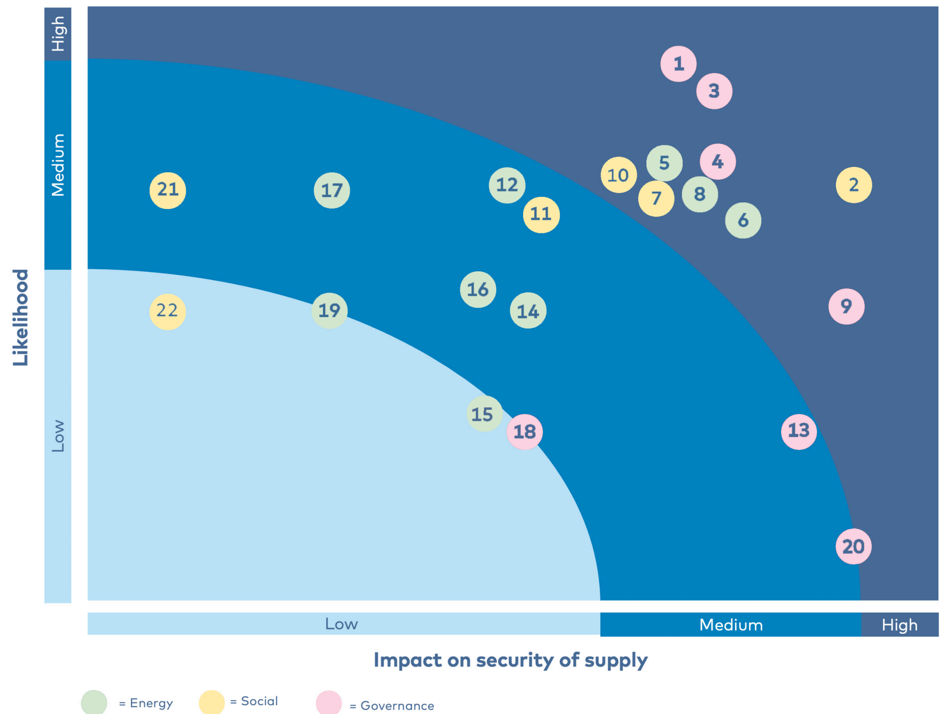


Figure 53: Risk analysis (assessment-based)

6.1 Long approval processes

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
1	Long approval processes	Governance	Long-term	◕	●
● = High	○ = Low				

Risk to security of supply

Extensive and long approval processes account for a significant part of the approximately 10-year lead times for infrastructure and energy generation projects (the Baltic Pipe was commissioned six years after the feasibility study). In particular for land-based generation and infrastructure, the challenge in obtaining approval for a project remains an issue. While there is a reason for the long approval processes, e.g., the need for public involvement and environmental impact assessments, in practice the long approval processes can hinder society's ability to build out renewable energy generation capacity together with the required electric grid infrastructure. This in turn limits society's opportunities to increase security of supply and energy independence in the long run.

Likelihood

The likelihood of continued long approval processes is significant, primarily due to requirements for environmental impact assessments and public involvement in the process despite public debate and awareness around the topic. For example, the selected EU countries have four times more wind capacity awaiting permits than under construction (with significant planned capacity, for which a permitting process has not yet started). This is shown in Figure 54.

Potential impact on the value chain

Long approval processes can inhibit society's ability to build enough renewable generation and electric grid infrastructure to transmit energy from the generation site to load centres to enable consumers to use the energy where needed. Considering the significant requirements for electrification associated with the green energy transition and the desire for energy independence, continued long approval processes could compromise the ability of the Nordic societies to meet these challenges.

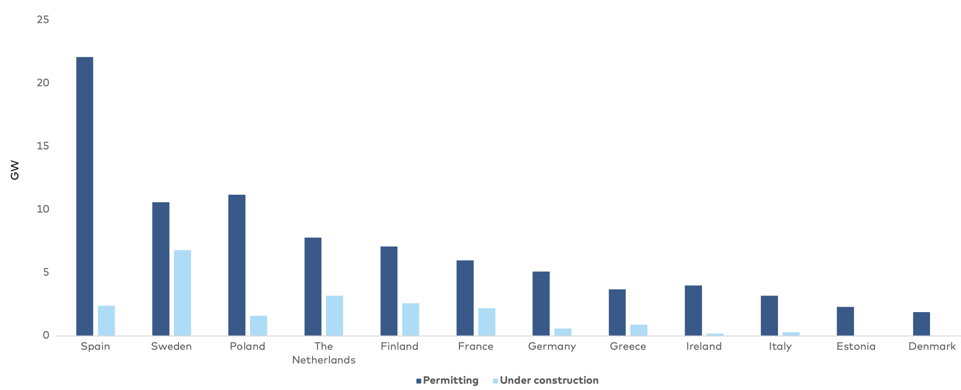


Figure 54: Wind pipeline for selected EU countries, broken down by development stage (GW). (Source: Eurelectric Power Barometer, 2022).

IMPCAT ON AFFORDABILITY	EVALUATION
Long permitting processes reduce the effectiveness of price signals in energy markets, resulting in both unnecessarily high prices for consumers and inefficient market functions. Consequently, consumers pay a price premium due to bottlenecks in the transmission system. Electric grid infrastructure cannot be built quickly enough to respond to the expected increase in demand and construction of renewable energy. High bottleneck revenues (price differences between zones) in the wholesale market signal the need for additional transmission capacity. However, while approval processes drag on, the price mechanism does not deliver the desired effect. Consumers are exposed to high electricity prices as a result of long approval processes. Eventually, the build-out of renewable energy either must slow down, or production is curtailed as sufficient electric grid infrastructure is not available. Long approval processes affect electricity prices, consumers and security of supply, and slow down the green energy transition.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
Long approval processes challenge the pace of the green energy transition due to the lack of renewable generation and electric grid infrastructure. Fossil-based generation is then required to supply demand and balance the electricity system.	●●●

● = Low ●● = Medium ●●● = High

6.2 Modest public infrastructure acceptance

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
2	Modest public infrastructure acceptance	Engergy	Short-term	●	◕

● = High   O = Low

Risk to security of supply

Public opposition to the construction of new energy infrastructure is not a new phenomenon – wind turbines, nuclear power plants, transmission lines, CO2 storage, etc have all met with public opposition in the past. Resistance to energy infrastructure in citizens' backyards is very high – and arguably often with good reason. A desire to prioritise biodiversity over new renewable generation and electric infrastructure is also an emerging topic. Opposition from the public and NGOs has provided to be a significant challenge that could lead to delayed or cancelled projects.

Likelihood

The Nordic countries have historically focused on developing effective and sustainable sources of energy, an approach that is also broadly supported by the general public. However, when it comes to implementing new wind farms and electric transmission projects, public opposition can either delay or prevent the project from being executed. A report from the Nordic Council of Ministers concludes that a lack of public acceptance could slow down or even block the expansion of renewable energy and energy infrastructure.

Potential impact on the value chain

The risk may impact the whole energy value chain depending on the strength of public opposition to the installation of the infrastructure. Moreover, the problem is likely to get worse over time as renewable energy generation and additional electric grid infrastructure become more visible in the landscape. Renewable energy sources require more land per energy produced than traditional types of energy production.

IMPCAT ON AFFORDABILITY	EVALUATION
If energy projects are either delayed or blocked completely, this will affect the prices of energy since it will not be possible to meet demand. Given the expected electrification of society, public opposition could significantly impact security of supply.	●●●

IMPACT ON SUSTAINABILITY	EVALUATION
If sustainable energy projects are either delayed or blocked completely, this will affect sustainable energy production and the green energy transition.	●●●

● = Low ●● = Medium ●●● = High

6.3 Inadequate electricity market design

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
3	Inadequate electricity market design	Governance	Short-term	◕	●

● = High O = Low

Risk to security of supply

Failures in electricity markets are particularly important because electricity is perceived as a public good. In addition, environmental costs of production are high, information is imperfect due to the high complexity of the electricity system and economics of scale put up a barrier for new market entrants. Trading electricity on a market platform in the same way as any other commodity rather than as a public good diminishes security of supply.

Leaving market players to develop future energy technologies within uncertain political framework conditions has a cost for society. Market players want lower risks and certainty when it comes to visions for society. Uncertainty relating to subsidies, preferred infrastructure and public funding increase the market risk and shorten the long-term planning perspective. A framework where externality costs are known, and development plans and assumptions are discussed as part of a long-term planning process is required to keep costs down and reach society's goals of decarbonisation. Information on the long-term electricity system and market development are necessary. Short-sightedness in electricity system planning and decision-making processes comes at a high cost for consumers and security of supply.

Likelihood

The Nordic countries' electricity market has generally functioned well, facilitating substantial price increases in 2022. However, the market structure will require a radical overhaul to accommodate the new renewable energy future and to balance the dimensions of the Energy Trilemma. An inadequate focus on balancing power and capacity requirements in energy-only markets impacts security of supply. Continuing with the current market structure poses a risk of not only energy shortages but also an inability to integrate renewable energy.

Potential impact on the value chain

Market players experience risks, which in turn causes uncertainty in the market. Uncertain politically determined framework conditions affect the operation of the market. Reduced controllable electric capacity in the market can cause load-shedding and increased prices for consumers. The existing market regulation must be developed to accommodate a renewable energy system where other commodities and services are relevant.

IMPCAT ON AFFORDABILITY	EVALUATION
As seen during the electricity crisis, prices could continue at very high-levels, impacting affordability for consumers, and resulting in continuing volatility in price-setting. In the worst-case scenario people will not be able to pay their bills. Societal costs are expected.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
If the market structure is not aligned with the needs of a renewable energy system, we could find ourselves in a situation where we cannot utilise the renewable energy produced, reducing the intended sustainability of renewable energy projects.	●●○

● = Low ●● = Medium ●●● = High

6.4 High mineral and energy supply dependencies

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
4	High mineral and fossil energy supply dependencies	Governance	Medium-term	◕	◕

● = High ○ = Low

Risk to security of supply

The Nordic countries depend on a small number of countries for the extraction and processing of metals and minerals required to build renewable energy generation. Production of many green energy transition minerals is more geographically concentrated than for oil and natural gas (Figure 55). With respect to processing, many important metals are processed in China, potentially making supplies vulnerable to shocks, e.g. trade restrictions, COVID lockdowns or other factors.

When it comes to the sourcing of fossil fuel products, there is not such a substantial dependency on imports to the Nordic region. This is mainly due to the production of hydrocarbons in Norway. The other Nordic countries, except to some degree Denmark, need to import fossil-fuels from other countries.

Likelihood

Given the current reliance on the import of the metals and minerals required for the green energy transition, the likelihood of mineral dependencies is classified as high. Due to the ongoing focus on accelerating the green energy transition, the lack of minerals could be a problem in the medium-term due to the fact that supply chains are not sufficiently mature for an accelerated green energy transition. Import dependencies for energy are also a cause for concern. The reduction in Russian energy exports to Europe highlight the vulnerability of overreliance on one country for energy supplies. Similar situations could be envisaged in the future and have occurred in the past.

Potential consequences for the value chain

Mineral and energy supply dependencies could compromise society's ability to deliver the green energy transition at a sufficient pace, while creating security of supply issues for fossil fuels in the event of supply disruptions. This would mainly impact the consumer through high prices, as generation capacities will naturally decrease.

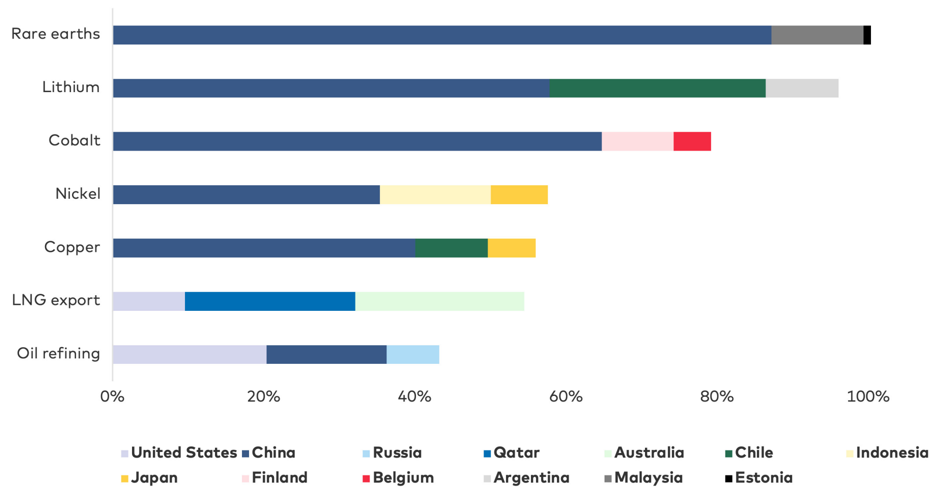


Figure 55: Top three countries' share of processing of selected minerals and fossil fuels, 2019. (Source: IEA).

IMPCAT ON AFFORDABILITY	EVALUATION
Dependence on a limited number of countries for supplies of fossil fuels and clean energy metals and minerals could, in the event of supply disruptions, significantly increase the cost of energy as well as the cost of the green energy transition. The materials required to build the necessary renewable energy generation capacity could also increase the cost of the green energy transition. Reliance on a few countries could cause a market situation where certain product prices are manipulatively high.	●○○
IMPACT ON SUSTAINABILITY	**EVALUATION**
Potential supply disruption of the metals and minerals needed to build renewable energy generation could delay the green energy transition by extending the lifetime of existing fossil-based capacity.	●●○
● = Low ●● = Medium ●●● = High	

6.5 Lack of electric grid infrastructure

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
5	Lack of electric grid infrastructure	Energy	Short-term	◕	◕
● = High	● = Low				

Risk to security of supply

Underinvestment in the electric grid infrastructure – both at transmission and distribution level – required for the green energy transition and electrification of society could reduce developers' willingness to invest in new renewable energy generation, for example, due to issues with grid connectivity, congestion or higher tariff levels on the producer side.

Development of the electric transmission infrastructure in the Nordic countries is needed to be able to respond to changed power flows due to different types of supply and demand patterns. New interconnectors to Europe also have an impact. The ability to balance uneven supply and demand patterns remains important tin order to ensure system stability and security of supply.

Likelihood

The likelihood of underinvestment in electric transmission infrastructure is assessed as high, given the requirements for the build-out of the infrastructure for the electrification and the green energy transition. In addition, future power flows are likely to be different. This will necessitate reorganisation of the transmission infrastructure, something that up to now has not proved successful. Nonetheless, TSOs are continuously highlighting the need for additional infrastructure and the measures that are being taken to endeavour to mitigate this risk. Distribution systems also need to be developed, because renewables have traditionally been connected at low-voltage levels. Bottlenecks in local electric distribution systems are also to be expected.

Potential impact on the value chain

Appropriate electric grid infrastructure is the cornerstone of a well-functioning system and electricity market. Because of this, transmission problems caused by a lack of electric infrastructure impact the full value chain.

IMPCAT ON AFFORDABILITY	EVALUATION
The electric grid infrastructure's inability to respond to congestion and integrate a large share of renewables could create price differentials between bidding zones and potentially lead to significant price variances between electricity market zones.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
Electric grid infrastructure is essential for ensuring a green energy supply. The negative impact of any inability to integrate renewable energy due to the failure to develop existing infrastructure and invest in new infrastructure is substantial.	●●○
● = Low ●● = Medium ●●● = High	

6.6 Absence of sustainable long-term energy storage

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
6	Absence of sustainable long-term energy storage	Energy	Long-term	◔	◔
● = High O = Low					

Risk to security of supply

Maintaining sufficient capacity in large gas caverns and fuel stockpiles at power plant sites has traditionally played a key role in ensuring security of supply during the winter season. In this connection, the EU requirement for countries to ensure that gas cavern storage facilities are 80% full before winter 2022/2023 has played an important role in maintaining security of supply. Using coal and oil-based power plants could be one way of maintaining security of supply during coming winters. Nonetheless, it remains important to further develop existing strategic reserves within other primary energy sources, e.g., hydro or biomass, to guarantee security of supply. Long-term storage of methanol, ethanol or ammonia could also contribute in this context.

Likelihood

The likelihood of insufficient long-term energy storage is high, given the reliance on a scarce global market for LNG and the inability to source natural gas from Russia. Moreover, it is not expected to be possible to rely on PtX for long-term storage of energy in the short and medium term, impacting the likelihood of sustainable energy storage in the future. Sector coupling and use of district heating networks could be an option for energy storage in the medium to long term.

Potential impact on the value chain

The potential absence of sustainable long-term energy storage as a means of supplying electricity during the winter, when renewable generation is less effective, impacts overall security of supply and the associated prices consumers pay.

IMPCAT ON AFFORDABILITY	EVALUATION
Maintaining appropriate capacity in strategic reserves across feedstocks is an important means of maintaining stable energy prices during the winter season. In periods of high import prices for LNG, it could be worth exploring oil- or coal-based storage from an affordability perspective. Moreover, due to the expected significant cost of utilising PtX solutions for long-term energy storage, continued use of fossil-based primary energy could also be beneficial from a cost perspective.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
There is currently a significant technological gap in terms of storing large volumes of renewable energy for longer periods, e.g., through PtX (sector coupling could be one alternative). This in turn could slow the pace of the green energy transition due to the fact that fossil-based primary energy is needed to ensure security of supply. Extending the lifetimes of fossil-fuel plants is a likely outcome here.	●●●
● = Low ●● = Medium ●●● = High	

6.7 Unchanged consumer behaviour

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
7	Unchanged consumer behaviour	Social	Short-term	◕	◕
● = High	○ = Low				

Risk to security of supply

General high demand for energy and periods of peak demand during the day (e.g., in the morning and early evening) constitute a high risk for the security of the energy supply. This risk may lead to planned load-shedding. Consumers in the Nordic countries are generally accustomed to high energy consumption due to generally low energy prices, as access to affordable energy is considered a public good (access to essential services is ensured by universal social welfare services).

Likelihood

Energy demand is generally inelastic, making the likelihood of unchanged consumer behaviour high. In particular among retail consumers in the Nordics, electricity is perceived as a public good, decreasing the desire for change, in this case reducing energy consumption. While there have been significant demand reductions for natural gas (Table 9), 90% of consumers are still willing to pay the maximum price for electricity in the wholesale market (Figure 39).

Potential impact on the value chain

Consumer behaviour and the propensity to exercise demand response mainly impact other consumers' ability to source energy when required.

	DENMARK	FINLAND	SWEDEN
Decrease	18%	51%	17%

Table 9: Natural gas demand, 2022 vs. 2019–2021 average. (Source: Bruegel based on ENTSO-E and Ember data).

IMPCAT ON AFFORDABILITY	EVALUATION
Continued inelastic consumer behaviour across society drives up prices significantly, potentially leading to energy poverty among some income groups. At the same time, higher general energy and peak demand prices impact the competitiveness of businesses. Furthermore, when considering the distributional effects of rising electricity prices, where cost-of-living increases have a greater impact on lower income households, this could have implications for the just transition. In Denmark and Sweden the increase in the cost of living has had a greater impact on lower-income than high-income households, while both groups have been more or less equally affected in Finland.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
Inelastic consumer demand, in combination with the increasing electrification of society (heating, transport etc.), requires a significant build-out of renewable energy.	●●○
● = Low ●● = Medium ●●● = High	

6.8 Increased weather dependence

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
8	Unchanged consumer behaviour	Social	Short-term	◕	◕
● = High	O = Low				

Risk to security of supply

The energy system is reliant on multiple weather-dependent energy sources for generation. Therefore, when changing weather conditions result in limited availability of multiple energy sources simultaneously, as discussed above and as seen in 2022, the system will have scarce resources to generate the energy required to supply demand. Especially when there is a scarce supply of dispatchable energy resources (fossil-based resources, nuclear and hydro), supplying peak demand remains a significant issue. In the event of insufficient precipitation in the Baltic Sea region, adequacy risks emerge in southern Sweden, southern Norway and east Denmark. In a low nuclear scenario, adequacy risks substantially increase in southern Sweden and in Finland, which will be reliant on electricity imports.

Likelihood

The likelihood of limited availability of multiple energy sources simultaneously is assessed to be high. This is mainly due to the recently experienced situation when limited Nordic hydro resources production, low levels of natural gas and LNG supplies and low levels of production from nuclear power plants in central Europe due to high temperatures all occurred at the same time. A focus on increasing energy independence through the build-out of renewables could perhaps reduce the likelihood in the long term. On the other hand, the increasingly volatile weather conditions expected in future as a result of climate change will impact weather-dependent generation.

Potential impact on the value chain

The consequence of limited availability of multiple energy portfolios is a significant scarcity of generation capacity, potentially impacting the ability of society to meet electricity demand.

IMPCAT ON AFFORDABILITY	EVALUATION
Scarcity of energy resources will significantly increase energy prices for consumers – in practice, raising concerns about energy poverty and job creation across society.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
Potential limited availability of renewable energy generation could increase public acceptance of the use of fossil-based primary energy resources, delaying the green energy transition.	●●○

● = Low ●● = Medium ●●● = High

6.9 Inadequate energy crisis management

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
9	Inadequate energy crisis management	Governance	Short-term	●	◑
● = High	○ = Low				

Risk to security of supply

In an increasingly interconnected and interdependent energy system where generation is contingent on weather conditions, coordinated and well-managed energy planning plays a pivotal role in maintaining security of supply. This makes it vital not to make hasty decisions in a crisis with potentially far-reaching consequences for the energy market, e.g., relating to market design or an increase in electricity demand (district heating, electrification etc.) before renewable capacity is in place. The interventions currently set in motion have been relatively cautious, as depicted by the ACER methodology in Figure 56.

Given the current high degree of coordination, the likelihood is classified as medium. Energy planning is currently coordinated at Nordic and European level through e.g., the Nordic Regional Coordination Centre, ENTSO-E, EU institutions, etc. Continuous knowledge-sharing through these organisations enables collaboration across public stakeholders, which materialises in shared development plans and scenarios. The risk of uncoordinated planning and decision-making in a crisis makes this risk particularly relevant. WindEurope reports that inflationary cost pressures, slow permitting processes and uncertainty around the EU's emergency electricity market interventions are stalling orders for new wind turbines (Q3 wind turbines orders fell by 36% in 2022 compared to 2021). These risks must be addressed.

Potential impact on the value chain

The consequence of inadequate energy crisis management that fails to consider the system-wide effects of initiatives at Nordic and EU level could impact the entire electricity value chain, e.g. if impacts of a redesign of the market structure are not carefully analysed.

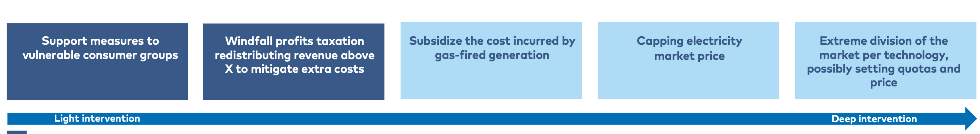


Figure 56: Spectrum of potential structural intervention measures for the EU electricity market (non-exhaustive). (Source: ACER).

IMPCAT ON AFFORDABILITY	EVALUATION
Crisis management and the risk of hasty decision-making directly impact price setting, job creation/jobs required for the green energy transition and public acceptance of infrastructure. This could potentially lead to a more acute crisis going forward with negative implications for all affordability-related issues.	●●●
IMPACT ON SUSTAINABILITY	**EVALUATION**
Uncoordinated crisis management measures could potentially delay the green energy transition by decreasing investments in transmission and generation infrastructure, particularly given the expected increased volatility of electricity prices.	●●○

● = Low ●● = Medium ●●● = High

6.10 Labour shortages

NO.	RISK NAME	CATEGORY	RISK OCCURENCE	IMPACT ON SOS	LIKELIHOOD
10	Labour shortages	Social	Medium-term	◐	●

● = High ● = Low

Risk to security of supply

The green energy transition requires an appropriately and sufficiently skilled workforce. Moreover, skilled labour is also needed to optimise and strengthen the infrastructure required to develop a renewable energy system. Skilled workers play a key role in ensuring security of supply, and appropriate human resources will be required to boost energy independence.

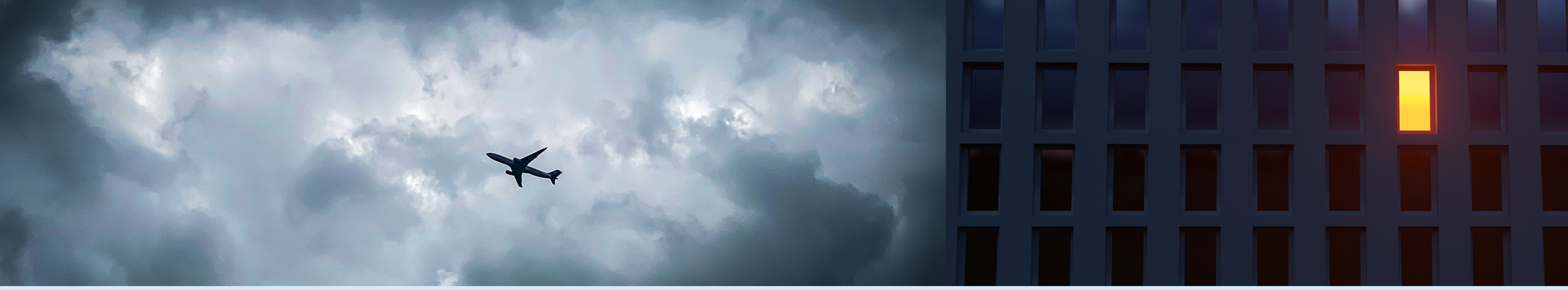
Likelihood

A lack of skilled labour has already contributed to supply chain disruptions and project delays in the energy sector, making it highly likely that this risk will materialise in future. The IEA estimates that the energy sector requires more higher-skilled workers than other industries due to the extensive degree of research and innovation in the sector. The number of new positions in energy is expected to more than compensate for the loss of fossil fuel jobs. It is estimated that 14 million new clean energy jobs will be created worldwide by 2030 and that 16 million workers will shift to new roles relating to the green energy transition. Some 60% of these new jobs will require some degree of post-secondary training. Finally, experts report that there is already a shortage of skilled workers, and that this, in combination with general pressure on employment markets, will present further challenges for investments in renewables.

Potential impact on the value chain

Labour shortages in the energy sector have consequences throughout the value chain as they prevent assets from being developed and maintained. In practice, this makes labour shortages a system risk.

IMPCAT ON AFFORDABILITY	EVALUATION
Inadequately skilled workers in the energy sector will impact opportunities to build affordable energy projects. In the long run, this will affect consumers' access to affordable energy due to the fact that the supply of energy will not increase.	●○○
IMPACT ON SUSTAINABILITY	**EVALUATION**
A lack of skilled workers in the energy sector will impact opportunities to execute the investments required to accelerate the green energy transition. This encompasses research in renewable energy and innovation, as well as the installation of wind turbines, solar panels and PtX technologies.	●●●
● = Low ●● = Medium ●●● = High	



7. MITIGATION MEASURES AND GAP ANALYSES

In this section, mitigation measures are mapped against the high-risk factors identified and described in the previous section in order to evaluate whether existing mitigation measures addressing the identified high-risk factors can be applied to increase security of supply. To this end, a gap-fit assessment was also performed to determine whether the mitigation measures were an effective response to the current energy crisis. The focus was thus to identify mitigation measures at respectively national, Nordic and EU level that have been applied during the current energy crisis.

The presented mitigation measures and associated case examples may not be the optimal options to implement in all the Nordic countries, but are rather intended to provide examples of mitigation measures and cases that have been discussed and applied by policymakers. The examples were specifically chosen to assess how well the Nordic energy market is equipped to ensure supply security going forward. Mitigation measures were categorised to evaluate their assumed effect in the time horizon as well as whether the initiatives have had a tangible and documented impact.

The process of identifying mitigation measures to respond to high-risk factors is shown in Figure 57. Not all mitigation measures are equally relevant for all countries. Nonetheless, the list can be used as a source of inspiration at country level for ways of responding to risks and drivers based on the country assessment in Table 7. The mapping of mitigation measures and associated gap analyses are a qualitative assessment that has been subject to the validation process described in Section 3.

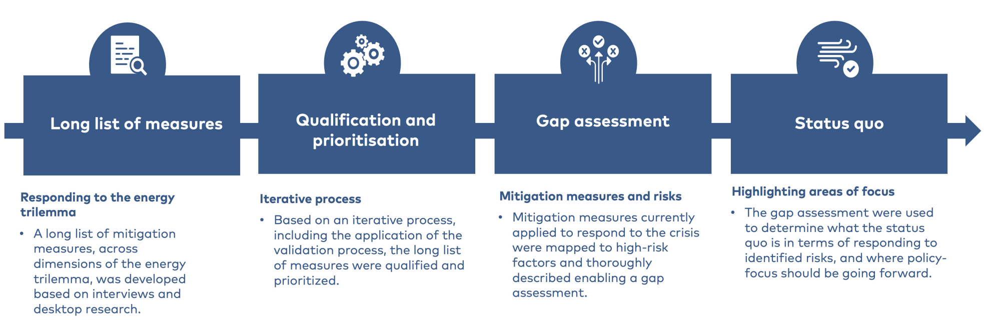


Figure 57: Process for identifying mitigation measures and gap analyses.

The review of the mitigation measures and gap analyses reveals that there are significant gaps associated with one risk ("gap exists"), that gaps are partially addressed ("gap remains") for eight risks and that gaps are fully addressed for one risk ("no gap"). A summary of the gap analysis is presented below in Table 10.

Based on the mitigation measures and gap analyses, this report provides policy recommendations that can inform decision-making to ensure security of supply while taking account of affordability and sustainability considerations in energy systems. Recommendations, which are made at national, Nordic and international (EU) level, can be found in Section 8.

RISK	MEASURE	DOCU-MENTED IMPACT	DO THE MEASURES ADEQUATELY AND EFFICIENTLY MITIGATE IDENTIFIED RISK?	GAP ANALYSIS
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation	
Long approval processes	Accelerated permitting for electricity generation and grid infrastructure	?	Measures designed to facilitate faster permitting are in the regulatory pipeline; however, given the implementation timeline for PCI projects and experiences from Denmark regarding a one-stop-shop, it is questionable whether initiatives will have the desired effect. Moreover, there is a need for structural measures to address permitting procedures for electric grid infrastructure in general, and not just by providing access to PCI and additional financing. There is still a gap with regard to addressing the risk of slow approval processes.	GAP REMAINS
Modest public infrastructure acceptance	Public inclusion in energy infrastructure	↑	Various measures exist and are, to some extent, being applied to help mitigate risks associated with infrastructure acceptance. Nonetheless, these risks do not currently appear to be being managed systematically and adequately, as public opposition to grid infrastructure and electricity generation assets is still being encountered. The identified measures are not certain to mitigate the identified risks.	GAP REMAINS
Inadequate electricity market design	Analyse adaptation measures for design of the electricity market	?	It is not proposed that the listed measures be implemented without a thorough examination of the required changes to the Nordic electricity market structure. A discussion and examination of the societal value and price for security of supply must be initiated. A gap remains when it comes to measures to design a electricity market that is fit to meet societal needs in terms of price stability, security of supply and sustainability.	GAP REMAINS
High mineral and fossil energy supply dependencies	Strategic sourcing of metals	?	Identified mitigation measures relating to metal supply dependencies do not mitigate identified risks. In the short term, there is a need to develop a long-term strategy at Nordic and EU level for sourcing the metals and minerals required for the green energy transition. With the Critical Raw Materials Act, such a process has been started. In the long term, the option to grow national mining industries in Sweden, Norway and Finland should be further explored.	GAP EXISTS
High mineral and fossil energy supply dependencies*	Strategic sourcing of fuels	?	Measures have been efficiently implemented but are not adequate to address the potential gap in the short term. Further long-term diversification is likely necessary. In the short term, the EU has applied various measures to safeguard natural gas supplies through increased sourcing of LNG to replace pipeline gas from Russia and to top up strategic reserves. Even so, there is a residual risk of a 30 bcm shortfall of natural gas next winter at EU level. In the medium term, the energy partnership between the EU and Norway would appear to have been strengthened, but there is a general need to diversify supply partners to reduce vulnerabilities to supply disruptions.	GAP REMAINS
Lack of electric grid infrastructure	Electric grid infrastructure	↑	Measures to mitigate the risk of underinvestment in electric grid infrastructure are required. The level of integrated grid planning at regional and international level must be increased. Access to public planning assumptions may be an option. Such a development is contingent on accelerating permitting processes, public inclusion in	GAP REMAINS

			infrastructure projects, etc., as discussed. In essence, a gap remains that needs to be addressed despite a number of initiatives already being in place.	
Absence of sustainable long-term energy storage	Energy infrastructure integration	↑	Measures to develop the required energy infrastructure are important. The varying nature of the Nordic countries means that there is no one-size-fits-all solution. However, general requirements for energy storage levels could be a relevant measure. Developing energy infrastructure for energy vectors other than electricity (molecule network and storage) will also be necessary to ensure renewable energy integration and security of supply. In essence, a gap remains.	GAP REMAINS
Unchanged consumer behaviour	Information campaigns and digital applications	→	Since it is difficult to radically change the general public's energy consumption, and given that energy-saving campaigns, digital applications and addressing consumption in public buildings are generally being considered in all the Nordic countries, this risk is assessed to be adequately addressed. Further evaluation of the impact of initiatives is required.	NO GAP
Increased weather dependence	Energy generation diversification	↑	The Nordic countries have addressed the need to diversify generation capacity in the short term (extending fossil-based generation). In the medium term, strategies have been applied and considered to include additional feedstocks for electricity generation, e.g., biogas and adding additional nuclear capacity to the grid. In the long term, coupling through other energy vectors could be an option. Long-term storage of energy, nonetheless, remains an issue. In essence, while measures exist to address the weather-dependency of renewable energy generation capacity, the identified measures do not adequately and efficiently address the needs for diversification of capacity and the steps society needs to take to engage in long-term storage of energy. A gap remains.	GAP REMAINS
Insufficient energy crisis management	Energy crisis management	→	While appropriate stakeholders will be consulted, there is always a risk associated with making large-scale changes to an existing system. Due to the market response to uncertainties around appropriate and effective crisis management, it is concluded that the existing measures only partially address identified risks.	GAP REMAINS
Labour shortage	Tripartite negotiations	→	Given the substantial need for labour to support the green energy transition, this risk is not appropriately addressed. The need for labour support requires a broader strategic plan addressing how to tackle the lack of skilled workers. Solutions include increasing energy-related education and more national planning on needed availability (skills and volume). However, tools (e.g., tripartite negotiations) are available to expand the labour supply and should be applied, supplemented by additional measures. Personnel from other sectors or countries may be engaged.	GAP EXISTS

*Separate mitigation measures are applied for the "high mineral and fossil energy supply dependencies". The risk is addressed collectively as it relates to both dependencies.

Table 10: Mitigation measures and gap analyses.

7.1 Accelerated permitting for electricity generation and grid infrastructure

RISK: LONG APPROVAL PROCESSES			GAP REMAINS
MEASURE	IMPLEMENTATION STAGE	EFFECT TIME HORIZON	DOCUMENTED IMPACT
Accelerated permitting for electricity generation and grid infrastructure	Proposed	Medium-term	→
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

The following is a structural measure proposing a more effective approval process to accelerate the green energy transition – relating to new electricity generation and grid infrastructure.

The EU Commission has commissioned a study on how to tackle slow and complex permitting processes for renewable energy projects (the final recommendations are expected in April 2023), and introduced an amendment to the Renewable Energy Directive, which proposes shortening the maximum permitting time to two years from when the first permit application is submitted. In addition, dedicated 'go-to' areas for renewables are proposed to provide a shortened and simplified permitting process in areas with lower environmental risks. In these areas, projects will need to be permitted within one year. If implemented, this would involve significant changes to the existing approval processes. An important measure is nonetheless to ensure that measures relating to approval processes are technology-neutral with regard to renewable energy. Given local conditions, appropriate national flexibility also needs to be included in the legislation. To ensure that the legislation is changed appropriately, regulatory changes must be properly considered and cannot be implemented overnight.

As discussed throughout the report, there is a need to develop the electric grid infrastructure to accommodate a future with more renewable energy production. A structural measure to address permitting for electricity grid projects is required. The updated version of the Trans-European Networks for Energy (TEN-E) regulation adopted in June 2022, is the EU Commissions' response to this challenge. The TEN-E regulation establishes 11 priority corridors for transmission infrastructure relating to electricity, offshore grids, and hydrogen infrastructure, addressing the need for transmission of electricity onshore and offshore. Infrastructure projects can be accepted under the Projects of Common Interest (PCI) framework, enabling projects to receive permitting faster and obtain financial assistance from the EU. Designation as a PCI ensures that projects are treated in the fastest way possible, limiting the permitting procedure to 3.5 years.

Case examples

The EU's interim report on tackling slow and complex permitting relating to electricity generation assets concludes that administration could be streamlined through digitisation measures that establish clear roles and responsibilities, supported by a one-stop-shop that manages the approval process across agencies. A similar arrangement can be envisaged for grid infrastructure projects. The Danish Energy Agency facilitates such a one-stop-shop and acts as a point of contact for seven other authorities. Nonetheless, the approval process remains significant, resulting in 9–11-year project development timelines for offshore wind. With such a constraint on project development time, planned renewable energy projects will not be finalised before the next decade, despite a one-stop-shop being in place to facilitate a smooth process.

While the TEN-E regulation could accelerate permitting for selected transmission cables, opening a few trans-European energy corridors does not solve the overarching problem in the Nordic or European countries. The measure could induce more political risk and incentives to wait for EU-funding and lower costs of financing, resulting in a less equal playing field and influencing the energy markets. If the required electric grid infrastructure projects are to be built in time, the permitting procedures do not only need to be fast-tracked for some trans-European projects –. measures targeting permitting processes for domestic grid projects will also be required.

Target group and impact on the value chain

The target group is renewable energy project developers, TSOs and DSOs. The purpose of faster approval processes is to enable a build-out of renewables and establish the necessary electric grid infrastructure in Europe and the Nordics. Ultimately, this will reduce energy import dependency and maintain more stable electricity prices for consumers.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risk?

Measures designed to achieve faster permitting are in the regulatory pipeline; however, due to the implementation timeline of PCIs and experiences from Denmark regarding a one-stop-shop, it is questionable whether the initiatives will have the desired effect. Moreover, there is a need for structural measures to address permitting procedures for electric grid infrastructure in general, and not only by providing access to PCI and additional financing. A gap remains when it comes to addressing the risk of slow approval processes.

7.2 Public inclusion in energy infrastructure

RISK: MODEST PUBLIC INFRASTRUCTURE ACCEPTANCE			GAP REMAINS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Public inclusion in energy infrastructure	Considered	Short-term	→
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

This is a structural measure designed to increase public acceptance by enabling the local population to benefit financially from local electricity generation projects. A financial benefit can be provided by allowing neighbouring residents and/or municipalities to invest in the energy project, e.g., by receiving a payment per kWh from the producer or paying less tax. When residents and municipalities are able to benefit economically from an energy project, they view the project in a more positive light and are more likely to support it. The greater public acceptance of energy infrastructure projects, the lower the likelihood of project delays or blocking.

Another way to increase acceptance structurally is to engage in stakeholder dialogue with local residents during project origination, ensuring co-ownership. This can be relevant for both electricity generation and grid infrastructure projects. Such measures are designed to involve local residents in a dialogue process as early as possible and before the project begins, allowing the view of local residents to be considered during the project origination, e.g., in spatial planning. Allowing local residents and municipalities to feel that they can influence the development of projects from an early stage rather than just be presented with adopted plans has a positive effect on public infrastructure acceptance.

Case examples

It is vital to provide opportunities for local residents to benefit financially through participation. The framework for achieving such financial benefits remains important and should be adapted to local conditions. In Norway, hydropower permits always have in-bult benefit-sharing and compensation mechanisms. Local communities, therefore, view hydropower as a stable source of income due to annual licensing fees. In addition, hydropower producers are obliged to make reparations to the affected ecosystems and outdoor recreation areas, e.g., through donations. In aggregate, this has a positive impact on local support. Denmark has previously implemented a "buyer's rights scheme" which offers local residents the opportunity to purchase a 20% stake in electricity generation assets. However, the scheme was abolished in 2020 as it was it was not working as intended, in that the scheme only attracted limited local interest and shares were predominantly purchased by few investors who did not necessarily have local affiliations. Other measures are now being applied to increase benefit-sharing and a renewable energy bonus.

Regarding public engagement during project origination, stakeholder dialogue has been an important asset in achieving local acceptance of projects in Ireland. The wind energy association recommends that project developers engage in stakeholder dialogue at a very early stage of the project development. In this way, issues can be resolved early, and the possibility of an appeal later in the planning process can be avoided, as the public and local population accept the presence of the assets. The OECD Due Diligence Guidance for Meaningful Stakeholder Engagement can be applied in a best-case scenario. Another measure to inform the public and achieve acceptance could be to designate large areas for energy production in the long term, hence enabling stakeholders to plan accordingly. This also gives the general public and local population greater opportunities to accept the physical presence of infrastructure. Sweden has designated the area around the Barsebäck nuclear power plant as one such area.

Target group and impact on the value chain

The target groups are the energy companies, TSOs, DSOs and residents living next to the energy infrastructure. Ultimately, the measures are intended to help corporate stakeholders, and the local population accelerate the green energy transition in a way that satisfies all parties.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Various measures exist and are, to some extent, already being applied to mitigate risks associated with infrastructure acceptance. Nonetheless, these risks do not appear to be dealt with systematically and adequately as public opposition to grid infrastructure and electricity generation assets is still being encountered. Hence the identified measures do not adequately and efficiently mitigate the identified risks.

7.3 Adapt electricity market design

RISK: INADEQUATE ELECTRICITY MARKET DESIGN			GAP REMAINS
MEASURE	IMPLEMENTENTATION STAGE	EFFECT TIME HORIZON	DOCUMENTED IMPACT
Adapt electricity market design	Considered	Short-term	?
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

Developing the electricity markets so that renewable energy can be integrated and security of supply can be maintained is an important task. For the past decades, efforts have focused on deregulating and coupling electricity markets across the Nordic countries and Europe. The market development is described in Section 5.

Simply repeating the mantra that the energy-only market (and the existing market platforms) will solve the issues experienced now and in the future is not a viable option. The following non-exhaustive list discusses some of the measures currently being tabled across Europe for the ongoing development of the electricity markets. Before developing any of the measures listed, a thorough investigation of future market requirements is needed. Some of the market changes are already being implemented in some countries, whereas others could be implemented.

- **Electricity market zones:** The Nordic (and European) electricity markets have been developed as zonal markets, in a trade-off that ensures uniform electricity prices across a wide area. One alternative is nodal markets, where the electricity price is set per node. The node can be an electrical substation. In such a market, the electricity price reflects local grid congestion. Theoretically, a nodal market is more efficient than a zonal market but presents an opportunity for market manipulation due to lower market liquidity. ACER is currently proposing a restructuring of the existing bidding zones in Europe. Five countries (Germany, France, Italy, the Netherlands, and Sweden) are being asked to address the need to redefine the existing market zones. We may find that ongoing re-definition of electricity market zones is required depending on differences in the timing of developments in electric grid infrastructure, renewable energy and flexible demand response. It is extremely important to take account of spatial and temporal aspects in demarcating electricity market zones.

- **Capacity payments:** Before the energy crisis, increasing renewable energy production resulted in lower electricity prices, which in turn led to the decommissioning of power plants. (See discussion in Section 5). Capacity payments are one way of ensuring adequate electric capacity. There are many different ways to provide capacity payments, including through capacity markets, strategic reserves and setting target capacities. The UK operates a capacity market, providing all bidders with the price of the highest bid accepted. In Denmark, a capacity payment was previously paid to small gas engines, which has now been abolished. Strategic reserves have been established in Sweden and Finland, with dedicated power plants entering the market in peak situations. A strategic reserve is currently being discussed for the DK2 market area, where conventional power plant capacity is expected to be insufficient. However, the proposal was rejected by the EU. These recent developments indicate that a discussion of the price for security of supply and evaluation of the best mechanism to ensure adequate capacity are needed.

- **Aggregator and flexibility markets:** The current electricity market regulation permits participation in plants above a certain size through market-responsible parties. Market platforms are being developed to allow distributed energy resources to participate through aggregators. The involvement of decentralised electricity markets, without a central operator, in the wider electricity market is also being trialled. One challenge present in various electricity markets is that re-dispatch costs in balancing markets have increased substantially due to the influence of renewable energy. It has also been observed that renewable energy is being curtailed as it cannot be utilised due to grid bottlenecks. The aggregator and flexibility market solutions not only have to reduce the cost of system operation but must also allow better integration of renewable energy.

We are yet to see commercial market solutions, but many are being developed.

- **Framework conditions:** Changes in the framework conditions, encompassing flexible distribution and transmission tariffs, and flexible electricity taxes, are vital to ensure better integration of renewable energy. Price signals sent to end-consumers are currently not sensitive to renewable energy production. The changes in framework conditions must ensure that sector coupling is prioritised. With increasing renewable energy production, it is important to ensure that market platforms and framework conditions are designed to secure improved sector coupling.

Case example

A special regulation in the DK1 market zone provides an example of the challenges involved in integrating renewable energy into the electricity markets, which other Nordic countries could be exposed to. The regulation used in DK1 could be applied to help alleviate problems in the German electricity network. When the German grid is stressed due to renewable energy production, Danish wind turbines can down-regulate their production and district heating producers can down-regulate their CHPs or up-regulate their electric boilers. As shown in Table 11, in 2020 the special regulation had a market volume equivalent to more than 10% of Danish electricity production. From a socio-economic perspective, it is not optimal to curtail wind production. However, the market signals provided indicate otherwise.

Because an increasing volume of energy is traded on the special regulation market, Energinet has initiated work to transfer the handling of surplus power to the intraday market, which will allow participation from power plants outside Denmark, including Norwegian hydropower. Integration of German wind power affects multiple countries and requires measures across the Nordic countries.

Target group and impact on the value chain

The target groups are, in principle, the entire value chain. Consumers, producers, TSOs, and DSOs are all impacted by the electricity market structure.

	2020	2019	2018	2017	2016
Received from TenneT (Germany) (GWh)	3,901	1,914	1,598	1,210	554
Down-regulation at Danish actors (GWh)	3,048	1,312	1,114	781	337
Stop/reduction of production on central power plants	35 %	46 %	53 %	64 %	51 %
Start of electric boilers in %	17 %	22 %	21 %	22 %	28 %
Stop of wind turbines in %	48 %	32 %	26 %	14 %	21 %
Average price for down-regulation (DKK/MWh)	-172	-92	-69	-69	-69
Used for up-regulation in balancing market, netting (GWh)	853	602	484	429	217
Netting in % of transferred amount from TenneT	22 %	31 %	30 %	35 %	39 %
Average price for netting in balancing market (DKK/MWh)	118	284	280	199	142

Table 11: Special regulation in DK1 (2016 – 2020 August).

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

It is not proposed that the listed measures be implemented without a thorough examination of the required changes to the Nordic electricity market structure. The overall message is that energy, in general, is a public good, and not like most other commodities, must be considered. A discussion and examination of the societal value or price for security of supply must be initiated. In aggregate, a gap remains with regard to facilitating an electricity market that is fit to deliver societal needs in terms of price stability, security of supply and sustainability.

7.4 Strategic sourcing of metals and minerals

RISK: HIGH MINERAL AND FOSSIL ENERGY SUPPLY DEPENDENCIES			GAP EXISTS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Strategic sourcing of metals and minerals	Considered	Short and long-term	?
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

In the short term, this is an emergency measure to diversify the sourcing of metals and minerals needed for the green energy transition. As discussed, the Nordics depend on a small number of countries to extract and process metals and minerals. Within processing, China is the dominant supply country (Figure 55), while the Democratic Republic of Congo supplies nearly 70% of the world market for cobalt and Chile 30% of the copper market (see Figure 58). There are hence significant import needs related to metals and minerals. Strategic sourcing and diversification of the supply chain are a necessity to reduce the risk of supply disruptions.

In the long term, this is a structural measure aimed at ensuring an appropriate and stable supply of the metals and minerals needed for the green energy transition. Metals and mineral supply chains are not geared to an accelerated green transition. To increasingly diversify the supply chain and reduce the risk of supply disruptions, one initiative could be to implement a new set of industrial policies to facilitate extraction of critical raw materials in the Nordic region. The relevant national authorities in the Nordic countries have discovered significant underground resources of critical raw materials that would enable the Nordics to supply almost all critical raw materials defined by the EU, although imports would likely still be required.

The Nordic countries offer an unexploited potential to supply Europe and the Nordics with much-needed metals and minerals.

Case examples

Strategic sourcing and diversification in the short term could be switched to regions where supply chains are shorter and less exposed to external factors such as political risks or pandemics. To respond to this, the EU has announced the development of the Critical Raw Materials Act, intended to secure a more resilient supply chain (i.e. less reliant on a small number of supply routes or countries) in which sustainability is embedded. The Act is subject to public consultation until 25 November 2022, and is expected to be adopted in Q1 2023 and subsequently enacted through the relevant EU institutions. Moreover, considering the abundance of many of the required metals and minerals for renewable energy technologies, sourcing could be changed to Finland, Sweden and Norway.

To support the long-term development of the mining sector, the Finnish government proposed an amendment to the Mining Act on 8 September 2022, which is expected to enter into force on 1 March 2023. The legislation aims to improve opportunities for local influence on mining projects while increasing business prospects and enhancing the environmental impacts of mining projects. Considering the +10-year (the IEA estimates 16 years) development timeline for mining projects, further action is needed if the Nordics are to successfully supply the EU with metals and minerals for the green energy transition.

Target group and impact on the value chain

The target group is the supply chain responsible for mining metals and minerals. The measure is designed to emphasise the need for a stable and secure supply of the metals and minerals needed to accelerate the green energy transition.

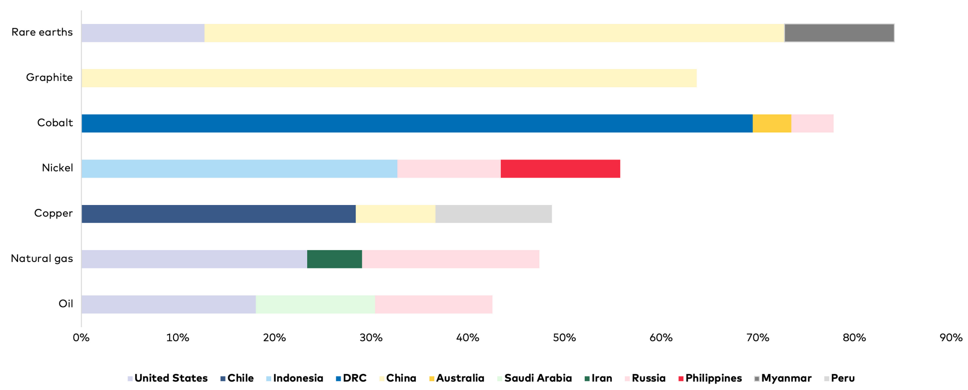


Figure 58: Percentage of selected minerals and fossil fuels extracted by the three main countries, 2019. (Source IEA, 2022)

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Identified mitigation measures relating to metal and energy supply dependencies do not adequately and efficiently mitigate identified risks. In the short term, there is a need to develop a long-term strategy at Nordic and EU level for sourcing the metals and minerals needed for the green energy transition. With the Critical Raw Materials Act, such a process has been started. To ensure resilience, the sourcing of metals and minerals could be switched to focus on the Nordics, given the abundance of many (but not all) of the needed metals. In the long term, the option to grow national mining industries in Sweden, Norway and Finland could also be explored.

7.5 Strategic sourcing of fuels

RISK: HIGH MINERAL AND FOSSIL ENERGY SUPPLY DEPENDENCIES			GAP REMAINS
MEASURE	IMPLEMENTENTATION STAGE	EFFECT TIME HORIZON	DOCUMENTED IMPACT
Strategic sourcing of fuels	Adopted	Short and medium-term	↑
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

This is an emergency measure intended to diversify supply routes through strategic sourcing to enable the Nordics and the EU to stockpile reserve primary energy sources for the coming winters. One way to reduce the risk of supply disruptions and maintain supply security is to diversify across supply routes, countries and the fossil fuels required for electricity generation (LNG, oil, coal etc.). This includes the capability to switch fuel for power plants and industrial processes in the event of supply disruptions or high prices for some commodities, as experienced in 2022. Should supply disruptions occur, end-consumers will then be more flexible and less vulnerable. Strategic sourcing of fossil fuels, including diversification, also requires the construction of necessary infrastructure, e.g., LNG terminals, to source fuels on global markets.

Case example

To address sourcing issues in the short term, the EU has proposed a Council Regulation intended to aggregate EU demand for LNG with the aim of negotiating better prices and reducing the risk of member states outbidding each other on the global market. This will also ensure security of supply across the EU.

In the first half of 2022, LNG accounted for 25% of national gas imports, mainly from the US and Qatar, with imports of US LNG doubling between January and October 2022 compared to full-year 2021. Gas exports from Norway are set to rise by 8% in 2022, mainly on the back of an increase in pipeline gas, to a total of 122 billion cubic metres (bcm). Whether these initiatives are sufficient to meet gas demand in 2023–2024 remains to be seen. The IEA concludes that a full shutdown of Russian pipeline gas supplies, combined with a return of Chinese LNG imports to their 2021 levels, would lead to a shortfall of 30 bcm (EU gas consumption in 2021 totalled 412 bcm) in Europe during the summer of 2023, the period when gas storage sites need to be refilled. Figure 59 shows the 30 bcm demand gap.

As a short and medium-term measure, Norway and the EU have agreed to strengthen their close cooperation in the field of energy, with a view to further expanding the scope of their partnership beyond 2030. Although there are increased prospects for Norway to sell natural gas and oil to the EU, there is a general need to reevaluate sourcing strategies for fossil fuels to achieve increased diversification as a means to decrease vulnerability in the event of supply shocks. Diversification of supply within solid fossil fuels should be one focus area, as the supply chain for oil and petroleum-based products is already well diversified. (See Figure 49). Historically, Russia has delivered a significant share of solid, oil and petroleum-based fossil fuels.

Target group and impact on the value chain

The target group is thermal power plants and end-consumers of fossil fuels for heating. The measures are intended to ensure the resilience of supply chains and reasonable prices, thereby maintaining security of supply for consumers.

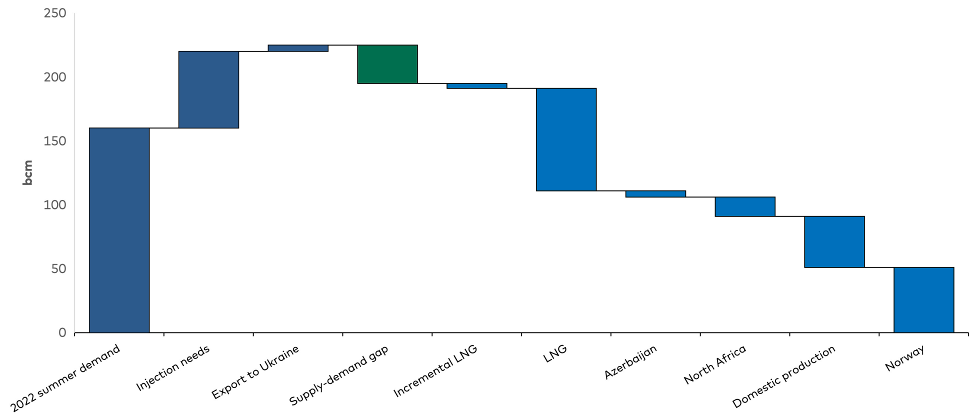


Figure 59: Breakdown of the natural gas balance in the EU and UK in the summer of 2023 in the event of a full shutdown of Russian flows and limited LNG availability. Source: IEA (2022).

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

In the short term, the EU has applied various measures to safeguard natural gas supplies through increased sourcing of LNG to replace pipeline gas from Russia and to top up strategic reserves. Nonetheless, there is residual risk of a 30 bcm shortfall in natural gas next winter (approximately 7% of total demand in 2021). In the medium term, the energy partnership with Norway appears to have been strengthened. However, there is a general need to diversify supply partners within fossil fuels in order to reduce vulnerabilities to supply disruptions. The applied mitigation measures relating to the strategic sourcing of fossil-fuels are assessed to have been implemented efficiently. However, these are likely to address the potential demand gap in the short term. Moreover, further long-term diversification measures will probably be necessary in the medium term.

7.6 Development of electric grid infrastructure

RISK: LACK OF ELECTRIC GRID INFRASTRUCTURE			GAP REMAINS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Development of electric grid infrastructure	Considered	Medium-term	↑
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

It is vital to ensure appropriate investments in grid infrastructure (transmission and distribution) and associated maintenance in order to provide the foundations for an efficient flow of electricity from the renewable energy generation site to load centres. (See discussion in Section 5). Development and maintenance of grid infrastructure is important because changed power flows from generation sites or new interconnectors could make it difficult for the system to provide the required flexibility to respond to new demands. The changed geographical location of consumption and physical impacts on infrastructure from climate change should also be considered in this context. This is particularly relevant bearing in mind the long-term planning required to build new transmission lines and interconnectors.

Case example

TSOs already engage in considerable planning efforts to ensure that necessary electric transmission infrastructure is available to secure a steady supply of affordable and sustainable electricity. To facilitate this process, each Nordic TSO is developing a 10-year plan integrated into a common Nordic and regional Baltic transmission infrastructure plan. Future power balances and generation centres have been identified in order to assess system needs, including changed power flows. Nevertheless, due to the required pace of the green energy transition, the desire to increase energy independence and the general electrification of society, it is still unclear whether the build-out of the electricity grid can keep up pace given the long development times discussed above. Here it will essentially be important to follow the development of transmission infrastructure in central Europe. If the infrastructure is not developed, it will not be possible to export sufficient renewable electricity production from the Nordic countries. Curtailment may be the result. The alternative is to develop new renewable generation in combination with e-fuel production. Providing access to public planning assumptions on the future development of the electricity system and establishing a coordinated electricity grid development plan between TSOs and DSOs to increase sector coupling could be an option.

Target group and impact on the value chain

The measure's target group is TSOs, DSOs and utility companies where the aim is to enable these parties to plan and develop the electric grid infrastructure required to facilitate the green energy transition.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Measures to mitigate the risk of investments in electric grid infrastructure are required. The level of integrated grid planning at regional and international level must be increased. Providing access to public planning assumptions could be an option. The development is contingent on accelerated permitting processes, public inclusion in infrastructure projects, etc., as discussed above. In essence, a gap remains that needs to be addressed.

7.7 Energy infrastructure and integration

RISK: LACK OF SUSTAINABLE LONG-TERM ENERGY STORAGE			GAP EXISTS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Energy infrastructure and integration	Adopted	Long-term	↑
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

Renewable energy development increases the need for flexible producers/consumers in order to ensure stability. Integration between the electricity system and other energy vectors is important. District heating and cooling (DH&C) systems, which operate according to the fluctuating electricity prices caused by renewable energy, can provide the same ancillary services as gas engines and electric batteries. Using heat pumps and electric boilers and storing the heat for later use in thermal storage, and using CHP plants, DH&C systems could offer both long-term energy storage and flexibility. The same is true of the gas systems used in PtX processes and gas CHP plants. Functional demands on the level of energy storage could be imposed to ensure security of supply. This relates to hydro reservoirs, gas cavern storage facilities, large pit thermal energy storages and fuel stocks at power plants. The requirements must be designed to ensure supply security and stable energy prices. The solution could impose functional demands on actors outside the energy markets.

Case example

The European Council has adopted a regulation designed to ensure that gas storage capacities in the EU are topped up before the winter season. Underground gas storage facilities must be filled to at least 80% of capacity before winter 2022–2023 and to 90% before the following winter periods. The measure is necessary because gas storage facilities were previously market-driven with no requirements for filling levels. Following the oil crisis in the 1970s, strategic oil reserves have also been in place to ensure supply in the event of supply disruptions. Similar strategic requirements for other fuel types can be envisioned. Today, it could be fuel stocks at power plants (coal, biomass, etc.), and in the future, PtX fuels could be regulated by equal reserve requirements.

The underlying energy infrastructure required to integrate renewables must also be in place. The construction of district heating infrastructure in Denmark provides one example of such a scheme. The Heat Supply Act of 1979 provided the framework for heat supply planning in all municipalities and defined responsibilities and procedures for interaction between the Ministry and the regional and local authorities. The main objectives were to develop the most cost-effective heat supply for society and to reduce oil dependency. The Act provided the framework to determine the optimal zoning between natural gas and district heating grids and for utilisation of surplus heat from power generation. It also provided the local authorities with an instrument to oblige consumers to be connected to the grids and enabled the state to force district heating plants whose sole heat source was heavy oil to use natural gas. The existing district heating infrastructure could also help integrate renewable energy into the electricity system

A further example is provided by the European Hydrogen Backbone development project that aims to establish a hydrogen network throughout Europe. The development of new hydrogen pipelines in Sweden, Finland and the Baltic Sea marks a new development for the Nordic countries. The aim is for hydrogen production from the Nordic countries to feed central European consumption, in much the same way as the existing electricity network. The general discussion will be whether energy should be moved via molecules (hydrogen network) or electrons (electricity network). Developing a hydrogen pipeline network with associated energy storage in caverns could provide additional flexibility for integrating renewable energy. The alternative would be to move the energy via methanol or ammonia. This would also require a yet-to-be-developed CO2 infrastructure. The envisioned hydrogen network is shown in Figure 60.

Target group and impact on the value chain

The target group is society. The need to develop a mechanism to ensure security of supply through energy storage level requirements and the necessary energy infrastructure has been highlighted by the energy crisis.

Figure 60: European Hydrogen Backbone 2040 vision. (Source: European Hydrogen Backbone initiative)

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Measures to develop the required energy infrastructure are important. The differing characteristics of the Nordic countries mean there is no one-size-fits-all solution. However, general requirements relating to energy storage levels could be one relevant measure. Developing energy infrastructure for energy vectors other than electricity will also be necessary to ensure renewable energy integration and security of supply. In essence, a gap remains.

7.8 Information campaigns and digital applications

RISK: UNCHANGED CONSUMER BEHAVIOUR			NO GAP
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Information campaigns and digital applications	Implemented	Short-term	→
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

Across the Nordic countries, several information campaigns have been aimed at the general public as an emergency measure designed to reduce electricity consumption. The public energy authorities have carried out some information campaigns, while other campaigns are being implemented by private actors in the energy sector. These communication campaigns provide consumers with information about how they can reduce their energy bills, e.g., by consuming energy when it is cheapest (avoiding peak hours), substituting expensive energy sources and implementing energy-efficiency measures. In addition, non-verbal communication campaigns have been deployed in several countries. These include reducing the temperature in public buildings and turning off the lights around monuments. These non-verbal campaigns also remind consumers that we are in an energy crisis and that everyone has a duty to save energy. Digital applications applied to monitor the prices of energy during the day have proved a popular and effective tool for consumers to plan their energy consumption. Private entrepreneurs have primarily developed digital applications.

Case example

The impact of information campaigns depends on the individual campaign's structure and design, the platform it is published on and how this fits with the target group for the information campaign. Since no evaluation of these information campaigns has been conducted, it is difficult to highlight individual campaigns.

While the specific impact of different information and digital applications cannot be determined at this stage, savings are being made. In Finland, nearly 9 out of 10 people reported energy savings, according to Fingrid resulting in a 7% year-on-year reduction in electricity demand between September 2021 and September 2022. At least some of these savings may be attributable to generally higher temperatures. Moreover, digital applications help consumers plan their energy consumption when it is cheapest. These digital applications have proven to be popular and offer major potential for added energy efficiency. Nonetheless, it is hard to radically change the public's patterns of consumption since peak hours are determined by societal structures, and in particular the labour market. Consequently, no potential gap has been identified.

Target group and impact on the value chain

The public authorities are the target stakeholder as they are (often) the originator of the communication campaigns and are responsible for formulating the campaigns in a manner that contributes to energy savings at end-consumer level.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Given that energy-saving campaigns, digital applications and addressing consumption in public buildings are generally being considered across all countries, it is assessed that this risk is adequately and efficiently addressed.

7.9 Energy generation diversification

RISK: INCREASED WEATHER DEPENDENCE			GAP REMAINS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Energy generation diversification	Implemented	Short, medium and long-term	↑
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

There is a need to structurally diversify generation capacity to safeguard security of supply when multiple energy sources are in low supply. As discussed, this was the case in 2022 when reduced nuclear generation, was accompanied by more expensive power plant operation based on natural gas, and potentially lower electricity exports from Norway due to low hydro reservoir levels. The generation mix ultimately must be able to supply energy capacity during peak-demand hours. Given that renewables are by nature weather-dependent, energy resources not reliant on weather conditions are needed to balance the system.

Various options exist in the short, medium, and long term to diversify energy generation. In the short term, keeping existing power plant capacity operational (thermal and nuclear) is an option to provide flexibility. At the same time, the application of oil- or coal-based capacity could be a more cost-effective solution during the ongoing energy crisis. In the medium term, one structural measure to handle this issue, and to increase baseload capacity while diversifying generation sources, is to increasingly build generation capacity with an alternative feedstock, e.g., waste-to-energy, biogas, e-fuel generators or nuclear. Further build-out of renewables and adequate energy storage could also help achieve a positive capacity balance.

In the long term, diversification through PtX technologies and sector coupling are also options to balance the system and provide diversification sources (see energy infrastructure and integration measure).

Case example

To provide short-term flexibility, Denmark and Finland have extended the lifetime of coal and oil plants to provide flexibility in the coming winters. To diversify generation in the medium term, the Swedish government has announced plans to change its 2045 goal of having an energy system based on 100% renewables to a 100% fossil-free system. This further highlights the need to build additional nuclear capacity to ensure baseload in the energy system.

Denmark has also announced plans to further develop the biogas sector, which currently provides approx. 25% of gas consumption, thereby decreasing the use of natural gas. Pumped hydro could also be an alternative generation source in Norway in a scenario with a continued volatile price setting. In the long term, the nations surrounding the Baltic Sea have agreed to install 19.6 GW of offshore wind by 2030, thus emphasising the need to add additional renewable generation capacity.

Target group and impact on the value chain

The target group of the measure are regulators and energy generation companies. Regulators need to develop a regulatory framework that incentivises energy generation companies to invest in technologies that contribute to achieving an appropriate energy mix. This will make it easier for the TSOs to balance supply and demand for energy.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

The Nordic countries have addressed the need to diversify generation capacity in the short term by extending the operation of fossil-fuel-based power plants. In the medium term, strategies have been applied and considered to include additional feedstocks for electricity generation, e.g., biogas (which could also help decarbonise energy-intensive industries) and adding additional nuclear capacity to the grid. In the long-term, sector coupling, e.g., through energy storage in district heating systems (see energy storage measure), can be applied to store energy. Long-term storage of energy, nonetheless, remains an issue. In essence, while measures exist to address the weather dependency of generation capacity, the identified measures do not adequately and efficiently address the need for diversification and determining how society needs to engage in long-term storage of energy.

7.10 Energy crisis mechanisms

RISK: INADEQUATE ENERGY CRISIS MANAGEMENT			GAP REMAINS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Energy crisis mechanisms	Decided	Short-term	↑
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

Stakeholders across the energy market are concerned about the long-term consequences of hasty decision-making to respond to high energy prices, especially interventions in the structure of the electricity market. This has been mentioned in interviews and in reports from private-sector organisations. Important elements in crisis mechanisms to avoid unintended effects of flawed policymaking and spur public democratic debate therefore remain the involvement of third parties (agencies, universities etc.), continuity planning and nuanced impact assessments. For crisis management to function well, mechanisms need to be planned to reduce potential negative impacts and to allow the market to function well after a crisis. In addition, mechanisms should preferably be well-known to energy market participants. Mechanisms should nonetheless be tailored to specific national and local conditions.

Case example

A variety of measures have been applied to safeguard against unintended effects. At EU level, ACER is heavily involved in connection with the potential design of a new price benchmark for LNG and redesign of the electricity market to deliver affordable electricity, safeguard the system against future shocks and enhance alignment with agreed climate targets. In this connection, it is important to make thorough analysis and impact assessments to mitigate potential negative impacts from intervening in the electricity market structure.

At international level, the IEA's energy stockholding system is an example of an effective and well-functioning crisis mechanism. The IEA's energy stockholding system was created following the oil crisis in the early 1970s and requires each IEA member country to hold oil stocks equivalent to at least 90 days of imports to respond to potential supply disruptions. The IEA applied its crisis mechanism to ensure adequate oil supplies by releasing the two largest ever emergency oil stocks on 1 March and 1 April 2022. This is the fifth application of the system since the 1970s.

Target group and impact on the value chain

The target group is all energy market stakeholders, meaning that substantial changes to the electricity market structure would affect the entire value chain.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

While appropriate stakeholders will be consulted, there is always a risk associated with making large-scale changes to an existing system. Due to the market response to uncertainties around appropriate and effective crisis management, it is concluded that the existing measures only partially address identified risks.

7.11 Tripartite negotiations

RISK: LABOUR SHORTAGE			GAP EXISTS
MEASURE	**IMPLEMENTENTATION STAGE**	**EFFECT TIME HORIZON**	**DOCUMENTED IMPACT**
Tripartite negotiations	Implemented	Long-term	→
↑ = Positive	↓ = Negative	→ = Mixed	? = No documentation

Description of measure

Tripartite negotiations are a structural measure that supports workforce availability by prioritising initiatives to ensure sufficient skills, wages and working conditions in critical sectors. In this case, prioritisation of labour market measures in the energy sector could ensure that appropriate skills and a sufficient scale of labour are available to implement the planned energy projects.

Case example

Norway has implemented an energy agreement between employee and employer organisations. The agreement includes several initiatives targeting employees in the energy sector. The agreement consists of wage supplements and guaranteed wage rates for several groups in the sector. Another focus of the agreement is to increase workers' skills so that these match the demanded skills. The wage increases and the skills enhancement measures are intended to enable the companies to carry out the tasks they have been assigned by employing a large enough workforce with the appropriate skills. Other elements such as sustainability, accessibility to technology and retirement policies are included in the agreement.

No evaluation of the newly implemented labour market initiative in the Norwegian tripartite negotiation has been conducted. However, experiences from other sectors support the view that wage and working conditions play a role in attracting labour to certain sectors. Thus, up-skilling employees in the energy sector can make the workforce more qualified. However, in interviews, experts highlight a gap between the skills demanded by companies and the green skills possessed by the workforce, indicating that further measures are required in this context.

Target group and impact on the value chain

The target stakeholder group in a tripartite negotiation includes the employer organisation, the employee organisation and the government. The duration of a tripartite negotiation depends on a single negotiation. In Norway, the collective agreement for the energy sector lasts three years (2022–2024). Sufficient and qualified workforce availability is necessary to accelerate the energy transition and boost security of supply through energy independence, thereby creating positive impacts throughout the value chain.

Gap analysis: Do the measures adequately and efficiently mitigate the identified risks?

Given the substantial need for labour to support the green energy transition, this risk is not appropriately and efficiently addressed. The need for extra labour requires a broader strategic plan addressing how to manage the lack of skilled workers in order to support the green transition. Solutions include increasing energy-related education and more national planning on needed availability (skills and volume). However, the tools (e.g., tripartite negotiations) are in place to expand the labour supply and should be applied, supplemented by additional measures.


8. TARGETING NORDIC ADDED VALUE

This section presents a set of recommendations based on the analysis of the drivers causing the energy crisis, the risk exposure of the Nordic systems going forward, and an evaluation of applied mitigation measures to respond to these risks. While the Nordic energy systems are all different, they also share some common features. This means that the formulated recommendations can be used for national decision-making across the Nordics and for strengthening the Nordic collaboration. However, further analysis is needed to determine how each recommendation can or should be implemented in each country. Given the current energy crisis, this report has been tasked with providing recommendations with an emphasis on how to achieve increased security of electricity supply, with affordability and sustainability as important second priorities. The main focus of the report is the electricity system.

8.1 Policy recommendations

National

- **Implement fixed timelines and shorten permitting processes** for generation and infrastructure assets while considering the relevant perspectives of local communities.

- **Ensure a high-quality labour supply for the energy sector by developing long-term national roadmaps**, including to determine whether and how the sector should be prioritised.

- **Apply goal-oriented impact assessments as a basis for decision-making**, addressing short- and long-term system-wide perspectives. The goals and assessments should balance all aspects of the Energy Trilemma and consider the benefits that a reliable energy supply can create for other sectors of society. In this context, the number of scenarios in national energy planning should be increased to encompass multiple energy system changes.

- **Increase system capacity and flexibility through existing energy assets** that are currently not fully utilised, e.g., by prolonging lifetimes or other means, in order to maintain affordable prices and security of supply. This should not overly delay the green energy transition.

- **Reinforce electricity crisis management so that it is properly dimensioned and well-planned** at local, national and Nordic level. It should be borne in mind that since electricity is both a traded commodity and a basic societal need, adopting a cautious approach during crisis situations remains pivotal. This is because both inaction and suboptimal policy decisions could result in market disruptions and risk creating future, even more acute crises.

- **Strengthen the energy industry's long-term attractiveness and competitiveness** within important sectors such as energy asset manufacturing, electricity generation, heat production, extraction of critical raw materials, energy service companies and grid infrastructure.

Nordics

- **Diversify sources of energy generation, carriers, and storage** in line with national climate targets, including hydrogen and biofuel infrastructure. Leverage the respective strengths of different technologies and energy carriers and opportunities to develop local energy systems while limiting excessive dependence on any single technology, facility or supply route.

- **Review ways of continuously adapting the electricity market model** to meet society's needs and desires to deliver a green and just energy transition, while maintaining a high security of supply. Based on developments in 2022, markets have not been able to balance the various elements of the Energy Trilemma. In this context, adequate roles, responsibilities for market actors, governments and the number of market interconnections should be considered.

- **Formulate shared plans and set requirements for yearly and multi-year long-term energy storage to replace fossil-fuel storage.** This could involve different energy carriers, e.g., hydrogen, methanol, ammonia, pumped hydro storage and biogas.

- **Strengthen and share the knowledge foundation for addressing public opposition to energy infrastructure**, e.g., through various forms of financial compensation and enhanced stakeholder dialogue in project design and development.

- **Support a flexible demand-side response** by utilising existing knowledge and developing new technologies and infrastructure to facilitate energy efficiency, system flexibility and ancillary services.

- **Strengthen Nordic electricity grid infrastructure** to avoid bottlenecks and renewable energy curtailment in connection with the increased electrification of society.

- **Re-emphasise the importance of Nordic collaboration across energy markets and systems** while highlighting each country's responsibility for positively contributing to regional, national and Nordic security of supply.

- **Share findings from nationally applied financial support schemes** to help consumers weather the current crisis and thereby safeguard future policymaking against undesired distributional effects relating to both energy poverty and long-term market developments.

- **Limit import dependency on the metals and minerals required for the green energy transition** by promoting sustainable mining in the Nordics. Consider making the region a global leader in mining on the back of high environmental and ethical standards.

EU and international

- **Coordinate policy responses between Nordic countries around EU initiatives**, thus making them increasingly applicable to the specific nature of the Nordic markets.

- **Assess the need for setting up a comprehensive stockholding system for various types of fuels and energy carriers to improve security of supply** through EU-wide regulations. This should be achieved by leveraging existing knowledge, including in relation to oil and international processes, in order to alleviate the current situation and prevent similar scenarios arising in the future.

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10. APPENDIX 1: Energy balance per country

Figure 61: Primary energy supply. (Source: Eurostat).

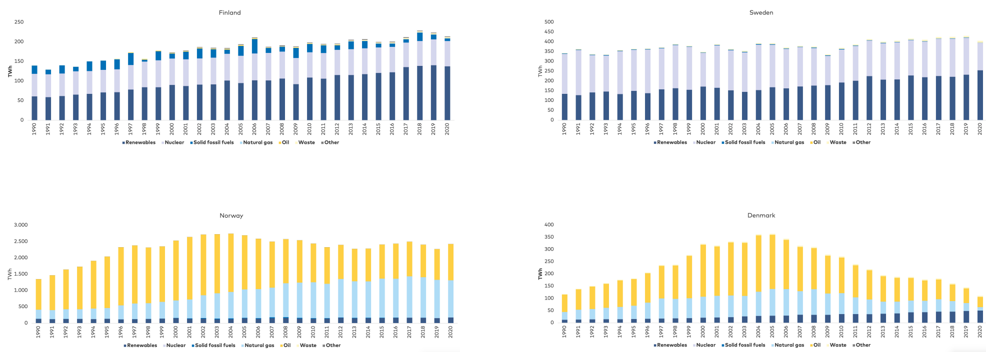


Figure 62: Total energy balance. (Source: Eurostat).

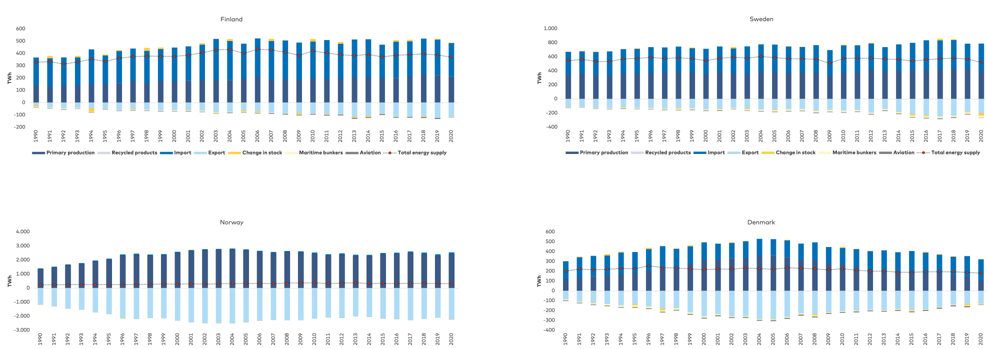
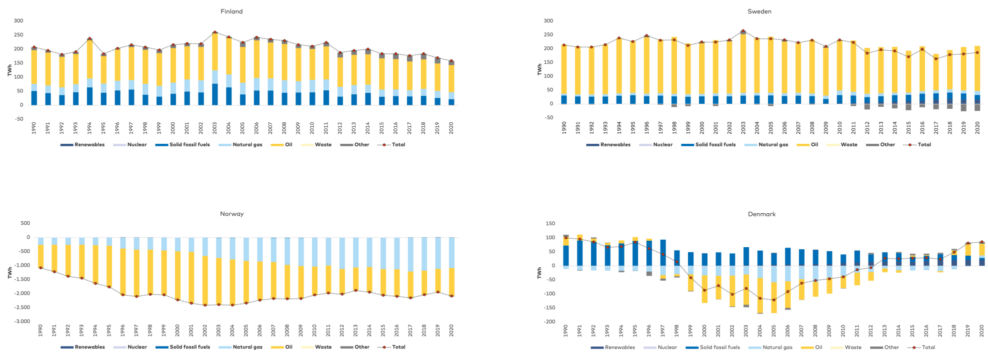


Figure 62: Total energy balance. (Source: Eurostat).

Figure 63: Net energy import. (Source: Eurostat).



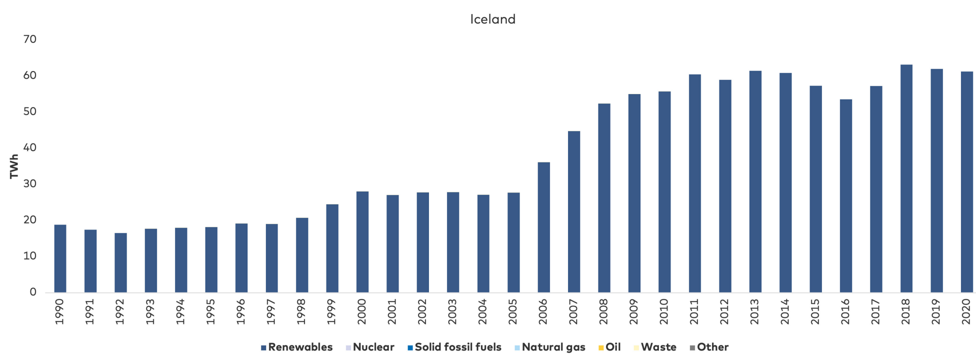


Figure 64: Primary energy production in Iceland.

The Icelandic energy system is largely based on domestic energy production from renewables (hydro and geothermal) and the import of oil products. As shown in Figure 64, the country's entire primary energy production is based on renewable energy.

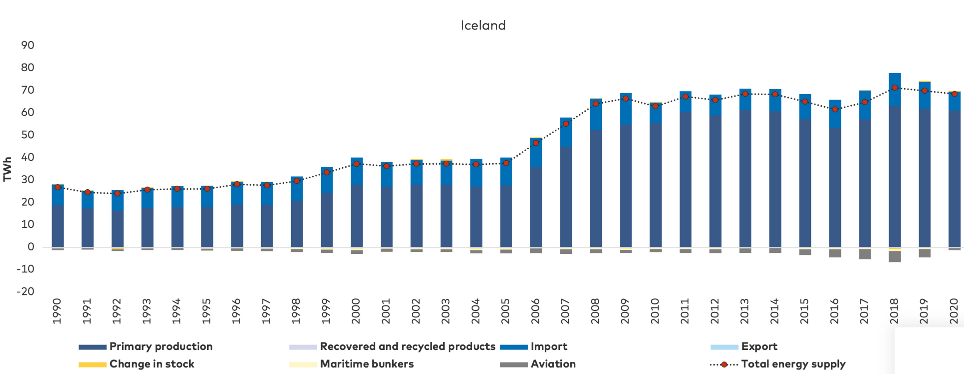


Figure 65: Total energy supply in Iceland.

Figure 65, shows that a high percentage of Iceland's total energy supply originates from domestic primary energy production.

11. APPENDIX 2: Brief descriptions of non-high risk factors

NO.	RISK NAME	CATEGORY	OCCURENCE	IMPACT ON SECURITY OF SUPPLY		LIKELIHOOD	
X = HIGH	**X = LOW**						
11	GHG goals opposition	Social	Medium-term		Some consumers believe that we are facing higher energy prices because the Nordic countries have tried to phase out fossil fuels too quickly and replaced them with insufficient renewable sources to reach the GHG reduction goals. Similar arguments have been made by some political parties who argue that we should either delay the phasing out of fossil fuels until the crisis has passed or the technology is sufficiently developed. These debates constitute a risk to security of supply if they lead to unbalanced decisions on which energy sources the Nordic societies should rely.		According to the interviewed experts, debates on whether the green transition has been rolled out too quickly are already underway in the Nordic countries. The experts also indicated that resistance to the transition is being articulated by some political parties in the Nordic countries, who argue that the green transition should be postponed or stopped because the development of sustainable energy sources is not sufficiently developed. Consequently, political decisions could either postpone or block the implementation of more renewable energy.
12	Material intensity	Energy	Medium-term		The material intensity of renewable energy technologies is significantly higher than for fossil-based technologies and requires increased extraction of raw materials. Given the competition for these materials on the global market and dependence on a small number of third countries for imports, there is a risk of not having access to necessary materials to increase security of supply through renewables.		The likelihood of inadequate security of supply due to a lack of materials for build-out of renewable energy is noteworthy. This is because current investment plans in the metals and minerals supply chain are not geared to transforming the energy sector at an accelerated pace.
13	Decreased collaboration	Governance	Short-term		Decreased collaboration on energy planning, build-out of transmission infrastructure, and energy trading across borders to favour short-term energy security gains impacts the system's ability to balance		The likelihood of reduced collaboration is assessed to be medium, primarily caused by the Norwegian government's notification of potential decreased electricity exports through interconnectors. Given the

					supply and demand of increasing weather-dependent generation. This would reverse the positive welfare gains leveraged by the integration of the Nordic electricity markets over the past 20 years, including through interconnectors.		status of Norway as the "battery" of the Nordics, the communication was worrying, in effect questioning future desire to collaborate in a similar situation. Although no specific political decisions have been implemented in the Nordic countries, the position shows that this is a possible future outcome.
14	Climate tunnel vision	Energy	Short-term	◑	Climate tunnel vision, making climate change mitigation the main or sole priority for governments and corporates, could influence the system's ability to maintain security of supply and stable prices. This is because one likely outcome could be the closure of baseload fossil generation capacity before appropriate renewable solutions and transmission infrastructure are available. This in turn will impact the ability to deliver energy to consumers and alter the balance between the dimensions of the Energy Trilemma.	◑	The current energy crisis, by reemphasising security of supply and affordability concerns within the Energy Trilemma, has reduced the likelihood of climate tunnel vision, The distributional impact of higher prices (rather than higher carbon taxes) needs to be urgently addressed to support a just transition
15	Climate adaptation	Energy	Long-term	◑	Exposure to physical risks from climate change requires TSOs and energy generation owners to safeguard assets against a number of climate hazards.	◑	Due to the analysis of exposure to climate change hazards included in the EU Taxonomy DNSH criteria and the desire of energy companies to achieve a high Taxonomy-alignment score, the likelihood of assets not being operational due to climate change is assessed as medium.
16	Electrification	Energy	Long-term	◑	Electrification of multiple sectors of society requires significantly build-out of renewable energy. While plans have been made, there is a risk that we cannot build the necessary generation capacity to keep security of supply high, especially considering the volatility	◑	There is a need for build-out of renewables to reach desired climate targets. However, given the current emphasis on exhausting wind resources in the North Sea and Baltic Sea, the likelihood of not having appropriate resources is assessed as medium

					of wind and solar generation.		
17	Delayed transition	Energy	Medium-term	◑	There is a general risk that the current energy crisis could delay the energy transition due to prolonged reliance on fossil fuels and longer lead times for infrastructure projects. Society would then not be able to increase independence and security.	◕	The likelihood of a delayed transition is indeed present, signalled by the extension of the operating lifetime of fossil-based capacity.
18	Corporate trading partners	Governance	Medium-term	◑	Acceleration of build-out of renewable energy to reach decarbonisation targets and increase energy independence could entail reliance on the same corporate trading partners in terms of manufacturing turbines or high-voltage cables. This could present an operational risk should the same technical fault occur in multiple assets simultaneously.	◔	While the risk is assessed to be low, the closure of 51% of France's nuclear facilities for maintenance simultaneously has shown that widespread technical faults can in effect be a systematic risk.
19	Inertia	Energy	Long-term	◔	Development of an electricity system based solely on renewable energy results in the challenge that there will be less spinning mass in the electricity system. Artificial inertia may be further developed together with synchronous generation.	◑	The issue of too little inertia in the electricity system is a real challenge that needs to be addressed when developing renewable energy. Technical solutions are available and will have to be developed, which is why the risk is only assessed as medium.
20	Energy company default	Governance	Short-term	●	Energy companies that have entered into fixed-price electricity supply contracts face a risk of default when costs increase to higher levels than the supply contract, exposing the system to a risk that electricity cannot be delivered due to company defaults.	○	The governments in Sweden, Denmark and Finland (where this has been a risk) have all made significant financial guarantees to avoid energy companies defaulting, in effect making the likelihood of default low.
21	Energy affordability (retail)	Social	Short-term	○	The lack of economic access to affordable energy does not, as such, constitute a risk to security of supply. Rather, in situations where the supply is low, reducing general consumption of electricity could be an	◕	Economic access to affordable energy already constitutes a risk for retail consumers. This risk will potentially increase over time depending on how the market drivers develop during the winter and the coming months, and how

					advantage. However, the lack of economic access to affordable energy has major consequences for the affordability of the Energy Trilemma.		politicians handle the situation.
22	Energy affordability (corporate)	Social	Short-term	○	Companies dependent on energy for their production are significantly affected by the rising price of energy. As a result, some companies may be forced to shut down their production. The closure of businesses will essentially positively impact security of supply since, in theory, it will reduce energy consumption in general. However, some industries that develop equipment for the energy sector could potentially affect security of supply.	◑	According to the interviewed experts, the Nordic countries are already questioning whether the green transition has been rolled out too quickly. The experts also indicated that opposition to the green transition is being articulated by some political parties in the Nordic countries, who argue that the transition should be postponed or stopped because the sustainable energy sources have not been sufficiently developed. Consequently, decisions could either postpone or block the implementation of more renewable energy.

Table 12: Brief descriptions of non-high risk factors

12. APPENDIX 3: National responses to relieve pressure on household finances

RESPONSE AND INTENDED EFFECT	DENMARK	FINLAND	NORWAY	SWEDEN
Subsidy/grant/cheque	1. In the 'Winter Package' for 2022 the following initiatives were adopted to reduce costs: increase in the start-up aid pool, increase the subsidy for decoupling from the gas grid. 2. Compensation for rising energy prices targeted pensioners and other social security recipients (worth €218.7 mill.): - Recipients of supplementary pension payments will receive an additional tax-free €672 split into two payments at a total cost of €151 mill.. - State education grant (SU) recipients, who also already receive a supplementary grant for the disabled or being a carer will receive an additional tax-free €269, at a total cost of €3.1 mill. - People on early pension schemes will receive an additional tax-free €269 (to be received early 2023). At a total cost of €64.6 mill.. 3. One-time subsidy payment "heating cheque" of €807 for households with low incomes and certain heating types, at a total cost of €269 mil..	The government allocated direct grants to the agricultural sector worth €219 mill. in direct support.	1. When the average market price (electricity spot price) for the month in a household exceeds 0.7 NOK/kWh, the state covers a certain percentage above the cap (household consumption of up to 5.000 kWh per month). 80% of the surplus price from January–September 2022, rising to 90% from October–December 2022. 2. Temporary subsidy scheme for voluntary organisations due to exceptional electricity prices. Operates in the same way as electricity subsidy schemes for households with an 80% subsidy when the average price is above 0.7 NOK/kWh". 3. Increased grant framework for municipalities of 300 mill. NOK (€29.46 million) in 2022 to cover increased social assistance payments due to high electricity prices. 4. Temporary subsidy scheme for agricultural and greenhouse enterprises. Modelled on the household scheme. For agriculture, the	1. From December 2021 through February 2022, all Swedish households were eligible for some form of electricity compensation. The measure is stepped: The higher the consumption, the higher the compensation. Households had to consume at least 700 kWh/month to be eligible for monthly compensation for the three months. The highest step is 2.000 kWh/month where households would receive SEK 2,000 a month for the three months. 2. Electricity price compensation scheme for the month of March 2022 covering households in electricity areas 3 and 4, i.e., southern and central Sweden. Also designed in steps. The lowest consumption threshold is 400 kWh (min support of SEK 100 = €9.19) in March and a maximum of 2,000 kWh (max support of SEK 1,000 = €91.9). 3. A support package for agricultural enterprises and the fishing industry as a one-time subsidy, consisting of four measures:

	4. Heating package 1 included 3 measures to address rising costs: - municipalities can apply for compensation directly for additional expenses - agreement with companies to equalise heating bills - strengthening public information on energy preservation. 5. Change from instalment payment to monthly payment allowing consumers to keep track of costs. 6. Accelerate the phasing-out of fossil fuels in district heating production. DKK25 million has been set aside in 2023 to support district heating companies that provide subsidies for large heat pumps and solar heating systems at district heating plants.		scheme is limited to a maximum consumption of 20,000 kWh/ enterprise. There is no maximum limit for greenhouses. 5. Increase in housing benefit allocation totalling NOK 1.9 billion. (€0.19billion) in 2022 to alleviate the situation of high electricity prices. Limits vary between municipalities and depending on the number of residents in households. 6. One-time payment of NOK 3,000 (€294.6) to students who have paid for electricity in addition to their rent and who received a loan/grant from the Loan Fund between 16 January and 15 June 2022.	- Extended support for the animal sector – SEK 1.6 bill. - Retroactive diesel tax refund – app. SEK 400 mill. - Extended support for northern Sweden farms - app. SEK 50 mill. - Support for professional fishing - app. SEK 40 mill.
Lower energy tariffs/ taxes	1. The electricity tax will be cut from 69.7 cents/kWh in 2023 to 0.8 cents, which is an EU minimum. The reduction will last for 6 months. 2. In the Winter Package the following initiatives were passed to reduce costs: - reduction in electricity tax for heat pumps - reduction in electricity tariffs via bottleneck revenues.	To mitigate the sharp rise in electricity prices, the government will lower the Value Added Tax rate from 24% to 10% between December 2022 and April 2023.	A national reduction in electricity tax of NOK 2.9 bill. (€0.28 bill.). .08 NOK/kWh reduction from January-March 2022, dropping to 0.015 NOK/kWh from April–December 2022. The measure will result in annual savings of NOK 750 (€73.2) for an average household.	No responses identified in this category.
Incentivize energy	In the Winter Package	The guarantee model	In 2022, the	No responses

efficiency/technology change	for 2022 the following initiatives were passed to reduce expenses: economic support for help replacing gas boilers and roll-out district heating and heat pumps.	allows funding to be allocated to investments that improve energy efficiency e.g. of buildings. In addition, funding may be used to renew buildings' heating systems so that they can utilise renewable forms of energy, such as geothermal heat, wind or solar energy.	government increased support for the Enova Foundation, of which NOK 100 mill.(€9.76 million) is earmarked for energy measures to reduce electricity bills in municipal housing.	identified in this category.
Postponements of bills	1. Possibility of voluntary deferral of extra energy bills for Danish citizens and businesses.	No responses identified in this category.	No responses identified in this category.	No responses identified in this category.
Information campaigns	The Danish Energy Agency published information on how households can save energy at home.	The Finnish government launched "A degree lower", a communication campaign aimed to motivate and inform the population about the need and ways to save energy during the upcoming winter.	Private companies launched information campaigns targeting Norwegian households with information on how to save energy.	The Swedish Energy Agency launched the campaign 'Every kilowatt hour (kWh) counts' informing consumers why energy needs to be saved to reduce the risk of shortages and electricity costs, and to show solidarity.
Public energy savings	With the realisation of a potential energy shortage, public buildings were targeted for the winter months. All public buildings and workplaces were recommended to lower the temperature to 19 degrees, unless special conditions require the temperature to be higher. The municipalities and regions were urged to implement the reduction by 1 October 2022, at the latest. The measure was mandatory for government buildings.	No responses identified in this category.	No responses identified in this category.	No responses identified in this category.

Tripartite negotiations	No responses identified in this category.	No responses identified in this category.	In September, 2022, the employer organization Samfunnsbedriftene reached an agreement with the employee organisations on a new Energy Agreement I and Energy Agreement II, which will apply for the period 2022–2024. The following actions areas are included in the agreement: wage adjustments and minimum wage rates, employee representative duties, skills enhancement measures, sustainability and climate, data and access technology and pension and senior citizen policy.	No responses identified in this category.
Investment in research	No responses identified in this category	The Finnish government has approved EUR 100 mill. in participation in a € 700 mill. program called InvestEU, which promotes investments in clean technology for SMEs, households and housing companies.	No responses identified in this category	No responses identified in this category
= Implemented initiative	**= Decided not implemented yet**	**= Not adopted**		

Table 13: National responses to relieve pressure on household finances (no initiatives for Iceland identified)

About this publication

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