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Energy and security in transition

Insights and lessons from the Nordic region

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Abstract

Rooted in the energy security literature and based on an empirical investigation of the Nordic region, this thesis is set to explore how renewable energy sources can affect and thus potentially change the conceptualization of energy security. The Nordic region has a high integration of renewable energy sources in the energy mix and a high level of integration and cooperation across borders. Moreover, the five Nordic countries rely on different energy sources with different levels of self-sufficiency and trade relations. It is therefore a well-suited region for a study on the changing energy security of renewables. To explore the energy security concept, energy and security of renewables in the Nordic countries is analysed by employing the wide framework designed by Bengt Johansson. The analysis reveals that renewable energy has various implications in the Nordic countries, of which some are similar, and some are distinct to certain countries. Going further, the renewable energy system is expected to be regional and many challenges related to the intermittent character of renewable energy sources can be solved by and through regional integration. The second stage of analysis therefore explores the compatibility between the Nordic regional vision of becoming a carbon-neutral region and the respective national strategies. Data from the Nordic Clean Energy Scenarios (NCES), a comprehensive report by Nordic Energy Research envisaging three different scenarios where the Nordic region becomes carbon-neutral by 2050, is compared with national renewable energy production plans towards 2040. The analysis shows that national strategies diverge from the NCES in different ways, and that the Nordic countries are currently not on track to reach the objective of carbon-neutrality by 2050. The thesis finds that these discrepancies can be attributed to mainly national priorities of self-sufficiency and security concerns, or internal debates and matters of public or political acceptance. Based on these two stages of analysis, the thesis concludes with five assumptions on what energy security in renewables can imply: it will be regional, liberalised and interdependent, it is contextual, and public acceptance can play a decisive role. These features can be both barriers and success factors for the realisation of the carbon-neutral Nordic region, and even for other regions to follow. Finally, this thesis contributes to the research on the energy security of renewable energy and the lack of empirically grounded investigations on the subject. It therefore in conclusion finds new avenues for enhancing social science research that can bring further insight into the renewable energy security concept.

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Solveig Evensberget
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List of abbreviations

CNB Climate Neutral Behaviour scenario of the NCES

CNN Carbon Neutral Nordic scenario of the NCES

CO_2 Carbon dioxide

DK Denmark

EU European Union

FI Finland

GHG Greenhouse gas

IEA International Energy Agency

IPCC Intergovernmental Panel on Climate Change

IRENA International Renewable Energy Agency

IS Iceland

NCES Nordic Clean Energy Scenarios

NER Nordic Energy Research

NO Norway

NPH Nordic Powerhouse scenario of the NCES

NPP Nuclear power plant

NVE Norges vassdrags- og energidirektorat (The Norwegian Energy Regulatory Authority)

OPEC Organization of Petroleum Exporting Countries

PtX Power-to-X (electrofuels)

RES Renewable energy sources

SE Sweden

TSO Transmission system operator

UNFCCC United Nations Framework Convention on Climate Change

Chapter 1: Introduction

This chapter introduces the thesis topic, the aim of the investigation, and the research questions that will be answered. It outlines the international commitments which form the basis of the relevance of renewable energy, presents the Nordic region, and the relevance of this study.

1.1 Introduction and research questions

Energy security has been a key priority for nation-states ever since the functioning of the state became dependent on the access to energy. The necessity to keep up with an almost ever-growing demand for fossil fuels has been the first concern of energy policy for centuries. The geographic concentration of particularly oil and gas has created powerful exporters and vulnerable importers - shaping the international system. This has resulted in the vast majority of established research and theory development on the energy security concept being focused on the supply and demand of fossil fuels.

The harmful climate effects of burning fossil fuels have made a transformation to a renewable energy system crucial. For several reasons, renewable energy sources (RES) are inherently different from fossil energy sources. First of all, most countries have the potential to cover at least part of their demand with domestically sourced renewables, and consequently decrease their dependence on imports. But a defining feature of renewables is that most are weather-dependent, making balancing mechanisms necessary in times of low supply. For many countries, this means imports. But since all renewable-dependent countries will be in the same position, trade relations will be characterised by interdependencies rather than the dependencies of fossil fuel trade.

For this reason, energy is increasingly becoming a matter of regional cooperation (Hancock, Palestini & Szulecki, 2020). Renewable energy sources have characteristics that make cooperation with other countries highly beneficial for a stable and reliable energy supply. Furthermore, renewable energy systems function better when they can benefit from various energy sources with a range of balancing mechanisms. The renewable energy market will rely on electricity as an energy carrier and the market will therefore be constrained by the size of the grid - which due to the technical qualities of electricity is likely to be regional, not global (Scholten & Bosman, 2016, 278).

Renewable energy sources can bring both benefits and new challenges for energy security. This thesis therefore aims to investigate how renewable energy might change the energy security concept. This will be done through an empirical investigation of the Nordic region. The Nordic region is world-leading in both renewable energy deployment and interconnectedness. The Nordic countries cooperate on a wide range of topics, and energy cooperation goes back a century. Nevertheless, the region consists of five different energy systems, relying on different energy sources and with different levels of self-sufficiency and trade relations. The region is therefore well-suited to explore national energy security priorities and regional integration, which can reveal potential barriers to further increase the use of renewables.

The first empirical part of the thesis will analyse energy and security of renewables in the five countries using Johansson's (2013a; 2013b) framework for analysis. This part of the analysis investigates the effect of renewable energy on the Nordic countries and aims to learn more about the national priorities that help shape the respective renewable strategies. This analysis will answer the first research question:

1. **In which ways does renewable energy affect energy and security in the Nordic countries?**

In 2019, the Nordic prime ministers signed a declaration to work together to become a carbon-neutral region. In this regard, Nordic Energy Research (NER), a research institution under the Nordic Council of Ministers, developed the Nordic Clean Energy Scenarios. Three different scenarios are put forth, each of them reaching carbon-neutrality by 2050. The paths differ in their level of cost-efficiency, the reliance on behavioural change, and the role of the Nordic region in export of clean energy and fuels to Europe - while all support the Nordic vision of becoming the most sustainable and integrated region in the world.

Despite the benefits of regional cooperation, they do not automatically erase the national priority of a stable energy supply, essential for the functioning of the state. What benefits the energy security of the region, may not always be considered beneficial to the respective countries in which the region consist of. And so, tensions may arise when regional integration and national security meet. The second stage of analysis will therefore investigate and compare the Nordic Clean Energy scenarios with national renewable strategies, to reveal compatibilities and discrepancies between the national and the regional strategy. This analysis will answer the second research question:

2. **How compatible are national strategies with the regional vision of a carbon-neutral Nordic region?**

Based on this analysis of the Nordic region, both on the national and the regional level, five assumptions will be made on how energy security in renewable energy may manifest. The aim is not to come up with a new definition of energy security, but to explore the concept based on the Nordic story, and consequently answer the last research question:

3. **In which ways can the Nordic case inform about the ways in which renewable energy sources can change and affect the concept of energy security?**

Given the track record of energy and its importance for national security and subsequent effect on international relations and security perceptions, research on the effect of renewable energy sources on the energy security concept is pertinent. This analysis shows how energy and security can act as both a driver and a barrier for renewable energy deployment and can therefore affect the prospects of reaching carbon-neutrality - for both the region and the nation.

1.2 Outline

Chapter 2 presents the research strategy. It also addresses critiques and challenges, validity and limitations. The theoretical background is established in chapter 3 and 4. Chapter 3 begins by establishing the philosophy of science that forms the basis of the research question, relating it to security studies and a contextual approach to security. The chapter continues by discussing energy security in depth, both the concept and the definition, and concludes by presenting the energy and security framework that will be employed in the analysis: Johansson (2013). Chapter 4 introduces renewable energy, both the features that characterise these energy sources and the implications this may have for energy security. This chapter also presents previous research on RES and energy security and geopolitics, and as the previous chapter presents a theory that will be used in analysis in the final chapter: Scholten & Bosman (2016).

Chapter 5 and 6 are the empirical components of the thesis. Chapter 5 is guided by Johansson's framework on energy and security and the subjective and objective dimensions of security. Different aspects of renewable energy in the Nordic countries, both current and planned, are investigated and classified according to the five dimensions of this framework. This is done in order to explore the implications renewable energy sources has on the Nordic energy systems. Chapter 6 builds on the previous chapter and introduces the Nordic Clean Energy Scenarios. These are three scenarios put forth by Nordic Energy Research that all reach carbon-neutrality by 2050. National policy projections are compared with the scenarios with a focus on power production, to reveal discrepancies and compatibilities.

Chapter 7 ties together the insights on the security implications of renewables from chapter 5, with the comparative exploration of the national strategies and the regional vision of chapter 6. First, the chapter explores the national approaches to renewable energy in all five Nordic countries through Scholten & Bosman's theory (2016) and relates it to security perceptions. Second, to use the insights from this study to explore how the renewable energy security concept could look like. The chapter further discusses the transfer-value of the Nordic recipe and the implications for further research and policy.

1.3 Committing to an energy transition

Renewable energy gained its current significance partly in the context of the various international commitments on mitigating climate change, of which some will be briefly introduced here. The Intergovernmental Panel on Climate Change (IPCC), the international scientific body entrusted to assess climate change, has estimated that we need to keep global warming below 2 degrees above pre-industrial level to prevent harmful interference in the global climate system (Savaresi, 2016, 17; IPCC, 2018). IPCC has further established that the cause of global warming is the emission of greenhouse gases from human activity, of which CO_2 is the most important (IPCC, 2021). The energy sector stands for two thirds of total global emissions, and globally fossil fuels stand for around 80 percent of total energy consumption (IRENA, n.d.; OECD/IEA, 2014). The International Renewable Energy Agency (IRENA) has estimated that a transition to renewable energy coupled with energy efficiency measures can provide 90 percent of the emissions reductions needed to limit global warming to 2 degrees (IRENA, n.d.).

Different international arrangements and agreements of various scopes and reaches have been initiated to reach this goal, but the Paris Agreement is currently the most important globally. At the 2015 COP 21 meeting, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) finally reached a legally-binding agreement on limiting global warming to 2 degrees over pre-industrial levels, and to “pursue efforts" to limit it to 1.5 degree (UNFCCC, n.d.; Savaresi, 2016). The IPCC 6th assessment report, of which the first part was released in 2021, further emphasised the severe need to cut global emissions fast (IPCC, 2021).

In 2021, the International Energy Agency (IEA), arguably the world’s most influential energy analyst, predicted in 2021 for the first time that no new investments in fossil fuel supply are needed if we are to reach the goals of the Paris agreement - and renewable energy production must be upscaled significantly. This was regarded by many as a radical shift in rhetoric and priorities by an agency that has a history of downplaying the potential of renewables. (Bjartnes, 2021a; IEA, 2020; IEA, 2021b).

On the European regional level, the European Green Deal, the EU's ambitious climate action (and growth) plan, aims to make Europe the first net-zero emissions continent by 2050. The plan includes a specific target to decarbonise the energy sector, accounting for 75 percent of EU emissions (European Commission, 2019). The initial goals in the Green Deal were a 40 percent emissions reduction by 2030 compared to 1990 levels. These goals were later raised to 55 percent - implemented through the “Fit-for-55” policy package, presented earlier this year (European Commission, n.d.-b). Although only three of the five Nordic countries are EU members, the two non-members (Norway and Iceland) are committed to working with the EU to reach the goals of the Paris Agreement, in accordance with the decision of EEA Joint committee No 269/2019 (EEA Joint Committee, 2019). The Nordic prime ministers have also declared in 2019 to work together for Nordic carbon neutrality (Nordic prime ministers, 2020).

The world is more aware than ever of the adverse implications of fossil fuels, and there is an increasing number and scope of international agreements and commitments to mitigate climate change, both global and regional. Therefore, we have good reasons to expect that the future energy system will be based on an increasing share of energy from renewable energy sources. But for this transition to succeed, we need to learn more about the barriers renewable energy deployment may face.

1.4 The Nordic region

1.4.1 Introducing the Nordic case

The Nordic region consists of five countries: Denmark, Finland, Iceland, Norway and Sweden, and the autonomous territories of Greenland and Faroe Island (part of Denmark), and Åland (part of Finland). Formalised intergovernmental Nordic cooperation has its roots in 1952 (the non-governmental Nordic Association was formed already in 1919), with the establishment of an official body for cooperation, the Nordic Council - although Finland did not join until 1955 after relations with the Soviet Union had thawed after Stalin's death. The Helsinki treaty of 1962 formalised the procedures and rules of Nordic cooperation, and in 1971 the Nordic Council of Ministers was founded. Throughout the years, an increasing number of binding agreements covering a wider range of areas has come to characterise Nordic cooperation. Today, the vision of the Nordic Council of Ministers is to become the most sustainable and integrated region in the world by 2030 (Nordic Council, n.d-a; Nordic Council, n.d-b; Nordic Council, n.d-c).

In the Nordics, 54 percent of total energy consumption comes from renewables, and 77,6 percent of electricity consumption. The equivalent numbers in the EU-28 (before UKs exit) are 19 percent of energy consumption and 34.2 percent of electricity consumption (NER, 2021a, 9). All the Nordic countries have ambitious climate-goals, and all Nordic countries reached the 2020 targets for RES consumption set under the EU's Renewable Energy Directive two years ahead of schedule (NER, 2021a, 5-7).

Nordic cooperation is most far-reaching in the power sector. The first international electricity interconnector in the Nordic region was laid more than 100 years ago between Denmark and Sweden, and formalised energy cooperation goes back to the 1980's (Ollila, 2017, 9). The Nordic region was one of the first to establish a liberalised electricity market, with the establishment of Nord Pool in 1996 as a means for power exchange between Norway and Sweden. Within four years, as Denmark and Finland joined - Nord Pool became the first international electricity stock market (Energy facts Norway, 2021b; Ollila, 2017, 29). The Nordic prime ministers and ministers of environment committed in the 2019 Helsinki Declaration to work towards reaching carbon-neutrality (Nordic prime ministers, 2020). Bilateral arrangements have also been successfully initiated, e.g., the joint Norwegian-Swedish market for electricity certificates from 2012, facilitating a common goal of increased electricity production from renewable sources by 28,4 TWh by 2020 (Energy facts Norway, 2019; NVE, 2019a).

1.4.2 Country profiles

This section aims to give a brief overview of the energy profiles of the five Nordic countries. It focuses on energy production, sources, import and export, relying mostly on data from the newest energy policy reviews by the International Energy Agency (except for Iceland, which is not an IEA member).

Denmark - world leader in wind deployment and descaling fossil fuel production

In the last 20 years, Denmark has almost phased-out coal for electricity generation, and now get almost half of power production from renewable energy sources, mostly from wind and bioenergy. Denmark is a world-leader in integrating wind power in the electricity mix while keeping supply stable, and both wind and solar are growing. Denmark aims to cover 50 percent of energy consumption from renewables by 2030, and have net zero emissions by 2050 (IEA, 2017a, 13-14). Denmark exports some natural gas, and still imports some coal, however rapidly declining in the last decades. While domestic oil and gas production is also declining, Denmark still both exports and imports oil (IEA, 2017a, 23). Denmark has vowed to phase-out oil and gas production completely by 2050 and has formed an alliance of countries pledging to set a date for a phase-out of fossil energy production[1] (Abnett & Jacobsen, 2021).

Finland - world-leading in biodiesel and increasing nuclear power

The Finnish power sector is largely low-carbon, with two-thirds of electricity production from nuclear, hydro and biomass - in that order (IEA, 2018, 11). Of total energy supply, biomass accounts for almost 30 percent, nuclear around 17 percent and oil 26 percent (IEA, 2018, 13). Almost two-thirds (64 percent) of Finland’s primary energy supply, including virtually all fossil fuels and uranium (nuclear fuel), is imported (2016 numbers) - and the majority comes from Russia (Jääskeläinen, Höysniemi, Syri & Tynkkynen, 2018, 2)Finland has four nuclear

[1] “The Beyond Oil and Gas Alliance”

power plants (NPP) and has no plans of a nuclear phase-out[2] - a fifth reactor is expected to be operational in 2022, and a decision for a sixth NPP (Hanhikivi) was made by the government in 2010 (the construction process has been delayed several times). All nuclear fuel is imported (Ministry of Economic Affairs and Employment of Finland, n.d). The aim is to halve oil consumption by 2030, largely by using biodiesel produced domestically from residues of the forestry industry. This has proven to be complicated, as will be discussed in later chapters. The Finnish biodiesel-industry is world-leading (IEA, 2018, 14-16).. Finland aims for net zero emissions by 2035 (Sustainable Development Goals, n.d.).

Iceland – largely renewable, but not connected

In Iceland, around 85 percent of the total energy supply comes from domestic renewable sources (65 percent from geothermal energy and 20 from hydro), and electricity production is completely renewable. The remaining energy supply is oil for transport, which is imported (Government of Iceland, n.d.). However, this has not always been the case. Until the 1970's, imported fossil fuels were the main source of energy - geothermal energy, although abundant, was used merely for washing and bathing. The fluctuations in the oil price of the 70's hit the Icelandic economy hard, and the country saw the need to ramp up domestic energy production – specifically geothermal energy and hydropower for heating and electricity production (Logadóttir, n.d.). Iceland has 2040 as the target year for reaching carbon-neutrality (NER, 2021b, 29).

Norway - renewable power sector, but a large fossil fuel producer

Norway is one of the world's largest exporters of oil and gas and provides almost one fourth of natural gas consumed in Europe. The oil and gas sector is by far the largest in the Norwegian economy and has provided enormous revenues for the state making Norway one of the richest countries in the world (IEA, 2017b, 9, 15). Electricity use is widespread, e.g., in heating and in later years also electric vehicles. Hydropower accounts for around 90 percent of electricity production, and wind power for the remaining 10 percent. Thus, Norway has fewer options for further reductions of GHG emissions than many other countries (Energy facts Norway, 2021a;

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[2] However, for two of the established reactors operating licences expire in 2027 and 2030, (Ministry of Economic Affairs and Employment of Finland, n.d).

IEA, 2017b, 11.). Because of oil and gas resources and an almost completely domestically-supplied renewable electricity sector, Norway is self-sufficient in energy supply - however occasionally relying on electricity imports when demand peaks (IEA, 2017b, 10, 16). Norway has not set an end-date of oil and gas production, unlike Denmark. Norway has invested in research and development of carbon capture and storage (CCS)[3] (IEA, 2017b, 12). The Norwegian parliament has decided on a goal of becoming climate-neutral by 2030 (Miljødirektoratet, n.d.). As emissions are counted in the country in which they are released in both the Paris Agreement and the preceding Kyoto protocol, Norway has been able to combine a growing oil and gas sector (aimed at exports) with increasingly ambitious climate goals (where the focus has mainly laid on emissions related to *production*) (Sending, et al., 2021, 19). This has even been termed the "Norwegian model": going green at home, but continuing fossil fuel exports (Lo, 2021).

Sweden - renewable electricity and nuclear disagreements

Sweden is a world leader in renewable energy. The electricity sector is largely decarbonised, as well as heating. Additionally, Sweden has succeeded in improving energy efficiency. Total energy consumption peaked in the late 20th century, and electricity demand is growing very slowly despite a growing population. Sweden has the lowest share of fossil fuels in their primary energy supply among IEA members (IEA, 2019, 11). Like Norway, Sweden is self-sufficient in electricity from an almost fully decarbonised electricity generation. But unlike Norway, a large part of this comes from nuclear energy - the rest largely from hydro. Wind production is increasing fast, owing in large part to the electricity certificate scheme and other support systems (IEA, 2019, 12). Sweden had previously decided on a nuclear phase-out by 2010, but this was postponed due to electricity shortages. There has been a significant opposition to nuclear power in Sweden, but this seems to be gradually changing with increased awareness of the climate emergency (Duxbury, 2021a). Sweden aims to have net zero emissions by 2045, and to have 100 percent electricity generation from renewables by 2040 (IEA, 2019, 11). Sweden is a stable net-exporter of electricity (IEA, 2019, 13). The share of biofuels in the transport sector is the highest among IEA members, mostly from imported

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[3] The plans of the demo-project "Longship" have passed in parliament (Norwegian Ministry of Petroleum and Energy, n.d.)

biodiesel - but domestic bioenergy for district heating is significant. Altogether this makes Sweden around 70 percent self-sufficient in energy, importing mainly oil (IEA, 2019, 21).

1.4.3 Autonomous regions

The Nordic region also includes three autonomous regions, which are all islands. Åland is an autonomous island group situated in the Gulf of Bothnia, on which around 30.000 Swedish-speaking Finns live on some 60 islands. Åland has its own parliament and a regional government (Ministry of Foreign Affairs of Finland, n.d.). In 2017, the regional government compiled an energy and climate strategy towards 2030, aiming to reduce CO_2 emissions and increase domestic production of renewable energy (Ålands landskapsregering, 2018). In this context, the demo project Smart Energy Åland has been initiated as a public-private partnership with the goal of demonstrating how a community can become self-sufficient in 100 percent renewable energy supply with prosumers ("consumers who produce") and smart technology, to be used as an example for other communities in the EU to follow (Ålands landskapsregering, 2021). The Åland islands have historically relied on electricity imports from Sweden, which is of closer geographic proximity than mainland Finland (Child, Nordling & Breyer, 2017, 50; NER, 2018, 4).

Greenland is the world's largest island. While having a large degree of sovereignty, Greenland is part of the Kingdom of Denmark. Two thirds of the islands lie North of the Arctic Circle, and most of the island is covered by a glacier, the Greenland Ice Sheet. Greenland is inhabited by around 55.000 people, most of which of the indigenous people Inuit (Rasmussen, 2021). In addition to being an isolated island when it comes to electricity connectors, what makes Greenland distinct is that many Greenlandic communities are also isolated from each other in small communities by the coast, and thus cannot rely on each other for backup capacity. Historically, the main source of energy has been imported fossil fuels, but the share of renewable energy has reached more than half in the last decades (Mikkola, Randall & Hagberg, 2016, 78). The lack of transmission capacity complicates the use of intermittent renewables, such as solar and wind. Greenland has a large potential for hydropower and aims to exploit this and supply 100 percent renewable heat and power already by 2024 (NER, 2018, 4). Different innovative and context-dependent (with little value as a template for others) projects have been initiated locally, such as using fish residues for district heating in Sisimiut or using glacier-water for hydropower in Ilulissat - the latter provides enough electricity to cover the entire town's consumption (Mikkola, et al., 2016, 78-79).

The Faroe Islands are an island-group of approximately 50.000 inhabitants also part of the Kingdom of Denmark and are located in the Atlantic Ocean between Norway and Iceland. The islands have traditionally been dependent on diesel generators for electricity, but ambitious low-carbon domestic resources are planned to be exploited (NER, 2018, 4). Around half of electricity production comes from renewable energy sources, notably from thermal, hydro and wind (SEV, n.d.). Fossil fuels remain the main source of energy for electricity, heating, and transport (Government of the Faroe Islands, 2019). The Faroe Islands are not connected by transmission lines to any other country, and thus need to produce electricity domestically (SEV, n.d.).

1.4.4 Previous research on the Nordics

The Nordic region and RES has been the subject of much technological research. A vast amount is produced by the Nordic Energy Research (NER), but also others such as Lund, et al. (2019) and Aslani, Naaranoja & Wong (2013). Research is more limited from the social sciences, but a couple important contributions will be mentioned. Sovacool (2017) aims to explain the renewable success story of the Nordics and finds that at least three challenges must be faced in order to succeed in the low-carbon-transition: contingency (path-dependencies from established energy policies), contestation (the role of political stability and acceptance) and justice (the winner and losers of the transition, such as job losses – but also the concern of exporting emissions). Sovacool (2017) builds his analysis partly on the Nordic Energy Technology Perspective from 2013, of which the NCES that this thesis employs builds further on (NER, 2021b, 25). He concludes that because the Nordic low-carbon transition is a unique result of the specific Nordic context it does not function as a blueprint for others to follow (2017, 581).

Tenggren Wangel, Nilsson & Nykvist (2016) do not focus explicitly on renewables but recognise the importance of electricity and a well-functioning grid in the low-carbon energy system and investigate institutional barriers for transmission grid development in the Nordic region (focused on Sweden). They find, among other barriers, that lack of coordinated planning across country borders is a challenge for grid development. They also point to the commercial character of the power market, which brings uncertainty as to the direction development will take (2016, 152). These barriers will be discussed further in later chapters.

1.5 Relevance of the study

This thesis aims to address the research gap in studies on the security aspects of renewable energy, as pointed out in Johansson (2013b, 598), Lucas et al. (2016), and others. A study like this has both a practical and theoretical relevance. The practical relevance comes from that exploring the security aspects of renewable energy and the potential tensions between national priorities on the one hand and the regional vision on the other, can help reveal potential barriers for further RES deployment and the realisation of the carbon-neutral Nordic region. The Nordic story can also provide some lessons for other regions embarking on a renewable transition.

The theoretical relevance relates to the concept of energy security, and how the literature on energy security is connected to and a product of the fossil fuel era. As will be shown in the next chapters, security in renewables is different than in fossils, which can ultimately change the concept. Based on the investigation of energy and security in the Nordic region, this thesis concludes with five assumptions on the features of renewable energy security. This can open up avenues for further research, which eventually may generate theory on the renewable energy concept. Although there is already a set of studies that address renewables and energy security, or renewables and geopolitics, presented in chapter 4, the latter especially has a lack of empirically grounded investigations. Thus, this thesis also aims to empirically investigate the relevance and utility of some of these contributions.

This chapter has introduced the topic and research questions, along with a brief introduction to renewable energy commitments and the energy systems of the Nordic region. The next chapter will introduce the research strategy that is used to answer the research questions.

Chapter 2: Research strategy

This chapter presents the research strategy that will be used to answer the research questions introduced above, along with a discussion of critiques, validity, and limitations.

2.1 Research approach

2.1.1 Literature reviews

This thesis consists of several different literature reviews for different purposes. The most elaborate literature review is on the concept and the definition of energy security (chapter 4). The aim of this review is to explore the concept and the broader lines of the energy security debate. It is both a theoretical genealogy and a historical review of the development of both the concept and the definition. The review will show how the concept has been a product of the geographic and technical features of fossil energy sources. The energy security literature review places this thesis in the historical context of this field of research (Ridley, 2012, 24-25), which is a necessary starting point for exploring whether the concept changes with renewables.

Some of the scholarly works included are already literature reviews, e.g., Azzuni & Breyer (2018), that have been used to capture the broader lines in the development of the concept and to affirm or deny interpretations of other works. Other articles are included for their distinct arguments, such as Lucas et al. (2016), examined with the aim to find their specific contribution. This approach has provided a thorough overview - establishing a solid foundation that facilitates a discussion of energy security in the renewable energy system. Additionally, the review is meant to justify the choice of framework of analysis of energy security used in the first half of the analysis.

Following the genealogy of the energy security concept and debate of chapter 3, literature on renewable energy and energy security, and geopolitics is discussed. It also includes a brief review to introduce existing research in the field. The various implications of renewable energy sources are then presented, from which certain technical challenges and implications of the renewable energy system have been identified. This theoretical chapter is more selective in nature compared to the previous, with the aim to show the various features of renewable energy that can affect the energy security concept, and to present the theory that will be used on the conclusive analysis of the empirical data, Scholten & Bosman (2016).

2.1.2 Approaching documents

This thesis uses theory actively to structure the empirical data in the analysis. The approach is in part inspired by qualitative content analysis (Hsieh & Shannon, 2005), practice-oriented document analysis (Asdahl & Reinertsen, 2021) and idea analysis (Bratberg, 2018). The aim is not a rigorous analysis of text documents, but to use theory actively to structure the empirical data.

The approach to the Nordic Clean Energy Scenarios (NCES) is partly inspired by Asdahl & Reinertsen's (2021) approach to document analysis. The authors put forth a way of investigating and analysing documents, in what they term to be a practice-oriented method (2021, 26). Asdahl & Reinertsen emphasise the decisive importance documents have today and present several different approaches the researcher may take in thinking of documents: as places, tools, as a craft, texts, cases, and/or as movements (2021, 12-13, 16-20). One can use all six approaches in combination, or choose the approach fit for your study (2021, 143). In this thesis, it has been useful to think of the NCES partly as a place - the renewable and integrated Nordic region (that may or may never manifest). The authors think of the place-approach as a type of "document ethnography", as a form of fieldwork in the document, which can enable you to relate it to the outside and contemporary world (Asdahl & Reinertsen, 2021, 36-37, 43).

The tool-approach has also been useful when studying the NCES - a tool for something we (or rather, that someone) wish(es) to achieve. Documents can be used to realise and attain a goal, or to shape a case, and are therefore not neutral (Asdahl & Reinertsen, 2021, 146-147). This makes it necessary to uncover what goal the NCES may be used to achieve and relate it to the sender. This is discussed further in later chapters. Although the practice-oriented document analysis is not a methodological approach that was used strictly, it has been a useful way of reflecting on the documents under investigation.

2.1.3 Structuring the empirical data

This thesis is a theory-guided venture where the aim of the empirical data is to shed light on established literature, explore the renewable energy security concept and identify new fields for further investigation. The aim is not an in-depth analysis of energy policy, but rather to get an overview of the five countries' energy systems, potential security challenges, and national priorities. This proved to be a large and comprehensive venture, making the theoretical framework an essential tool for structuring the data and make it tangible.

The empirical data of chapter 5 has been analysed in a way inspired by the directed qualitative content analysis, a method for analysing text data through categories derived from a theoretical framework (Hsieh & Shannon, 2006, 1281-1282). This method was however considered stricter than necessary for the purpose of this thesis. The method entails a rigorous coding of text data and an in-depth analysis of documents - implying that the whole text documents under analysis would need to be categorised and reduced to categories only (Hsieh & Shannon, 2005). The aim of chapter 5 is to explore the various ways in which energy and security is affected by a renewable energy transition in the Nordic countries, and consequently to show how renewable energy affects the five countries differently. The framework employed in this chapter is the energy and security typology by Johansson (2013a, 2013b), which provides five dimensions each capturing different aspects of the energy security concept - and importantly, the distinct features of the energy systems of the different Nordic countries.

Data was gathered from the International Energy Agency (IEA), the respective countries' own energy authorities, and Nordic Energy Research (NER) resources to get an overview of the energy sectors of the five Nordic countries and the three autonomous regions. The five dimensions from the theoretical framework had two roles: to structure the vast amounts of gathered empirical data, and act as categories for further exploration of subjects of which data had not yet been gathered. The data was analysed with an open and interpretative approach. This was more in line with the constructivist approach that introduced in the next chapter, because it was considered relevant insight if e.g., one dimension is more present in one country, or absent in another, or whether other dimensions that these five are present which would imply the need of a revision of the theoretical framework. The analysis showed that no big revisions were necessary, although certain dimensions had a higher focus in some countries.

The analysis of the Nordic energy systems using Johansson's framework also has a purpose of mapping the different underlying understandings of energy and security, or "ideas". Mapping ideas may help explain choices of action. Idea analysis is the qualitative analysis of the presence of ideas in text, where the aim is to find underlying assumptions and convictions. The motivation, interest or preference that leads to action are interesting and not to be taken for granted (Bratberg, 2018, 67-71). While the Nordic region is often grouped together as one, this analysis finds that there is much separating these countries also, e.g., diverging perceptions of security. An argument in Scholten & Bosman's (2016) theory (presented in chapter 4), is that the security situation shapes the choice of renewable energy strategy. Thus, this analysis is meant to shed more light on how the ideas of interpreted security of each Nordic country relates to the approach of the given country to renewable energy.

Following this, the NCES are presented, and the most important predictions discussed. The regional vision of the NCES is then compared with the national strategies of power production towards 2040 The comparison is based largely on a prediction analysis done by Norwegian energy regulatory authority (NVE), and a few other official sources where the NVE report is lacking. This analysis finds that national strategies diverge from the NCES in various ways.

The conclusive chapter aims to tie together the insights about the renewable energy and security situation (chapter 5), with the analysis of the national strategies and regional vision (chapter 6). Each Nordic country will be discussed with the help of the two scenarios by Scholten & Bosman (2016). This has two purposes: 1:- to explore the five Nordic countries' energy systems and the ideas that have shaped them, to relate security to renewable energy and show how this may lead to diverging regional and national plans, and 2:- to empirically test the theory of Scholten & Bosman (2016), consider its feasibility in explaining real energy systems, and whether it has value outside of the thought-experiment.

In the conclusion, the insights from both the theoretical background and the empirical investigation will be used to make five assumptions on how the energy security concept might look like in a renewable energy system. The aim is not to come up with a definition, but to list different elements both the concept and the policy objective might include to secure an affordable and acceptable access to renewable energy. This conclusive analysis is exploratory in its approach, with an additional goal of identifying implications for further research and policy.

2.2 Critique and limitations

2.2.1 Research approach critique and challenges

The main challenge of this research project has been to get an overview of the national energy systems, and to stay on an "overview" level in analysis. In order to have enough space to discuss the theoretical and conceptual aspects, and because the scope of a master's thesis limits doing both in-depth, it was considered necessary not to dive too deeply into the empirical data. Additionally, the emphasis in the literature about the renewable energy system becoming increasingly regional motivated the study of the whole Nordic region, not just a few countries. The overview perspective, while still making sure to give a correct presentation, is a challenging venture. This has been a time consuming, but also rewarding process. The theoretical framework has been crucial tools in this process.

Another critique is the idea of using the study of one region to make a more general theoretical assumption. The Nordic region is a distinct region in many respects, e.g., its wealth and high levels of trust. This could imply that this region is not representative, and that other countries and regions can hardly follow the path the Nordics have taken. While this may be true, it is not considered to be problematic for the purpose of this thesis. In fact, as will be introduced in the next chapter, energy security is assumed to be a contextual concept, and one argument that this thesis aims to make is that there is no fit-for-all solution. The solution for succeeding in a renewable energy transition depends on the context of the given country or region. Additionally, the Nordic region was chosen specifically because of the high inclusion of renewables in the current energy mix in combination with high ambitions for the future, potentially making this region one of thefew where such an investigation is possible today.

Thinking of the NCES as a place and a tool, as put forth in the practice-oriented document analysis, also includes thinking of the sender and the receiver (Asdahl & Reinertsen, 2021). The NCES is a product of research conducted by Nordic Energy Research (NER), a research institution under the auspices of the Nordic Council of Ministers, working for cooperative energy research in the Nordic region. Although NER as an institution also works closely with national governments and energy authorities (NER, n.d.), the scenarios are not separate from the Nordic vision of becoming the most sustainable and integrated region in the world (see 1.4). Cooperation and regional thinking are presumably favoured in the future they envision, another “place” than perhaps what the states themselves envision, and the NCES can be a tool to realise this vision.

Furthermore, this thesis is researching a novel concept, and this also has downsides. First, the NCES do not have peer-reviewed published critique yet, as they were released only in September 2021. In an attempt to bypass this challenge, several events have been attended in which the NCES were presented, discussed, and criticised. Also informal conversations with some of the researchers responsible for the NCES have been conducted. Second, there are not many other empirical works to lean on. In fact, the literature review found no other studies that do what this thesis aims to do. Moreover, there are daily new developments in the field of renewable energy in the Nordics (as well as Europe and the rest of the world). This virtually made the data-collection never-ending. This has been both motivating and exhilarating, but challenging to know when to stop.

Lastly, as this thesis holds a view where contextual security perceptions matter, one might see interviews as the most natural way to obtain insight. In the initial phases of this thesis venture, this was the planned strategy, although the focus area of the time was the Baltic states. Two semi-structured expert interviews (and many informal discussions) were conducted in Vilnius in the autumn of 2020, but it turned out to be an unproductive approach. It was difficult to get the informants to reflect on energy security, security perceptions and the role of renewable energy in the wider security context. Renewable energy was taken for granted as not relevant for energy security (which seemed to be thought of as synonymous to supply security), which however interesting of an aspect, was not the topic of investigation. Thus, interviews were discarded as a method, for the simple reason that most people (experts in the field, in this case) do not reflect on the (energy) security concept. This was still considered to be a relevant experience after the focus region was changed from the Baltics to the Nordics. However, the change in region might have produced a different output, because of e.g., language or the choice of informants. Nevertheless, interviews were considered unfit in the early stages of researching this topic. Interviews and other qualitative methods may be relevant in an extension of this study, for example to test hypotheses and findings, as will be explored in the final analysis of the thesis.

2.2.2 The validity of the results

This thesis is a qualitative study, and the aim is not to generalise based on the results, or to define anything. While staying firmly rooted in theory, the approach has been open to exploring aspects that are not covered by theory. This has, for example, resulted in nuclear energy playing a greater role in the analysis than anticipated, although the theoretical framework implies a more limited focus on renewables. The Nordic region has been chosen not because of its representability, as discussed above, but that does not mean that no lessons can be learned from the Nordic story. This will be discussed in the conclusive chapter.

In the methodological design presented above, a set of frameworks is used to analyse the empirical data. Bratberg (2018) emphasises the importance of keeping the model used to analyse the empirical data, separate from the model that is made through the analysis (the results), to make the results of the analysis verifiable by others (Bratberg, 2018, 90-91). As explained in the next chapter, an attempt is made to solve this challenge by separating the analysis into a deductive component in which the theoretical framework is employed, and a separate inductive component in which the new energy security is explored.

2.2.3 Limitations

First, this thesis does not aim to investigate the transition process, or to make assumptions on which transition scenarios are more likely and how. That would require a different research design, employing e.g., Geels & Schot (2007) multi-level perspective. Second, there is not a focus on the EU and the role of EU legislation and decision-making. Third, the level of analysis is the state, which means certain aspects of within-country issues have not been included, such as the potential tension between large-scale centralised power production, and small-scale decentralised deployment (Johansson, 2013b, 600). Fourth, there will be a focus on the Nordic integrated region, which refers to the four Nordic countries that are connected to the Nordic grid. This excludes Iceland for certain parts of the analysis (such as in 6.2). This is undesirable when the case under investigation is the Nordic region, but no satisfactory alternative was found. It is always pointed out when Iceland is excluded.

Chapter 3: Energy security

This chapter reviews the literature on energy security, as a concept and as a definition. It begins by presenting the philosophy of science, because this relates to the chosen approach to security, which in turn affects the following energy security analysis. The chapter concludes by presenting the Johansson (2013a; 2013b) framework that will be employed in chapter 5.

3.1. Philosophy of science

Three interrelated concepts form the basis of any scientific research: what we see the world as (ontology), affects what we think knowledge about the world is (epistemology), which affects what we think is the best way of acquiring this knowledge (methodology) (Moses & Knutsen, 2019, 1-4). These "lenses" that we see the world through can be subconsciously established or consciously decided-upon (Moses & Knutsen, 2019, 1, 5). Two main perspectives, or ideal types of perspectives, can be distinguished: the naturalist and the constructivist methodologies. They differ in the view of the world, knowledge of it, and the ways to obtain it. This does not mean certain research methods exclusively belong to a specific methodology, but that the assumptions behind the choice of method and the ways in which it is employed are different (Moses & Knutsen, 2019, 3-5).

The naturalists assumes that a "real world" exists, independent of our experience, understanding and interpretation of it (Moses & Knutsen, 2019, 7-8). In contrast, constructivists emphasise interpretation as important in the observation of social patterns. It matters how the viewer understands the world, as we cannot observe the social patterns of the world around us with complete objectivity and neutrality.Observations will always go through the filter of our own mind and are interpreted based on our individual and social characteristics (Moses & Knutsen, 2019, 8-10). This thesis has a more constructivist-leaning view of science, related to the security-approach discussed below.

3.1.1 Security studies

A brief introduction to security studies is considered a necessary starting point for discussing energy security. Security is a contested term with many meanings, but the meaning of the word is commonly associated with "(...) the alleviation of threats to cherished values" (Williams, 2013, 6), implying that certain values are more important than others, and that security is achieved when the most important (or *cherished*) values are not threatened. The referent object is the object we want to secure, which in traditional security studies has been synonymous to the state (Williams, 2013, 7). However, referent objects are not limited to the state.

The most influential theoretical perspective in the study of security has historically been the realist tradition, which has indeed focused on the security of the state. Realists (e.g., H. Morgenthau, K. Waltz, J. Mearsheimer) see the international system as inherently anarchic, and the relations between states primarily defined by power, competition, and self-interest. Within the realist tradition there are several theoretical directions, most importantly classical realism and structural realism (defensive and offensive). These directions do, however, agree on some fundamental aspects of what drives states in the international system (Elman & Jensen, 2013). The second most influential tradition of international security studies is liberalism. Liberalists (e.g., I. Kant, R. Keohane, J. Nye) do not see the world as defined by power and competition, but rather that international cooperation benefits everyone and fosters peace. As within realism there are several theoretical directions, most notably traditional liberalism, and neoliberalism (Navari, 2013).

Partly as a reaction to the realist and liberalist traditions, a whole range of different approaches to security studies have since emerged. Some of which have been grouped together in a theoretical tradition called "constructivism", which puts weight on the interactional and subjective aspects of security. The basic assumption is that security is a concept that is always interpreted. Arguably the most influential constructivist approach is the framework put forth by Barry Buzan and his fellow scholars at the Copenhagen School (McDonald, 2013)

In the late 1990's, the scholars of the Copenhagen school set out to create a novel framework for analysing security (Buzan, Wæver & de Wilde, 1998, 2-4). They believed that security is not necessarily a product of objective threats, but rather that something is *interpreted* as a threat. The process of framing an issue as a security issue is done through a 'speech act'. Through this process, any type of issue can potentially move from the 'politicised' to the 'securitised' on a spectrum. Securitising an issue through a speech act means that the issue is successfully presented as a threat. This implies that 'the audience' (e.g., in a state this would likely be the inhabitants of said state, or members of parliament) perceive the issue in question as a security issue and subject to an existential threat. The securitisation process is not limited to the state, also other actors can initiate such a process (Buzan et al., 1998, 24-26). This framework thus emphasise the role the audience has in creating security issues. Security is a type of social construct, which distinguishes this approach from traditional security studies where security is seen as objective (Buzan et al., 1998, 203-204).

3.1.2 A constructivist approach

This thesis assumes a constructivist approach to security when investigating the changing energy security of renewable energy. Energy security has for most of its existence in academic literature been rooted in the realist tradition (Orttung, 2017, 208). Analysing energy security through a constructivist lens, however, emphasises the variety of interpreted securities which manifest themselves in different countries and among the people. This is arguably a more useful way of understanding the dynamics shaping energy strategies in different countries, and for understanding the changing energy security concept.

The different approaches to international security are a similar way of thinking as the questions of ontology, epistemology, and methodology (Moses & Knutsen, 2019, 5). The topic of this thesis naturally adheres more to a constructivist methodological tradition rather than a naturalist one. This is because the interpreted security situation is considered to be of great importance in shaping the approach a country takes to renewable energy (this assumption is rooted in theory introduced in chapter 4). It implies that security is something that can alter, and which can mean different things to different actors. Not whether renewable energy sources change some objective truth about risk and security, to push naturalism to an obvious extreme.

Bradshaw (2009, 1933) points to the importance of considering the different set of energy security challenges that countries face - which can lead to different and even conflicting notions of energy security. Energy security for a country and energy security for a region can conflict, which this analysis will show is the case in certain aspects of the Nordic region. This thesis assumes that security is always an interpreted concept, which is why something can be interpreted as a threat to one country, and not in another - all other factors being equal. An issue becoming a security issue is not necessarily contingent on the specific issue being an objective threat or not. This is what Buzan et al. (1998) are attempting to explain with the securitization theory. The securitization theory will not be employed actively in this thesis, but it aims to continue on the argument that security is a contextual and interpreted concept, and therefore builds on the constructivist scientific tradition.

Holding an approach to science that leans towards the constructivist paradigm, does not mean that this thesis is purely a constructivist venture, but rather a mixed one. Recall the three research questions that were presented in the introductory chapters:

1. In which ways does renewable energy affect energy and security in the Nordic countries?
2. How compatible are national strategies with the regional vision of a carbon-neutral Nordic region?
3. In which ways can the Nordic case inform about the ways in which renewable energy sources can change and affect the concept of energy security?

The aim of the first research question is to explore the empirical data using existing theory on the subject. This question is more deductive, which is a type of reasoning usually associated with the naturalist paradigm (however, not objective, and neutral observation, but within the framework of a theory). The second research question is of a descriptive nature. The concluding part of the analysis and the third research question aims to find out what the empirical investigation can inform about the changing concept of energy security and is thus more exploratory and inductive in nature. As Moses & Knutsen (2019, 1, 5) argue, scientists do not need to strictly adhere to a paradigm, but instead to take on an approach that fits with the given research project. Different stages of the research process might take on a more naturalistic approach, whereas other stages may take on a more constructivist approach - this does however not mean that the basic assumptions of the world, knowledge, and how to obtain it, change.

3.2 Energy security

3.2.1 The concept of energy security

The concept of energy security is "as old as fire". Ever since humans started using sources of energy for heating, cooking, and protection, securing access to these resources has been a key priority (Azzuni & Breyer, 2018, 2; Valentine, 2011, 4573). Historically, energy demand has increased with economic growth - and has been closely connected to economic development and improved standards of living. With the development of human civilization and the increasing dependence on various sources of energy, the concept of energy security became gradually more complex (Azzuni & Breyer, 2018, 2; Bradshaw, 2009, 1922; Johansson, 2013a, 199).

New sources of energy have replaced old and outdated ones many times in the past, and each transition has had enormous repercussions. In 18th century Britain coal replaced wood and catalysed the industrial revolution. A couple centuries later, oil replaced coal as the main source of energy, and eventually came natural gas (Yergin, 2020, 377-379). Historians have identified what has been termed “the grand fuel sequence”, popularised by Václav Smil, as the sequence in which all societies go through as they develop - from biomass to coal, from coal to oil and gas. This sequence has occurred in many large, industrialised countries, but far from all countries have followed this order of transitions (Bridge et al., 2018, 231). Previous energy transitions have transformed the global balance of power in major ways, and the renewable transition can be just as transformative (Van de Graaf & Sovacool, 2020, 53).

3.2.2 Securing energy

With increased global demand for energy, energy security came to affect the international system and to shape and affect the relations between states. The classic example is the famous shift in the primary fuel for the British navy during World War 1 from Welsh coal to Persian oil, making Britain's relation to Persia a matter of national security (Øverland, 2018, 36; Yergin, 2006, 69). The geographic asymmetry in global fossil fuel reserves, e.g., the high concentration of oil in the countries surrounding the Persian Gulf, made the flow of oil tankers through the Strait of Hormuz or the Suez Canal crucial for countries on the other side of the globe. The global dependency on oil from the Middle East (and the “cartel” Organization of Petroleum Exporting Countries (OPEC)) facilitated the oil crises of the 70’s where the oil supply was hampered. This led to a manifold price increase with huge repercussions on the economy of the Western world (Øverland, 2018, 36; Bradshaw, 2009, 1923). The oil crises of the 70’s brought about the foundation of the International Energy Agency in 1974, established to help its members respond to major disruptions in oil supply (U.S. Department of Energy, n.d.).

Fossil fuels have traits that facilitates exploiting the vulnerability of import-dependent countries by using energy resources as a tool to exert leverage in various ways. These include manipulating energy flows, infrastructure or prices, a practice known as “energy statecraft”

(Van de Graaf & Sovacool, 2020, 54). Russia is often highlighted as a country that exerts this form of influence. For example, during the conflicts over natural gas flows with Ukraine in 2009 (disputes occurred also in 2006 and 2014) where disagreements over gas prices, among other things, led the state-owned Russian gas company Gazprom to “turn off the tap”. This resulted in gas shortages in Europe as the pipelines transit through Ukraine, and was a move widely regarded as means for Russia to achieve foreign policy goals (Van de Graaf & Sovacool, 2020, 53-56; Bradshaw, 2009, 1929).

Consequently, because of events such as the above-mentioned examples (a fragment of the various tensions that the quest to secure fossil fuel supplies has brought), and because securing the access to these resources has been a key priority for any state or region that does not have a domestic supply - the conceptualisation of energy security has traditionally focused on fossil energy sources (Bradshaw, 2009, 1921). This concern was intensified by the forecast that the world was running out of oil, sparked by the concept of ‘peak oil’ predicted in 1956 by Shell geologist Marion King Hubbert to become a reality in all global oil fields. More precisely, Hubbert predicted that the natural limitations of oil reserves and extraction will result in a decline in production after a peak, not that we will run out - but in parallel with increased demand, this can ultimately mean that supply will not keep up with demand (Rasure, 2021).

More recent calculations, however, show that global supplies of fossil fuels are still abundant. Combined with new technologies that allow us to extract previously inaccessible resources (shale oil and gas), we simply cannot burn all available fossil fuel resources without risking catastrophic climate change. This means that we need to find a way to stop burning fossil fuels because of its adverse effects on the climate, rather than being forced to do so because of limited supply (Bridge, et al., 2018, 102-103). The idea of the ‘carbon budget’, is a way of visualising this: if we agree not to surpass 2 degrees of global warming (or even 1.5), how much (more) carbon can we emit, i.e. how much carbon is left in our budget? The last IPCC report shows that we have around 460 gigatons of CO_2 left if we are to not exceed 1.5 degrees, or around 11.5 years of current emission rates (Peters, n.d.; Hausfather, 2021).

3.2.3 Defining energy security

However old the *concept* of energy security might be, the efforts in *defining* the concept are more contemporary. In their review of the evolution of the term ‘energy security’, Azzuni &

Breyer (2018) finds that the first definition can be traced back to Willrich in the 1970s and the wake of the 1973-oil crisis. Willrich defined energy security as "assurance of sufficient energy supplies to permit the national economy to function in a politically acceptable manner" (2018, 3). The exclusive focus on supply and affordability bears similarities to the definition by the International Energy Agency (IEA), defining energy security as "the uninterrupted availability of energy sources at an affordable price" (IEA, 2019). This definition is also similar to the one by Bradshaw (2009) who defined it as "securing the supply of reliable and affordable energy", although Bradshaw argues for the need for a renewed definition in the same article ("the energy dilemma", next paragraph). The definition by IEA and others who focus on supply and price is widely used, perhaps because of its simplicity - but it should also be seen through the lens of the oil-embargoes of the 70's and the security concerns that followed (Bradshaw, 2009, 1926, 1933).

The United Nations Development Programme was the first actor to add an environmental dimension to their energy security definition, in 2004 (Azzuni & Breyer, 2018, 3). This is what has been termed the energy dilemma: how to secure reliable and affordable energy that is also environmentally benign (Bradshaw, 2009, 1921). Both a third and a fourth dimension have later been added to the concept of the energy dilemma that show the various facets of the energy security concept: a dimension of equity (universal access and affordability) and a dimension of social justice ('energy trilemma' by the World Energy Council, and an 'energy prism' by Bridge et al. (2018, 3-4)).

The dimensions of equity and social justice in the security debate, lead to and from the question "whose security?" (e.g., Dalby, 2008, 31)[4]. Security issues and challenges can hit people, societies, and countries very differently, and security for one can result in insecurity for someone else, e.g., when it comes to the access to scarce resources. The equity or fairness dimension is an important consideration to consider in the global low-carbon transition. Most countries in the currently richest parts of the world were able to develop their economies without any restrictions on fossil energy use (which has led to the changing climate that we are currently trying to mitigate) (Bridge et al., 2018, 266-268; Dalby, 2008, 32-36). Denying this

[4] Although in a discussion about environmental security and not energy security, the point still stands

privilege to developing countries is not easy to justify. On the other hand, renewable energy sources might be more affordable and accessible than fossil energy sources in the not-so-distant future, permitting a leapfrog straight to a low-carbon economy (Tamhane, 2020).

Others have attempted to simplify the energy security concept by creating a definition that is able to cover "everything", such as Jewell et al. (in Cherp & Jewell, 2014), who defined energy security simply as "low vulnerability of vital energy systems" - an alternative to the widely used approach introduced by the Asia-Pacific Energy Research Centre of the 'four A's of energy security' (availability, affordability, accessibility, and acceptability). Jewell et al. (in Cherp & Jewell, 2014) criticise this dimension for not considering security for *whom*, for *which values* and from *what threats*. However, in their quest to encompass "everything", this definition becomes vague and rather general, and not immediately meaningful (Azzuni & Breyer, 2018, 4). Others again attempt to encompass all dimensions of energy security in an elaborate index of indicators (e.g., Paravantis & Kontoulis, 2020).

Lucas et al. (2016) strongly argues against reducing the energy security concept to single concepts such as import dependence or absence of supply disruptions, because it may distort the result of the investigation and produce biased results (2016, 1043). How energy security is defined affects energy policy objectives, and thus the definition must be coherent with the strategy target for the relevant topic of investigation. For example, how are we to determine the level of energy security in a country with high levels of import dependence, but also a highly diversified energy supply? Choosing only one dimension as a proxy for energy security would produce a skewed picture (Lucas et al. (2016), 1036, 1043). For example, as Bradshaw argues, energy security cannot be thought of as being separate from climate change policy (2009, 1934).

This thesis does not aim to come up with a new definition of energy security. It aims to increase understanding of the development of the concept, on how to *achieve* security in renewable energy - of which a definition must at least include a stable flow at an affordable price as the IEA defines it. This is arguably the very minimum a definition can be reduced to, but this thesis will not dwell further on this. The definition is not considered particularly important for this investigation, especially because the pitfalls of excluding important aspects when defining, as Lucas et al. (2016) argue, should be avoided. The focus will lay on the concept, and how to achieve it. And in order to explore the concept and how renewable energy sources may affect it, a wide framework will be used that can capture both the multifaceted concept, and the diversity of the countries of the Nordic region: Johansson's typology on energy and security (2013a; 2013b).

3.3 Johansson's (2013a) typology on energy and security

Johansson's (2013a) typology is distinct from other conceptualisations of energy security in that he sees energy as both an object to secure, and as a subject that can affect security, and combines these two perspectives in a single framework. His framework is a framework of energy *and* security, i.e., not energy security, relating energy to the wider security situation. 'Subjective' in this framework does not mean the interpretative and subjective understanding of security discussed in 3.1., but how energy can affect the broader system - and in fact even generate insecurity in other parts of society. Think of it grammatically as different syntactic constituents in a sentence - classified according to who or what is the agent (who or what acts / who or what is acted upon). Nevertheless, Johansson's framework also holds an approach which emphasises the "subjectiveness" of interpreted security: "(...) *security can scarcely be understood without relating it to an actor, activity, technology or system*." (Johansson, 2013a, 200). This approach is in line with the methodological and security approach presented above.

3.3.1 Energy and security as an object

Johansson's (2013a) objective dimension of energy and security relates to the well-functioning of the energy system. It has two aspects: security of supply and security of demand, both objects that can be exposed to security threats. Supply security is the central aspect of energy security, and the aspect most often associated with the energy security concept, as seen above. It is essentially about both availability and affordability (price), and includes the infrastructure for extraction, transportation, transformation, refining and distribution. The level of seriousness of threats to supply security depend on two different time aspects: the level of permanence (how long the disruption/price increase/etc. lasts) and the prior warning time (how long time the state has to prepare for the disruption/price increase/etc.). The longer the disturbance lasts the more serious consequences it can have, but the longer time to prepare for it, the better it can be handled (Johansson, 2013a, 200-201). Security of demand applies to energy exporting countries and is of great importance to these countries for e.g., balancing the national budget. The larger share of GDP from energy exports, the more crucial demand security becomes. As for supply security, this aspect includes both prices and the infrastructure. But also other aspects. such as climate policies, may be seen as threats to oil-exporters (Johansson, 2013a, 202).

3.3.2 Energy and security as a subject

The subjective dimension of energy security refers to the ways in which energy can act as a generator of insecurity (or even a threat multiplier) (Johansson, 2013a, 202). It has three aspects. First, economic and political risk factors, which refer to the various ways energy can affect the economic and political sphere, e.g., how vulnerabilities and dependencies in energy can be exploited. These factors also include the de-stabilising impact that abundant energy resources can have in poorer countries ('the resource curse'), as well as critical infrastructures' vulnerability to terror attacks (Johansson, 2013a, 202). It can also affect within-country, such as in public resistance to infrastructure. Second, technological risk factors refer to the risks from the physical and technological features of the energy system, such as dam failure, explosive gas, nuclear meltdowns, -waste management or even -proliferation, and so on. Third, environmental risk factors include both the risk of climate change and the environmental risks of air and water pollution, but also biodiversity loss from e.g., biofuel production (Johansson, 2013a, 202-203).

The main benefit of Johansson's typology is that it can be applied to any type of energy system (Johansson, 2013b, 599). Thus, it can be used to analyse the current hybrid fossil-nuclear-renewable system and the future low-carbon energy system in the Nordic region. Additionally, it captures the diversity of the Nordic region: a region of exporters and importers with diverse security priorities. The typology allows us to view energy security from different perspectives (Johansson, 2013a, 203), capturing the wide reach of the interaction between energy and security affecting many different aspects of society. This framework may be criticised for being too wide in its attempt to be all-encompassing in its approach, but this is rather considered as a benefit in this thesis where the goal is to explore the renewable energy security concept. A narrow definition could inhibit this exploratory approach.

This chapter has now presented the energy security concept, and the framework of analysis that will be employed in chapter 5. The next chapter will introduce renewable energy sources and the second part of the theoretical background.

Chapter 4: The renewable energy system

This chapter introduces renewable energy sources and technologies, the distinct features and the implications this has for both international relations and the energy security concept. It also presents the Scholten & Bosman (2016) theory which will be used in the conclusive analytical chapter.

4.1 Introducing renewables

4.1.1 Renewable energy sources and technologies

Renewable energy is energy produced from renewable energy sources. Their distinguishing feature is that they replenish themselves in either hours or decades - in contrast to fossil energy sources that take millions of years. Hydro power is the most common and widely used renewable energy source and has been used for electricity generation with a steady growth also throughout the fossil fuel era. Hydropower is electricity produced from falling water (thus mountainous, rainy areas have higher potential) using a turbine connected to a generator. In order to control how much electricity is produced, dams are built to store the water in a reservoir until required (Jelley, 2020, 20, 53). This makes hydro power plants a natural storage facility, and thus more flexible than other renewables.

Solar energy, if we consider the sun directly and not the energy it produces indirectly through wind, biomass growth, and so on, can be exploited in two ways. Either through capturing thermal energy directly from solar heat which can be used to heat water for e.g., heating of homes, or even using the heat to generate power, or electricity (Jelley, 2020, 49-53). The second option is to generate electricity from the sunlight through a photo-voltaic system (PV solar panels) (Jelley, 2020, 72-76). Wind power is electricity generated when wind meets a turbine, connected to a generator. Wind turbines can either be placed on land or offshore, and can either have a fixed foundation, or float (Jelley, 2020, 59, 64-66).

Bioenergy is energy derived from biomass, which includes everything from burning wood for heat, to advanced biofuels for cars or even plane. Producing biomass for energy use requires vast amounts of land which can offset the carbon emissions they are supposed to reduce (Jelley, 2020, 42-46) (discussed further in 5.1.2.2). Biofuels have the benefit of being able to replace oil without any additional infrastructure or end-use technology, as e.g., electric vehicles need. Bioenergy can only be considered renewable if the biomass grows back equivalent to the extraction pace, making sustainable production crucial (Jelley, 2020, 45-49).

Geothermal power is power generated from geothermal heat from the Earth's interior and is therefore only viably accessible in parts of the world where tectonic plates interface, such as in Iceland. Geothermal energy can be used for e.g., district heating, industry or electricity production (Jelley, 2020, 95-97). The above-mentioned renewable energy sources have the highest potential and are the most widely. It is also possible to harness energy from tides, or from waves at the coast. These energy sources have limited potential because these are difficult to harness, and because cheaper renewable alternatives exist (Jelley, 2020, 89-93).

Nuclear energy is not renewable, but as there are virtually no CO_2 emissions - it is a low-carbon form of energy that some claim may solve challenges of supply security and climate change mitigation (e.g., IAEA, 2019). It is included in this analysis because it plays an important role for electricity production in two Nordic countries, Sweden and Finland. Recently, 10 EU countries (Finland included) proclaimed that nuclear energy should be classified as sustainable in the EU taxonomy (Simon, 2021). Most nuclear power plants use the radioactive and highly energy-rich basic element uranium as a fuel, which is depletable. Nuclear energy production produces radioactive waste that must be managed, and the very serious, although small, risk of accidents has resulted in many countries phasing-out their nuclear programmes or never starting them at all (Jelley, 2020, 98-101).

Lastly, two technologies that can play an important role in the renewable energy system must be mentioned, Power-to-X (PtX), or electrofuels, and carbon capture and storage (CCS). PtX is the process of using electricity to produce fuels, of which hydrogen and ammonia are the most known. Hydrogen can be produced either from natural gas, or through electrolysis from water and electricity. If this electricity is renewable, hydrogen as a fuel has no emissions (only water is released when used). 'Blue hydrogen' refers to producing hydrogen from fossil fuels with carbon capture and storage (CCS), whereas 'green hydrogen' refers to hydrogen produced using renewable energy sources. Hydrogen has its potential in those sectors that are hard to electrify, e.g., shipping, industry, and heavy transport. Additionally, hydrogen functions as a battery, and can be useful for storing electricity from e.g., wind and solar that would otherwise be lost during times of high supply (Tae, 2021; Benjaminsen & SINTEF, 2019; NER, 2021b, 72). CCS is a technology of capturing and storing carbon that would otherwise be released into the atmosphere and is therefore also termed as "negative emissions". CCS technology could enable the continued use of fossil energy, but as it is expensive its use will probably be limited to the sectors where other solutions do not apply (NER, 2021b, 106, 110; Jelley, 2020, 102-105).

4.1.2 The distinct features of renewable energy sources

Scholten & Bosman (2016) distinguish five geographical and technical features of renewable energy. First, renewable energy sources are more geographically distributed than fossil energy sources, and all countries will have access to at least some source of energy domestically. However, some countries will have more, or more easily exploited energy sources, meaning that certain countries or regions will be able to generate energy more efficiently than others. Second, many renewable energy sources are intermittent or weather dependent. Third, renewable energy can be produced in smaller units, and can create a system with many smaller energy producers rather than large, centralised producers. Fourth, renewable energy technology can require rare earth materials, that exist in a limited number of locations. Lastly, the most important energy carrier will be electricity, which means that electricity grids and other necessary infrastructure needs to be established and reinforced to connect producers to consumers (Scholten & Bosman, 2016, 277). This brings us to two aspects of the renewable energy system that will be elaborated a bit further: electricity interconnectors and land use.

4.1.2.1 The role of electricity interconnectors

International electricity interconnectors are an essential part of a renewable energy system. A renewable system will be largely electric, and far more efficient if it can include various sources of renewable energy that can exploit the potential from different geographic locations. Interconnectors will contribute to a more reliable supply and help overcome the challenges related to the intermittent character of renewable sources (Puka & Szulecki, 2014, 125). The Nordic Clean Energy Scenarios expect direct electrification to be the cornerstone and the main solution for reaching carbon-neutrality by 2050 in all three scenarios. Moreover, the exchange capacity between the Nordic bidding zones[5] will have to be increased by 60-70 percent between 2030 and 2050 (NER, 2021b, 52, 125). An interconnected region can produce sun power in one area, wind power in another. And, if the sun does not shine and the wind does not blow - the grid can be balanced by utilising hydropower or bioenergy that can more easily be stored. Or, alternatively, in storage technology such as batteries or hydrogen.

Puka & Szulecki (2014) distinguish a set of challenges related to the construction of cross-border interconnectors between member states within the EU. Despite the wide range of benefits from interconnectors, such as higher resilience, safer supply, widespread inclusion of renewables, and cost-efficiency, interconnector projects more often than not face 'gridlocks' in different stages of the construction processes (Puka & Szulecki, 2014, 124-125). They identify four possible explanations for this: insufficient financing, diverging stakeholder interests and the relations between them, conflicting administrative processes, and institutional procedures, and lastly diverging political discourse and energy security perceptions (Puka & Szulecki, 2014, 126-127).

The principles of cross-border electricity trade can be illustrated with an example: two countries (A and B) both have an electricity demand of 2000 MW. Electricity is sold at 40 euros/MWh in country A, and at 60 euros/MWh in country B. With sufficient interconnection between the two countries (because of increased production due to exports in country A and the competition country B's generators now face) electricity prices in the two countries will equalise at 50 euros/MWh. The price increase in country A is a cost the consumers will have to pay. But the producers will see increased income from higher demand, which can lead to an overall welfare gain in country A. In country B there is a welfare gain for consumers, in the form of reduced electricity prices. And so, there are welfare gains in both countries, but the losses and gains of interconnections are redistributed between consumers, and producers. This helps illustrate why cross-border interconnector projects can be complicated to agree on (Jacottet, 2012, 2-4).

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5 The Nordic power market is divided in bidding areas in the Nord Pool power exchange, decided by the national TSO; for now Norway is divided in five zones, Sweden in four, Denmark in two and Finland has one (Nord Pool, n.d.)

Tenggren et al. (2017) investigated barriers to the development of the transmission grid in Sweden. They found, among other barriers, that despite strong integration in the Nordics and with Europe, a joint plan on the development of the grid is lacking. This can lead to different plans and investments between countries and can be a key barrier to the development of the grid needed to decarbonise the Nordic region. The authors advice harmonising governance which can enable better joint planning - and to recognise that as interconnected the Nordics already is, decisions made in one country affect all. Stronger collaboration across borders (also with continental Europe) can help overcome barriers to grid development (2017, 153-155).

From the perspective of the region as a whole, being interconnected is beneficial. This is also the case for the Nordic region: according to NCES, increased interconnection is a prerequisite for reaching carbon-neutrality, a goal agreed-upon by all Nordic prime ministers (Nordic prime ministers, 2020). The Nordic region is as already discussed highly interconnected. But more transmission lines and international interconnectors are necessary if the region is to achieve carbon-neutrality and if new export opportunities are to be exploited (introduced in 5.1). The redistributed costs and benefits shown above illustrate why interconnectors can be a challenge and how national interests can conflict with the region's best interest. This section has not focused on public acceptance, which can also be a significant barrier to grid development – this will be discussed in later chapters.

4.1.2.2 Land use

Renewable energy sources (RES) have many advantages over fossil energy sources, but they cannot compete with the energy density of fossil fuels. Renewable energy sources deliver substantially lower energy output from a given volume. RES require land, which may compete both with natural ecosystems, and human needs such as food production (Capellán-Peréz et al., 2017, 760-761).

Bioenergy has perhaps the most serious land-use implications. Conventional biofuels (1st generation) are produced from food crops, such as corn, wheat, soy, and the controversial palm oil. Advanced biofuels, (2nd and 3rd generation), are conversely derived from residues and waste, dedicated energy crops, and other non-food crops (Azapagic, Chilvers & Jeswani, 2020, 3). Producing biofuel stocks can require cultivation of previously uncultivated areas and is thus referred to as direct land use change. Indirect land use change takes place when using food crops for production of biofuels creates a competition over land areas with food or fodder production. The need to exploit more land to produce food in order to meet human needs can lead to removal of carbon sinks through e.g., deforestation or removal of grasslands (Azapagic, et al., 2020, 3, 7).

However, it is not only bioenergy that has consequences for land use. Capellán-Peréz, de Castro & Arto (2017) found that covering 100 percent of electricity demand with solar power in the EU-27 would require around 50 percent of all available land (i.e., land not already used and excluding protected land) (Capellán-Peréz et al., 2017, 770). Also, hydropower can result in land use change: hydropower dams create artificial lakes which can affect water quality, fish population and displacement of inhabitants (Jelley, 2020, 56-57).

Wind turbines can be 100 meters tall and very visible, especially because they are placed in locations with high wind, such as mountain plateaus or coastal areas (Jelley, 2020, 59, 63). They can be hazardous to birds and disturb wildlife. In Norway it was also found that reindeer husbandry, an important part of the indigenous Sámi people's culture and heritage, is disturbed by wind turbines (NVE, 2019a, 35-40, 57-58). In addition to the land-use changes associated directly with the energy source, the transmission lines needed to transport electricity also take up a considerable amount of land. Power lines have consequences for the land area in which they are built in. Trees, for example, have to be cut down which separates or even destroys natural habitats with repercussions for wildlife and biodiversity (Battaglini & Bätjer, 2015, 183-184).

The challenges related to the land requirements of renewable energy technologies can be subject to public opposition. This has already affected renewable deployment in the Nordic region, e.g., wind deployment plans were scrapped in Norway after massive public opposition due to their impact on nature (Solberg, Skei & Befring, 2019). This is discussed further in 5.2.1.3.

This subchapter was meant to show that renewable energy sources have a range of characteristics which distinguishes them from fossil energy sources. These features will affect how energy is traded and how energy security is achieved. Like others, Johansson recognise that the characteristics of renewable energy affect energy security in various ways that are distinct to these energy sources (Johansson, 2013b, 598, 603). The established previous research on renewables and energy security, and the geopolitics of renewables will now be briefly introduced.

4.2 Renewables and energy security

Several scholars have investigated the links between renewable energy and energy security in different contexts. However, there has been little focus on how renewable energy sources may affect or even change the concept of energy security itself. A handful of them will be introduced here.

Lucas, Francés and Gonzáles (2016) investigated what motivates renewable energy deployment in the EU, by using a set of indicators in an analysis of panel data from 21 EU countries. They found that energy security is the main motivator for renewable energy deployment. Previous studies (e.g., Aguirre & Ibikunle, 2014; Marques & Fuinhas, 2012; 2011; and Marques, Fuinhas & Manso, 2010), have not reached the same conclusion. Instead, environmental concerns, public policies to promote RES, and persistency effects have been found to be key motivators (however, Marques et al. (2010) found energy dependency to stimulate RES). Some even found a high pressure for energy security to be an impediment to RES deployment (Aguirre & Ibikunle, 2014).

Lucas et al. (2016) criticise these works for the use of too narrow indicators for energy security and a one-sided focus on import dependence. The reason why energy security motivations have not been found to influence RES deployment in previous studies is thus because the indicators of energy security have not been sufficiently wide to cover different energy security strategic priorities. The energy security and its relation to RES deployment consequently depends on the chosen energy security strategy (Lucas et al., 2016, 1043). Therefore, energy security cannot be properly analysed when reduced to only one dimension, such as import dependence. This supports the choice in this thesis to use a wide framework to analyse energy security (Johansson, 2013a).

Others have also investigated the relationship between energy security and renewables. Francés, Marín-Quemada & González (2013) investigated renewable energy contribution to energy security and found that renewable energy sources could mitigate risks. Due to the various features of renewable energy sources, they are less vulnerable to the different types of risks associated with the energy system compared to fossil energy sources (e.g., technical, socioeconomic, environmental risks). Valentine (2011) analysed the consequences of renewable energy on the energy security concept and found that the once symbiotic relationship between fossil fuels and energy security has turned into a parasitic relationship. Moreover, renewable energy sources have taken their place in improving energy security.

4.3 The geopolitics of renewables

After 2010, there has been a moderate increase in research on how renewable energy will shape power structures and international relations, but oil and gas still dominate studies in energy geopolitics research (Vakulchuk, Øverland & Scholten, 2020, 2, 8). Both Øverland (2018) and Vakulchuk et al., (2020) found that large parts of this literature reflect old patterns of thinking related to fossil energy. Vakulchuk et al. (2020) conducted a literature review of the emerging literature on the geopolitics of renewable energy and found two opposing arguments: 1- we will see renewed conflicts between states, and 2- we will see reduced conflict between states (2020, 3).

The first perspective argues that renewable energy will lead to similar types of conflicts as fossil energy (either the same or transformed). Thus, the world will continue with the same level of conflict around energy issues as today (Vakulchuk et al., 2020, 3). The second perspective argues that geopolitical tensions will diminish with increased share of renewables in the global energy mix. This is because it is difficult to control, manipulate or stop the flow of renewable energy, and because renewables are more evenly distributed - thus lowering the potential for asymmetric relations, vulnerabilities, and conflict (Vakulchuk et al., 2020, 4).

Øverland (2018) aimed to debunk four common assumptions about the future renewable energy system: **1**:- we will see increased competition over the rare and geographically concentrated materials needed in renewable technologies. Øverland finds this assumption over-exaggerating the “rareness” of these materials, and for disregarding innovations of technology that can make rare materials redundant, and the possibility of recycling materials (Øverland, 2018, 36-37). **2**:- we will see new resource curses in countries with large supplies of critical materials and/or surpluses of renewable energy that can be exported, parallel to what we have seen in countries with high concentrations of fossil fuel resources. Øverland (2018, 37) claims this is unlikely because the nature of renewable energy trade is inherently different. **3**:- cross-border electrical grids can be used as foreign policy tools. Øverland criticises this assumption by stating that electricity trade will be interdependent and less asymmetrical in nature, thus making it incomparable to e.g., gas flows. **4**:- increased electrification and digitalisation makes cybersecurity is an important concern for states. In conclusion, Øverland predicts the global renewable energy system to be less geopolitical in nature (Øverland, 2018, 38).

In an attempt to create a way to measure geopolitical gains and losses of an energy transition, Øverland, Bazilian, Uulu, Vakulchuk & Westphal (2019) presents the GeGaLo index as a way of measuring the effects of a full-scale renewable energy transition. The authors find that geopolitical power will be more evenly distributed in a renewable system, and that there consequently will be winners and losers of the energy transition. This is one of a very few analyses of the geopolitics of renewable energy using quantitative data (Øverland et al., 2019, 11).

The geopolitics of renewables is a new research field and is to some extent dominated by theoretical investigations rather than empirical. Scholten & Bosman's (2016) thought experiment (next subchapter) will be used in this thesis to help structure the insights from the empirical investigation, which is also a scholarly work within the geopolitics of renewables field. This thesis does not directly aim to explore the geopolitics of renewables but recognises the close connection between energy security, geopolitics, and international relations, and thus leans on this research to answer the research questions.

4.4 The implications of renewable energy on international relations

In their quest to analyse a renewable energy, Scholten & Bosman (2016) conducted a thought experiment exploring the political implications of a renewable-based international energy system. The basis of this experiment is a hypothetical energy system that is 100 percent renewable (2016, 276). This is not yet a reality anywhere, but their analysis is still a useful way to structure and understand what forms renewable strategies. This theory will be used in the conclusive chapter.

4.2.1 Implications for the market structure

Based on the geographic and technical characteristics of renewable energy, the authors found five implications for the renewable energy market structure (Scholten & Bosman, 2016, 277). First, the abundance and distribution of energy sources will change power relations between states, as we no longer have scarce resources concentrated in specific geographic regions. Because some regions can produce energy more efficiently, states will be able to choose between producing domestically or importing more cost-efficiently ("make-or-buy"), and even choose between several producers if the infrastructure is in place. This gives consumers more leverage vis-à-vis producers compared to a fossil system (Scholten & Bosman, 2016, 278).

Furthermore, the renewable energy market is limited to the grid size - because (electricity) trade without the necessary infrastructure is impossible. On the one hand, including more producers leads to higher capacity and ability to compensate for production fluctuations (intermittency). On the other hand, electricity loses capacity if transported over large distances. The authors consequently expect renewable energy markets to be regional, but not global (Scholten & Bosman, 2016, 278). This supports the choice of this thesis to study a region.

As renewable production can occur in small units, states can choose a strategy with centrally operated energy production from large energy companies, or a strategy with a distributed production from small, local producers (Scholten & Bosman, 2016, 278-279). Fourth, the transport sector will be affected, and the high demand for biofuels may lead to scarcity conflicts similar to more current conflicts around oil. Lastly, the nature of the renewable energy sources with variable capacity might lead to volatile electricity prices - making balancing mechanisms necessary (Scholten & Bosman, 2016, 279).

4.2.2 Strategic implications: continental and national scenario

Based on the market implications of renewable energy presented above, Scholten & Bosman (2016) propose two scenarios of strategies that states will choose: The Continental scenario and the National scenario. Each scenario is situated in the extremes on a spectrum of policy-choices – and is a result of security assumptions and strategic realities.

In the Continental scenario, renewable energy will be produced in the countries that can do so most efficiently. Additionally, the state will choose a centrally controlled system of production and transport infrastructure. The states who prefer cost-efficiency over security will choose this approach. The authors predict the physical infrastructure (the electricity grid) to become of great strategic importance, as controlling the grid means ultimately controlling the market (Scholten & Bosman, 2016, 279). The interconnectedness of countries within a grid community means that all members of the community have a strong self-interest in the well-functioning of the grid, because problems in one part will have repercussions for everyone connected to it. This makes geopolitical pressure through e.g., cut-offs unlikely. But if they were to happen - an electric black-out can have far more serious and acute consequences than e.g., the delay of a delivery of fossil fuels. In the Continental scenario, countries that have efficient production potential, large consumer potential, or storage or balancing capacity, will hold strategic positions in the community (Scholten & Bosman, 2016, 280).

In the National scenario on the other hand, the state will choose to be largely self-sufficient by domestic supply. The countries favouring security over cost-efficiency will choose this approach (Scholten & Bosman, 2016, 279). In the National scenario, energy will be produced, transmitted, and consumed nationally - or even locally. Countries will become self-sufficient in domestic supply of energy, becoming "prosumers". This is evidently only possible in the countries with a sufficient supply and generation capacity. This scenario is in principle without geopolitical tensions, as states are not dependent on any other states for their energy supply. Tensions may however rise domestically depending on whether a centralised production model or a decentralised, small-scale model is chosen (Scholten & Bosman, 2016, 280).

The authors found that based on the characteristics of renewable energy and the individual countries interpretation of security, the renewable energy strategy chosen falls on a spectrum between self-sufficiency (the national scenario) or cost-efficiency (continental scenario) (Scholten & Bosman, 2016, 279-280). These two scenarios are ideal types, and the authors themselves recognise that most countries will probably choose some form of middle-way (Scholten & Bosman, 2016, 280). Nevertheless, behind every energy policy or strategy document, these two priorities will have to be outweighed. This trade-off is also recognised by Johansson (2013b, 603). The level of import-dependency vs. the level of domestic-production, if we were to view it as a spectrum where less of one means more of the other, will thus vary according to state priorities and where they situate themselves in a security landscape. Going back to the assumptions of security that forms the basis of this thesis (3.1), the interpreted security is considered of importance here, and not necessarily the presence of an objective threat.

4.5 Lessons from this chapter

Both scenarios of renewable energy strategies put forth by Scholten & Bosman (2016) can improve different aspects of energy security. The continental scenario can improve security of demand, security of supply, and affordability. Regions of the world will be interconnected and production will happen where it is most efficient. Moreover, the electricity-based energy system will be based on an interdependent interest in the well-functioning of the energy market. However, being dependent on imports can affect energy security negatively, at least it can be interpreted that way. The national scenario can also improve security of supply and demand, but in a different way than in the continental scenario. If the capacity is there and the resources are available, the state ensures that enough energy is produced domestically, either centrally or through a decentralised system. There will be no risks of disruptions of import and no transit conflicts which can improve energy security. But on the other hand, there will not be capacity to balance the grid with imports in cases of supply disruptions domestically.

Also, the five different dimensions in Johansson's (2013a) framework are unlikely to be improved by the same set of policy changes all at the same time. Thus, there will always be a priority list of which aspects are considered to be the most essential to improve, depending on the context in which the given country finds itself in. Which aspect of energy security a country favours is related to the understanding of security that is prevalent in said country - and certain insecurities are bound to come with that must be balanced against the security gains from the chosen strategy.

This chapter and the previous are the theoretical foundations that has influenced the chosen research strategy in this thesis. Energy security and the overall security situation are considered to be concepts that are connected, in line with the above-discussed theory. This is why the next chapter investigates the energy and security dimensions of renewable energy in the Nordic region to understand better the different understandings and ideas that form the choice of renewable energy strategy.

Chapter 5: Energy and security in the Nordic region

> "(...) on a more general level, energy *independence* may provide less security than *interdependencies* between states [emphasis in original]" (Johansson, 2013b, 603).

Johansson (2013b) has applied his own framework in an analysis of the future renewable energy system. His findings contradict that of other studies claiming that renewable energy sources will automatically lead to better energy security, e.g., because it can decrease import dependence (see 4.2). As the introductory quote reveals, he finds that energy independence is not necessarily a desirable goal in a renewable energy system (Johansson, 2013b, 603). With increased electrification, domestic supply of renewable energy sources will for many countries not suffice (2013b, 599). Returning to Scholten & Bosman (2016), the 'national scenario', will simply not be a viable option to choose for many countries - regardless of whether this is the desired strategy from a security perspective. This points to energy security as a concept being altered in different ways with the inclusion of more renewables in the energy mix. One of these ways being that interdependence may become a favoured objective over independence - a trait of the fossil energy system.

The following subchapter dives deeper into the energy systems of the Nordic countries by employing Johansson's (2013a; 2013b) framework for analysis. Johansson's own analysis of the future renewable energy system (2013b) is used as a starting point, and examples from the Nordic countries are presented continuously. The aim is to get an understanding of the energy and security tensions that arise on a national level in the Nordic countries with increased use of renewable energy.

As Johansson also experiences in his own analysis, renewable energy can affect security in a large number of ways. He found himself limited from discussing all of them in a research paper - he instead aims to show the variety of issues worth investigating (2013b, 600). This thesis aims higher but does not aim to discuss every single aspect, simply because that would outside the scope of this thesis. The aim is to get an overview and to stay on the state-level to show the diversity of the Nordic countries. These insights will in turn be used to understand what affects the chosen renewable energy, in line with Scholten & Bosman's theory (2016). Nuclear energy is included in this analysis even if it is not renewable, because it is considered to play an integral part in the future low-carbon Nordic energy system.

5.1 The renewable energy system as an object

The ‘energy system as an object’ approach, refers to the functionality of the energy system and its ability to deliver energy services. It can be viewed from the perspective of the consumer or the supplier - while both will have a mutual (but differing) interest in the functionality of the energy system (Johansson, 2013b, 599).

5.1.1 Security of supply

The first dimension of Johansson’s framework on energy and security is from the perspective of the energy consumer. Johansson’s (2013b) analysis distinguishes between changes in the long term (>10 years), medium term (1-10 years) and short term (<1 year). This division in time frames has been found to be less relevant in the contemporary analysis of the Nordic region because they are arguably already past the short and medium term in RES deployment.

5.1.1.1 Long term

In the long term, renewable energy affects security of supply positively in that renewable sources are non-depletable flows, and not depletable stocks (for bioenergy this is only true if utilised sustainably). Although we are not physically running out of fossil fuels, we are running out of the amount of carbon we can release into the atmosphere without risking catastrophic climate change (recall the idea of the ‘carbon budget’ in 3.2.2). If utilised sustainably, we will not run out of RES (Johansson, 2013b, 601). This will affect security of supply positively in all Nordic countries, but as the share of renewables is already high, the *increased* security of supply will perhaps be less in the Nordics compared to a region with low RES deployment.

Norway, Sweden, Iceland, and Denmark (almost) all gain the majority of their electricity consumption hydropower, geothermal heat and wind power, all non-depletable flows. Nevertheless, increased electricity consumption due to e.g., increased electrification (discussed in the next chapter), will require that enough capacity is built to sustain security of supply.

Finland is in a different position than the four other Nordic states. A modest share of electricity consumption comes from hydropower, but as much as 30 percent of total energy supply comes from bioenergy (IEA, 2018, 13). Bioenergy is depletable unless exploited sustainably, so the long-term supply security of bioenergy is dependent on how it is utilised (Denmark and Sweden also have a significant portion of bioenergy in their energy mix and this aspect also affects them). Additionally, Finland is an import-dependent country in energy, the bulk coming from Russia (fossil fuels, and nuclear fuels). Nuclear energy accounts for around one third of domestic electricity production in Finland (NER, 2018).

The overall dependence on Russia is however expected to decrease with diminishing fossil fuel consumption in the next decades (Jääskeläinen, et al., 2018, 2, 19). The security aspects of this trade relation are discussed further in 5.2.1. Nevertheless, the secure supply of electricity in Finland requires the supply of nuclear fuels to be stable. An interesting development in this regard, is the government-approved plans for extracting and refining uranium in Eastern Finland, the first in the EU (Reuters, 2020). This project is still in an early phase, but it has the potential to affect the dependence on Russian nuclear fuels.

The autonomous regions in the Nordics have the potential to benefit significantly from harvesting domestic RES compared to imported fossil fuels that are expensive and polluting, as was the case in Iceland. Greenland and Faroe Islands have both been dependent on imported fossil fuels, also for electricity generation. Greenland, however, has increased its share of renewables significantly in later years (see 1.3.3). Nevertheless, the literature shows that complete independence through renewables may be a risky path to walk down due to the lack of balancing mechanisms and the intermittent character of renewable energy sources, especially in Greenland where many communities are not connected to each other. Storage in batteries or hydrogen can be a potential solution. Åland is already connected to the Nordic grid, and so is in a different position than the two others.

Johansson (2013b) points to the various ways in which climate change in the long term can affect the weather and ultimately the weather-dependent renewable energy sources (Johansson, 2013b, 601). The 6th IPCC Assessment report (2021) predicts that for the Northern European region (of which the Nordics are part of), the weather will become warmer and more wet (increased precipitation, but also more extreme rains and floods) (IPCC, 2021, 32-33). This may create more unpredictable hydropower production and a demand for increased balancing capacity. Both wind turbines and hydropower dams will have to be constructed in a way that ensures their functioning, safety, and stability even when being subject to floods or extreme winds. On the other hand, more wind and water may lead to a higher electricity output. Both NVE, the Norwegian energy regulatory authority, and the Swedish counterpart Svenska Kraftnät inform that changes in weather patterns are strictly monitored for the safety of their dams (NVE, 2021a; Svenska kraftnät, 2021). More about dam safety in 5.2.

5.1.1.2 Medium and short term

The medium (1-10 years) and short term (<1 year) supply security aspects of renewables are as mentioned less relevant in the Nordic region. As Ollilla (2017) writes, the Nordic region is 25 years ahead of the rest of the world in terms of carbon-intensity of the electricity mix. Increased inclusion of RES may increase diversity in energy supply in the medium term, which can be favourable for dealing with disruptions or price changes, but this benefit will not continue to increase when the energy system has become predominantly renewable (Johansson, 2013b, 601).

In the short term, Johansson (2013b) argues that the electric nature of the renewable system based on intermittent energy sources will make balancing supply and demand a significant challenge. There are solutions to this, such as balancing with transmission lines to neighbours, or batteries. The Nordics are already well connected, and Ollilla (2017) points out that the high degree of supply security from renewable energy sources in the region is partly because they are interconnected (disregarding Iceland). This provides a means for balancing the market based increasingly on fluctuating energy sources (Ollilla, 2017, 31).

5.1.2 Security of demand

This second approach within the objective dimension is from the perspective of the producer. The analysis shows that this can be viewed from two different points of view in the Nordic region. On the one hand, as renewables replace fossil fuels, fossil fuel exporters will see a decreasing demand security. On the other hand, the growing market for renewables creates new opportunities for exporters of renewable energy.

5.1.2.1 Declining fossil energy demand

In regard to the climate, one can argue that the prior warning time for fossil fuels exporters has been long. The first assessment report by the IPCC was published already in 1990, in which

CO_2 and other gases emitted from human activities were identified as a source for the greenhouse effect (IPCC, 1990, xxv). Since then, an increasing amount of research has established this to be a scientific fact (e.g., IPCC, 2021). However prepared oil and gas exporters are for the end of the fossil fuel era, the increased use of RES will obviously negatively affect the security of demand for fossil energy exporters (Denmark and Norway among the Nordics, however on two very different scales). The degree to which will depend on the importance of energy exports for the national economy (Johansson, 2013b, 602).

Norwegian petroleum revenues account for around one fifth of income in the Norwegian national budget, but this accounts for only a bit over half of the income from taxes and fees (Finansdepartementet, n.d.) Although this points to Norway having a diversified economy, decreased fossil fuel demand will lead to a considerable cut in export revenues. Denmark has already vowed to put an end to their fossil fuel exports (Abnett & Jacobsen, 2021), and thus escapes the risk of stranded assets. Arguably, the considerably smaller size of the petroleum sector explains why it seems to be easier for Denmark to choose to dismantle it than in Norway (see 1.3.2).

Natural gas has been named by some as a possible bridge fuel - a less polluting (fossil) fuel to replace coal before renewables take over (Plumer, 2014). The EU taxonomy on sustainable investments may even include gas in the transition phase, although this is currently heavily debated (Simon & Taylor, 2021). Norway provides between 20 and 25 percent of EU gas consumption, and virtually all Norwegian natural gas is exported to the EU and the UK (Norwegian Petroleum, 2021). The EU goal is to decrease the demand for fossil fuels, with no exceptions for natural gas. This autumn's skyrocketing gas prices in Europe in combination with Russia already being the largest supplier has possibly made this even clearer (Bjartnes, 2021b; Eurostat, 2021).

Both EUs climate ambitions and the dependency issues means demand for gas in Europe may decline in the long term. Currently around 5 percent of Norwegian natural gas exports are liquefied natural gas (LNG) which can be transported by ship. Thus, the bulk is non-liquefied natural gas, requiring pipelines to be transported from producer to consumer (Norwegian Petroleum, 2021). If the European demand for natural gas decreases as the Green Deal is set out to, looking for new markets for Norwegian gas is not so straightforward. One option is to construct new pipelines for export, another option is to increase LNG production (which is energy-intensive, and today only exported from one LNG facility on Melkøya with gas from the Snøhvit field (Norwegian Petroleum, 2021). Without considerable investments in infrastructure, Norway will not be able to export its gas elsewhere than Europe. However, natural gas may be viewed as a 'bridge fuel' for Norwegian exports also – a way of generating income in the transition phase before fossil exports are decommissioned.

5.1.2.2 Expanding renewable exports and technology

The renewable energy system brings new opportunities for energy exports and can therefore bring increased security of demand. All the Nordic countries are rich in renewable energy sources (NER, 2021a, 5). Nordic renewable energy can play an important role in both balancing the market within the region and export to each other, but also in exporting to the rest of Europe (the NCES predictions on this is elaborated in the next chapter). As of now, Denmark seems to be the country in the lead when it comes to renewable exports.

Denmark is looking to become a significant exporter of renewable electricity. The country has scaled up wind power production significantly in recent years, and ambitious plans for the world's first energy island(s) have passed in parliament. These two 'energy islands' are connected to offshore wind parks situated in the Baltic and the North Sea and can be connected straight to the importing country without taking the detour via the Danish grid. The production potential exceeds that of domestic demand, and is aimed at exports. There are also plans to develop hydrogen and electrofuel production in connection with these islands (Danish Energy Agency, n.d.; NER, 2021b, 78).

In a commentary in the Norwegian technical weekly magazine (Teknisk Ukeblad), it is claimed Norway has been falling behind in recent developments. Norway has been too focused on the fossil fuel sector to pursue the potential of the increasing demand for renewables (referring to the Hywind Tampen offshore wind park, aimed at electrifying production in two oilfields in the North Sea) (Pettersen, 2021; Equinor, 2021a). The Hywind Tampen offshore (floating) wind park is the first of its kind in supplying oil platforms with electricity. Norwegian energy company Equinor also constructed the first floating wind park in the world in 2017 outside of Peterhead, Scotland (Equinor, 2021a; 2021b). In January 2021, two new areas in Norwegian waters were opened for concessions applications to establish offshore wind parks, Utsira Nord and Nordsjø (Regjeringen, 2020). A white paper from the Solberg government to the parliament on the future of Norway as an energy nation supports both an offshore wind and a hydrogen industry (but also a continuation of the petroleum sector) (Zero, 2021). A new government is now in place in Norway, and this white paper has yet to be processed. There are therefore no concrete plans in place entailing Norway is set to become a large-scale renewable energy exporter.

Sweden is a significant exporter of low-carbon electricity. In fact, despite the impression above as Norway falling behind, Norway and Sweden were both among the top three largest power exporters in Europe in the second half of 2020, due to high precipitation (high hydropower production). Sweden has had a rapid growth of wind power in recent years, and has plans for offshore wind (Starn, 2021; Duxbury, 2021b).

In a renewable system, the grid decides which trade partners a country can choose between. However, hydrogen and other electrofuels have the potential to circumvent this. These fuels can therefore create export opportunities for the regions and countries not connected to the grid (Iceland, Greenland, and the Faroe Islands). These regions have abundant renewable energy sources, but no means of generating income from exporting them due to the lack of interconnector capacity. A study on the possibility of exporting renewably produced hydrogen from Iceland to continental Europe by ship (to Rotterdam) has shown it can be technically feasible and financially attractive already by 2030 (Landsvirkjun, 2021).

In addition to electricity exports, there are opportunities in technology in the renewable energy system, such as carbon capture and storage (CCS) technology. Norway and Iceland are currently in the lead among the Nordics in research and investment in CCS, with the Northern Lights project and the Carbfix operation respectively (NER, 2021b, 105, 115).

Johansson (2013b, 602) brings up the potential of dependency on RES export income, which can create new vulnerabilities. However, the income from RES exports are more distributed between source, producer, transit, and this vulnerability will therefore unlikely be of the same scale as countries dependent on fossil exports (2013b, 602). Renewable energy trade is characterised by interdependencies rather than dependencies and vulnerabilities, which puts renewable energy exporters in a different strategic position compared to the current fossil energy exporters. Therefore, the strategic position of fossil fuel exporters will change - regardless of the size a new RES export industry takes.

5.2 The renewable energy system as a subject

This section investigates the different ways in which renewable energy can act as a generator for insecurity in the countries of the Nordic region.

5.2.1 Economic and political risk factors

This dimension refers to the different ways in which energy can generate insecurity in the economic or political sphere of a state. Because of the more even geographic distribution of RES, Johansson, as others, points to the fewer potential risks compared to in the fossil energy system (2013b, 602). However, some renewable technologies can be vulnerable to terrorist attacks, such as hydro plants and electric grids. Whereas e.g., offshore wind or PV technologies (solar) are less vulnerable (Johansson, 2013b, 602). Regarding the vulnerability of the electric grid, the increasing reliance on electricity has at least two different features in regard to vulnerability to attacks that one can keep in mind. The first is that increased electrification of society (and consequent reliance on electricity) makes the potential consequences of an attack on the grid serious. On the other hand, increased interconnection makes electricity flows and production more dispersed, which may result in an attack on e.g., a specific power line being less harmful for the system as a whole.

The potential for terrorist attacks is of course present in the Nordics as well as in every other region of the world, but this thesis has chosen to focus on what affects the Nordic region specifically, and what this can inform about the renewable energy security concept – there will therefore not a focus on terrorism. In the Nordic region, at least three different economic or political risks have been found to be of importance. The first one is directed specifically at Finland and its relations with Russia. The second risk is the potential for new import dependencies, and the third is related to public acceptance of wind power and power lines.

5.2.1.1 Finland's security challenges

Finland has a history with Russia that puts the country in a different position than the other Nordic countries security-wise. Finland went through two brutal wars with the Soviet Union that resulted in enormous casualties and concession of land to the Soviet Union. During the

Cold War, Finland aimed to take a neutral position between East and West but did not go against Moscow and never joined NATO. Despite thawing relations by the end of the Cold War, the Finnish position towards the large Eastern neighbour has remained pragmatic at the very least. And although Finland cooperates with NATO, they have never joined the alliance (Julsrud & Giverholt, 2021; Ponniah, 2017). This brief history contributes to forming the basis of the context of the Finnish security situation.

Finland is the most import-dependent country among the Nordics and gets the majority of both fossil fuels and nuclear fuels from Russia. In addition to the import of fuels, there is another potential security aspect of nuclear energy that may be characterised as a political risk factor in Finland - the construction, building process and choice of project partners, as found in a report by the NATO Hybrid Centre of Excellence (CoE). Hanhikivi is a nuclear power plant (NPP) planned for construction in Northern Finland, but the construction process has faced several delays. The completion of Hanhikivi NPP will have a large effect on the degree of self-sufficiency in energy in Finland as it has the potential to produce 10 percent of Finnish electricity demand (Ministry of Economic Affairs and Employment of Finland, n.d.; Hybrid CoE, 2019, 28-29).

Fennovoima, the Finnish nuclear energy company founded for the construction of Hanhikivi NPP, signed in 2013 an agreement with a Rosatom (Russian state-owned nuclear energy company) subsidiary, to both deliver the reactor and a ten-year contract for fuels supplied by Russia. Later, 34 percent of Fennovoima's shares were transferred to a Finnish Rosatom subsidiary. The Finnish government requires 60 percent domestic (or EU / EEA) ownership of NPPs in Finland. As the bulk of the Hanhikivi financing would come from Rosatom and the Russian state, there are disagreements whether this can be achieved (Hybrid Coe, 2019, 29-30). Interestingly in 2015, it was revealed that a Croatian energy company that offered to invest in the project (and thus circumvent the EU ownership rule), was in fact Russian-owned – pointing to the completion of the Finnish NPP being in the interest of the Russian state (Hybrid CoE, 2019, 30-31). And as the report concludes: "When a project has national strategic importance for Russia, state involvement can be expected" (Hybrid CoE, 2019, 32).

This example shows how energy issues are closely entangled with security policy and foreign policy. Russian foreign policy and energy statecraft is not the topic of this thesis, but this example was meant to illustrate how Finland has a different strategic reality compared to its other Nordic neighbours.

5.2.1.2 New import dependencies - bioenergy and critical materials

Altogether, the renewable energy system will be less characterised by import-dependencies than the fossil-based because most countries will be able to source at least part of their energy consumption domestically. There is however some potential for new import dependencies.

Firstly, bioenergy is an important source of renewable energy for district heating and power production in Finland, Denmark and Sweden. Finland and Sweden both have large forest industries, and their high share of bioenergy in the energy mix comes largely from forestry residues. In Finland, forest-based biomass accounts for 80 percent of the renewable energy used (Ranta, Laihanen & Karhunen, 2020, 97). Waste and agricultural biomass are also important sources for bioenergy, the latter specifically in Denmark. In Sweden, one fourth of the waste used for electricity production is imported. Of total bio energy, waste excluded, Denmark imports approximately half. Denmark has no forest industry and has low domestic potential compared to Sweden and Finland (Ranta et al., 2020, 101, 109).

Thus, biomass is oftentimes imported in the Nordics, and the potential for import-dependencies in bio*fuels*, or biodiesel, may be even larger. This is bio-based energy for use in transport. In Sweden, all biodiesel is imported (IEA, 2019, 21). A Finnish legislation from 2019 sets the goal to increase biofuels in road transport to 30 percent by 2029 (later increased to 34 percent by 2030) and is at the forefront in developing biofuel technologies (Business Finland, 2019; IEA, 2018, 14-16). The obligation is planned to be met by producing fuels from waste. However, an Yle (Finnish national broadcaster) investigation finds that the Finnish classification of "waste" is broader than in other Nordic countries and includes environmentally harmful palm oil residues (from e.g., Indonesia). Both Sweden and Norway stopped classifying this residue as waste due to sustainability and environmental concerns after it became public knowledge that large shares of biodiesel came from palm oil residues. In Finland, the information about the share of palm oil residues in biofuels is a trade secret of the partly state-owned energy company Neste (Huuhtanen, 2021). Also, the IEA believes Finland's ambitious transport biofuel target will be difficult to meet by domestic sources (IEA, 2018, 14).

If the biomass cannot be sourced domestically, it may become a new source of import dependency similar to oil, although these resources are less geographically concentrated). Biomass imports may also result in additional sustainability and land-use concerns in in the country from which the biomass is imported from. Recall Sovacool's (2017) argument on justice and the challenge of exporting emissions in the Nordic energy transition.

Second, as a potential source for insecurity and import dependence, Johansson points to the critical materials needed in renewable energy technologies and batteries that are concentrated in only a few locations (2013b, 602). Recalling Øverland's (2018) myth-debunking (in 4.3), this might be an exaggerated potential security issue. Additionally, Finland has domestic supplies of all the critical materials needed for electric vehicle (EV) battery production, and good conditions for sustainable extraction (Morgan, 2020), which may mitigate this problem in the Nordic region.

5.2.1.3 Public acceptance

Public acceptance rises as a key challenge (perhaps even *the* key challenge) in renewable energy deployment and can become rather tense political issues. The Norwegian case has already been mentioned, where massive local resistance against onshore wind power plants led to the government scrapping the national plan (Solberg, Skei & Befring, 2019). The Norwegian focus has instead shifted towards offshore wind (although no large-scale plans are yet established, as discussed above), because of fewer conflicts over land-use. Nevertheless, offshore wind is not free of conflict, e.g., the Norwegian Fishermen's Association have expressed concerns over wind turbines in coastal areas (NTB, 2021).

In Sweden, public resistance against wind power in the Southern regions of the country has resulted in new instalments being constructed only in the Northern regions. Lack of sufficient transmission capacity brings significant challenges for transporting the electricity supply to the high-demand South. The latter point is also a challenge in Norway, where lacking transmission capacity between the supply-rich North and the high-demand South leads to substantially different electricity prices for consumers (Elster, 2021). Offshore wind was also in Sweden considered to be the feasible alternative to the more controversial onshore counterpart. But it turned out that also offshore wind plans face opposition because the plants are situated close to the shore (Duxbury, 2021b).

Kirkegaard, Cronin, Nyborg & Karnøe (2021) have found that also in Denmark, public opposition towards wind power is growing. Whereas power production from wind is relatively new in Norway and Sweden, it has a long history in Denmark as smaller, local cooperatives. The authors claim that with the development towards large-scale, industrialised power production aimed at exports, the locals are no longer included in the decision-making - a paradigm shift which has led to lower public acceptance of wind power in general (Kirkegaard, et al., 2021). In Finland, public acceptance to wind power has been more volatile, and has both decreased and increased in later years (83 percent acceptance rate in 2019) (NER, 2021b, 123). The low share of wind power in the Finnish energy mix might partly explain the high acceptance.

Tenggren, et al. (2016, 154), in their investigation into the institutional barriers to grid development, found that in Sweden, local resistance is not a key barrier to the development of the transmission grid. Previous find supports this and finds that it is in contrast to the Norwegian situation (Sataøen et al (2015), as cited in Tenggren et al., 2016). In Norway, establishing sufficient infrastructure for exports has proved difficult due to concerns over increased electricity costs for Norwegian consumers. In the autumn of 2021, Norwegian consumers (as the rest of Europe) experienced unusually high electricity prices, due to a combination of long-lasting dry weather (low hydropower production), and high prices on the continent (Cienski & Hernández-Morales, 2021). International interconnectors, as the newly opened North Sea link to United Kingdom, and electricity exports are blamed by politicians on all sides of the Norwegian political spectrum (Ramnefjell, 2021).

Norwegian industries are worried they will lose their competitive advantage because interconnectors will equalise electricity prices (Øverbø, Aune & Tomer, 2021). There is little focus on the gains of international interconnectors, such as balancing capacity in times of low domestic supply, or the economic gains of electricity export. This is even though the Norwegian energy regulatory authority (NVE) has found that during the winter electricity prices would be 2-3 times higher if it were not for international interconnectors (NVE, 2020, Bjartnes, 2021c).

Gullberg (2013) invested the political feasibility of Norway to contribute to the renewable transition in Europe by becoming the “green battery of Europe” (referring to the potential balancing capacity of the abundant hydro resources). She found that although many decisionmakers and interest groups are positive to the economic gains of exporting electricity, there is less willingness in the near term for the large-scale investments needed to transform Norway to an electricity exporter of the size being "Europe's battery" would require (Gullberg, 2013, 622). Despite even higher green electricity demand in Europe today than in 2013, Gullberg's conclusions were reiterated by Moe, Hansen & Kjær in 2021. The authors even claim that the potential for Norway as Europe's battery has declined since Gullberg's investigation from 2013 (2021, 282-284). The Norwegian political unwillingness to be an electricity exporter is more a matter of political acceptance than public acceptance, but these two aspects will be discussed together in the conclusive analysis.

This subchapter has shown that significant challenges related to the public acceptance of wind power and interconnectors are already in place in the Nordics. With the increased electricity demand that a transition to carbon-neutrality will lead to, more production and interconnections will have to be established. Public acceptance may become a key barrier for this to succeed.

5.2.2 Technological risk factors

The technological risks of renewable energy production are altogether much lower than in fossil energy production. However, there are still a few potential security hazards of the renewable Nordic energy system that will be introduced here.

5.2.2.1 Dams and wind turbines

Dam safety for hydro power is the most significant technological risk, but the risk of dam failures have decreased rapidly over time (Johansson, 2013b, 602). Dam safety has already been discussed above in relation to climate change and changing weather patterns. There have been no fatal dam failure accidents in Norway in contemporary times (NVE, 2021a). In Sweden one person died in a dam failure in Sysslebäck in 1973 (SVT, 2018). Dam failures can also have serious environmental consequences. For example, the dam failure by the copper mine in Gällivare, Sweden in 2000 released heavy metals in the adjacent waterways (SVT, 2010).

Regarding wind power, as discussed in 4.1.2.2, wind turbines can be harmful to birds and wildlife, as well as affect the ability for indigenous peoples to maintain their traditional livelihood. This is when they function properly. However, there can also be safety issues related to the possibility of wind turbines collapsing. In Sweden and Denmark there have been several incidents where wind turbines (all from the Danish company Vestas) have collapsed, luckily without casualties (Viseth, 2020; Nilsen, 2008). Also, in Norway a Vestas wind turbine has failed, when a blade fell of a turbine in the Frøya wind park in November of this year (Børstad, 2021).

5.2.2.2 Hydrogen

Another potential risk can be hydrogen, which is a highly explosive substance (Johansson, 2013b, 603). Compared to conventional fossil fuels however, when used responsibly, hydrogen is safer in many aspects according to the American National Resources Defence Council: it is non-toxic, it burns at a low temperature (low risk of secondary fires), it is light (so it disperses fast), hydrogen needs many times more oxygen compared to fossil fuels to explode - and lastly, because hydrogen has been around for a long time, safety standards are high and have been developed over many years (Tae, 2021).

5.2.2.3 Nuclear waste

An important aspect of the high dependence on nuclear energy in Sweden and Finland, is radioactive waste (this may also fall under the ‘environmental risk factor’ dimension). Finland is working on solving this issue with Onkalo, a state-of-the-art geological waste repository 450 meter below the ground-level currently under construction. Onkalo will store waste from all of Finland's NPPs. It is the first of its kind and has been termed as a game-changer for long-term sustainability of nuclear power (Gil, 2020).

In Sweden, plans for a similar solution have been launched, but the plans are still in public consultations. Fortum, Finnish energy company and the co-owner of two NPPs in Sweden, has warned that the delay of the construction of a waste facility will result in the interim waste storage facility filling up. This can in turn lead to disruptions in electricity supply already from 2024 because the NPPs have nowhere to store their waste (World Nuclear News, 2021). This example shows how the different dimensions of Johansson’s framework interrelate, in this case a technological (or environmental) risk factor of nuclear waste may in turn affect security of supply.

5.2.3 Environmental risk factors

The main benefits for renewable energy are the low impact these energy sources have on the climate compared to fossil energy. All renewable energies (except *potentially* bioenergy) will lead to less CO_2 emissions and less polluted air, compared to its fossil-based counterparts. Bioenergy has to be managed sustainably for it to have any climate effects, so that the emission-cuts do not exceed the emissions-gains of removing carbon sinks (the biological material the fuel is produced from). Most renewable energies also have a great benefit as it does not lead to air pollution, particulate matter, or gases (Johansson, 2013b, 603). However, the land-use (direct and indirect) that renewable energy technologies require may have harmful consequences for ecosystems and biodiversity (Johansson, 2013b, 603), as discussed above. The analysis of this chapter is summarised in Figure 2 below.

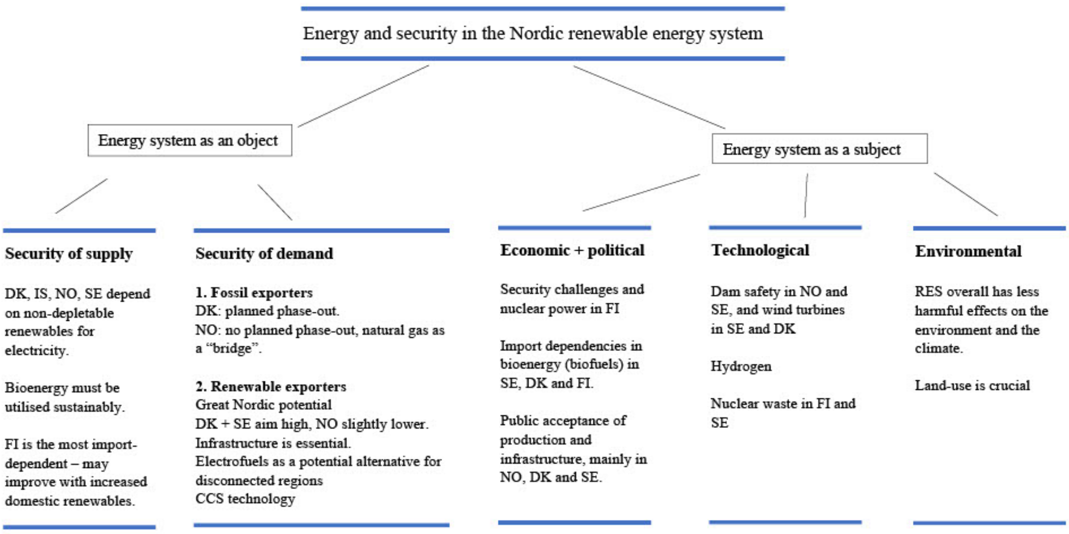

Fig.2 Energy and security in the Nordic renewable energy system, adapted from Johansson (2013a, 200). Denmark (DK), Finland (FI), Iceland (IS), Norway (NO), Sweden (SE).

5.3 Concluding remarks for this chapter

This chapter has shown the diversity of the Nordic region, and the diverse implications of renewable energy deployment. The discussion above shows that renewable energy sources affect security also in the Nordic region. Certain aspects, such as demand security, brings diverging challenges and opportunities for fossil fuel exporters and renewable energy exporters. Other aspects, such as the Finnish security situation and relations with Russia, are highly context-specific.

Of the security challenges that arise with renewable energy, some are new, and some are similar to the ones of fossil fuels. Of the new, public acceptance rises as a key political risk factor, perhaps to a larger extent than for fossil fuel production. The benefit of relying on domestic renewable energy production, also brings the challenge of local acceptance to energy infrastructure. In the fossil-based energy system, people in import-dependent countries had to relate and respond to energy infrastructure and production facilities to a substantially lesser extent because they were located in a different country. And the lower energy density of renewable energy sources means that more production facilities must be established to deliver the same energy output, amplifying potential conflicts over land-use.

The potential import dependencies of bioenergy bear some similarities to traditional threats to energy security, and vulnerabilities related to import-dependencies of oil or gas. However, the number of countries to import from are likely to be larger, making the importers less vulnerable to supply-cuts. Additionally, at least part of the biomass consumption can be covered domestically (or within the region), making imports more a matter of cost-efficiency than security of supply. This gives importers stronger leverage than in a fossil energy system.

Johansson conclusively argues that his own typology fits well for analysing renewables (2013b, 604), supporting the outline of this thesis. This section has shown the utility in using this framework. Even though it is extensive, it has provided a thorough overview of the various implications of renewables and the diversity of the region. The first research question “In which ways does renewable energy sources affect energy and security in the Nordic countries?” has now been answered. The next chapter explores the Nordic Clean Energy Scenarios (NCES) and their compatibility with national renewable plans, to investigate the national and the regional approach and bring further insight to the energy security of renewables.

Chapter 6: The regional vision meets national strategies

The former chapter outlined the different ways in which renewables can affect the energy-security nexus in the Nordic region. The second part of the analysis will build further on this, aiming to explore the possible compatibilities or discrepancies between regional visions and national strategies. The vision of the Nordic Council of Ministers is for the Nordic region is to become the most sustainable and integrated region in the world (Nordic Council, n.d-a). However, as we have seen both from the theoretical basis and the empirical investigation, neither renewable energy deployment nor international interconnectors are always straightforward to establish - and what may be considered good for energy security in a region may not be considered the same by each nation the region comprises. This chapter dives deeper into this latter potential tension, by investigating the compatibility between the Nordic Clean Energy Scenarios, and the respective renewable energy strategies in the five Nordic countries.

6.1 Main findings of the Nordic Clean Energy Scenarios (NCES)

The NCES is a detailed technical report (with extensive additional resources online), and not everything is relevant for the purpose of this thesis. Therefore, only the main findings will be presented here.

6.1.1 The three scenarios

The **Carbon-Neutral Nordic (CNN)** scenario is the pathway towards carbon-neutrality that has the lowest cost, considering the current national plans, strategies, and targets. In the **Nordic Powerhouse (NPH)** scenario, the Nordic region takes a leading role in the energy transition in Europe, exporting renewable electricity and fuels, and carbon storage opportunities. The **Climate-Neutral Behaviour (CNB)** scenario explores an option where behavioural change and energy efficiency measures leads to lower demand for energy and materials. The most important aspect that makes these scenarios a significant contribution to the number of already existing energy outlook scenarios, is that all three scenarios reach carbon-neutrality by 2050 (NER, 2021b, 7).

6.1.2 The five solution tracks

The NCES identifies five different solution tracks, of which the three different scenarios for carbon-neutrality employ to different degrees. The first of this is **direct electrification**, - the cornerstone of all three scenarios. By *direct* electrification, the NCES refers to the process of directly substituting fossil-based activities with electricity, e.g., fuel combustion with electric cars. All three scenarios see a rapid increase in electrification (NER, 2021b, 55-57). Electricity is an efficient energy carrier and is therefore the cheapest solution in most cases (NER, 2021b, 58-59). The NCES projects that electricity demand grows (from 420 TWh in 2020) by 40-100 percent by 2050. A possible maximum is a 140 percent increase – in the case of large export volumes of Power-to-X fuels (NER, 2021b, 42, 60-61). The increase in electricity demand will be supplied mostly by wind power (NER, 2021b, 146).

The second solution track of the NCES is **Power-to-X** (PtX): using (renewable) power to produce fuels, either hydrogen that can be used directly, or converted to other fuels (ammonia, methane, etc.). This solution track depends on which scenario materialises: the cost-efficient CNN scenario predicts only a moderate increase in PtX demand (36 TWh in 2050), whereas the NPH scenario predicts it to become a large industry (217 TWh in 2050). PtX is neither a particularly efficient nor cheap solution but can be useful in sectors that are difficult to electrify (NER 2021b, 70-73). As the cost of producing hydrogen is connected to the electricity price, the Nordics with abundant, cheap electricity are in a good position to produce competitive PtX (NER, 2021b, 74-77). Because of hydrogens potential in industry, for efficient energy transport, for storage and grid-balancing, and export-opportunities to the EU, future demand for PtX may even exceed that of the NPH scenario (cases of 'HighPtX' and 'Very-HighPtX') This would require a manifold increase in mainly wind (off- and onshore) capacity (NER, 2021b, 77, 78-85). In the case of 'HighPtX', Norway will become a significant exporter of PtX to Europe. In a case of low or no PtX, Norway emerges as the Nordic powerhouse, and the rest of the region becomes net-exporters of electricity – this therefore requires substantially higher interconnection capacity within the Nordic region (NER, 2021b, 133-136).

The third solution track is **bioenergy** - which is expected to still play an important role in the Nordic energy system towards 2050, but for different purposes. As electrification is still the most efficient solution in all scenarios, bioenergy should no longer be used for power and heating, but instead in transportation (heavy and long distance) and industry which are harder to electrify. In Finland, Sweden, and Denmark, approximately 25 percent of total energy consumption comes from biomass (peat excluded), Finland reaching close to 30 percent.

Norway gets around 6 percent of energy from biomass, and Iceland virtually nothing (NER, 2021b, 90-92). Biomass can be used directly in the heat and power plants, or the combustion engines that we already have. It can also be stored easily and at a low cost and when combined with CCS (BECCS) it may even provide negative emissions. Bioenergy from forest industry biomass has the largest potential in the Nordics, largely in Sweden and Finland (Denmark has low domestic potential) (NER, 2021b, 93). Nordic forests are growing faster than harvest, so the Nordic biomass stock is increasing. Still, NCES recognise that imports may cover a small share of consumption due to its lower costs compared to domestic sources which can be expensive to convert to fuels (NER, 2021b, 94-103).

The fourth solution track is capturing emissions through **carbon capture and storage** (CCS). According to the NCES, CCS is essential for the Nordics to reach carbon-neutrality. It is estimated that approximately 12 percent of total emissions in the Nordics in 2050 are captured and stored. CCS technology can compensate for the emissions that are difficult to abate in other ways and is therefore essential for reaching carbon-neutrality (NER, 2021b, 105). CCS may allow for the continued use of fossil fuels, as is the case in the cost-efficient CNN scenario (NER, 2021b, 77). The technology is still new, and a lot is still uncertain[6], and because CCS is largely a technology aimed at domestic emissions reductions and less a matter of renewable energy and energy security, there will therefore not be a big focus on CCS in this thesis.

The fifth and final solution track is **behavioural change**, which has the potential to either be a driver for reaching carbon-neutrality, or a barrier. The first aspect of this is behavioural change which results in lower energy demand. The CNB scenario reaches carbon-neutrality through this, where behavioural change leads to overall lower consumption of energy and materials. The other aspect of the behavioural solution track is public acceptance. As all NCES scenarios require a massive scale-up of wind power, social resistance to these projects is listed as a key barrier to the transition towards carbon-neutrality (NER, 2021b, 118-119, 123, 147). Public acceptance and conflicts with other interests are mentioned as a possible barrier to the rapid

[6] E.g. expected costs are still uncertain due to the lack of large-scale installments (NER, 2021b, 110-113).

increase in RES deployment and the power grid investments that this would require (NER, 2021b, 86-88) – but there is no focus on possible ways to overcome this.

The NCES also emphasise that infrastructure is key in order to facilitate the transition towards carbon-neutrality. It estimates an increase of 60-70 percent in exchange capacity between Nordic bidding zones between 2030 and 2050, as well as increased interconnectors connecting the Nordic region with other markets (NER, 2021b, 129). NCES also emphasise more cooperation. Although already interconnected, important decisions regarding the Nordic electricity system are rarely taken jointly at the Nordic level, despite corresponding commitments and the many benefits of joint decision-making and planning in infrastructure development, renewable energy, PtX, and CCS (NER, 2021b, 130).

6.1.3 Most important predictions of the NCES

At least six lessons can be taken from the Nordic Clean Energy Scenarios that are particularly relevant for this thesis. First, electricity demand will increase a lot in the Nordic region towards 2050 due to electrification, electrofuel production, and exports. This will require more production, and major investments in grid and interconnectors. Second, the increased electricity demand will mostly be covered by wind power. Third, bioenergy will still play a role towards 2050, with all the benefits and challenges that have already been discussed throughout this thesis. But the role of bioenergy will be different than today. Fourth, The Nordic region has the potential to become a significant exporter of electricity and power-to-x fuels, and thus play an important role in the EU energy transition.

Furthermore, nuclear energy continues to play a role, but nuclear is not considered to be a dealbreaker in either direction for reaching carbon-neutrality, and the NCES predicts RES deployment to increase regardless of the status of nuclear energy after 2040 (NER, 2021b, 166, 168). The consequences of removing nuclear energy from the Nordic electricity supply are recognised, both in regard to the balancing capability and the electricity it generates (especially as demand increases) but it is still not considered to be decisive (NER, 2021b, 167, 170).

Lastly, the carbon-neutral Nordic region requires increased cooperation and integration, as well as joint planning and decision-making. Renewable energy plans are currently at the national level, and there is no joint plan for reaching carbon-neutrality as a region. The NCES emphasise that reaching one of the three scenarios is possible, but only if all five countries "... do what is necessary..." (NER, 2021b, 130). The interconnected Nordic grid is an essential tool for achieving carbon-neutrality, and as changes in one part of the grid affect the rest of the system, coordinating on a regional level in grid development will be more efficient and have lower costs. The NCES recommends coordinated strategies on the development of offshore wind, PtX production, and CCS (NER, 2021b, 140).

6.2 The Nordic vision meets national plans

The Norwegian energy regulatory authorities projection of the developments in Nordic power production until 2040 (NVE, 2019b) is a synthesised report based on the respective countries energy policy, plans, projects and potential, as well as current knowledge of technological developments and price developments. The analysis of the future power production in the EU members among the Nordics (SE, DK and FI), is based on the EU National Energy and Climate Plans (NECP), that all EU members had to compile as a commitment to EU climate and energy goals (NVE, 2019b, 5-6). The NVE report has a different starting point than the NCES (which assumes the goal of carbon-neutrality by 2050, and backcasts ways for the Nordic region to reach it), and rather projects the likely power production developments based on current policy. It is therefore considered suitable for testing the compatibility and revealing possible discrepancies with the NCES.

There are a few challenges related to comparing these two reports. First, the timeframe of the two reports are different, NCES projects towards 2050, whereas NVE projects towards 2040. However, in conjunction with the report publication, an online tool was launched by Wråke, et al., where one can explore the full modelling results. In the following analysis, this tool has been used to find data for 2040[7]. Additionally, the NVE report focuses on power production exclusively, whereas NCES analyse the whole energy system. This is not considered to be a major setback for the analysis, as the NCES as presented finds that electrification across all sectors is the main solution, and that changes in the energy system is by and large a result of

[7] In the following analysis, only the "Power Production by Energy Source" has been used, found under the tab "Power & DH". Data from each scenario (CNB, CNN, NPH) was consequently retrieved from the left tab for the year 2040, as well as the country selection (Iceland was excluded). The reference "Wråke et al., 2021" refers to this operation.

the increased electricity demand this causes. This does however mean that the following comparison is focused almost exclusively on power production. Lastly, because Iceland is not part of the Nordic electricity market, it is excluded from the NVE synthesised report. This is more of a problem, but it was not easy to find alternative data for Iceland fit for this purpose, so in the following analysis Iceland is unfortunately excluded.

The findings from the comparison in power production between the three Nordic Clean Energy Scenarios – Climate Neutral Behaviour (CNB), Carbon Neutral Nordic (CNN) and Nordic Powerhouse (NPH) (NER, 2021b) and the NVE synthesised analysis based on current policy projections (NVE, 2019b) is summarised in Table 1 below. Bioenergy is not included in the NVE projections but is discussed below.

	Total	Hydro	Wind	Solar	Nuclear
NVE	510 TWh	230 TWh	160 TWh	20 TWh	46 TWh
CNB	545 TWh	244 TWh	173 TWh	28 TWh	78 TWh
CNN	564 TWh	244 TWh	191 TWh	28 TWh	78 TWh
NPH	620 TWh	244 TWh	233 TWh	30 TWh	87 TWh

Table 1. Power production by energy source in the Nordic countries in 2040, Iceland excluded.

6.2.1 Total electricity production, and hydro power

On a Nordic level there will be a net increase in total power production of almost 100 TWh to 510 TWh towards 2040, according to NVE (2019b, 3, 6). All NCES scenarios projects a higher power production: from 545 TWh in CNB, up to 620 TWh in NPH (NER, 2021b, 61; Wråke et al., 2021). Recall that the case of 'High-PtX' could require even more electricity than the NPH scenario predicts. The dominating source of energy for power production continues to be hydropower according to the NVE (2019b, 3, 6). NVE projects that hydropower production may increase slightly (almost entirely in Norway), to a total of 230 TWh in 2040 (from ca. 220 in 2019). The slight increase in production NVE credits partly to more water in the magazines due to weather changes, and partly due to new production facilities, or upgrades and enlargements (2019b, 9-10). Recall the arguments on the changing climate presented above in Johansson's (2013b) framework - although the NVE specifies that it is too early to say that the increase in hydro capacity is due to climate change, it is not ruled out (2019b, 9-10). All three NCES scenarios predict hydropower production to be at 244 TWh in 2040 (Wråke et al., 2021), only a moderate increase from current numbers.

6.2.2 Wind power

Both NVE (2021b) and the NCES predict wind power to be the fastest-growing energy source toward 2040. NVE predicts total Nordic wind power production to increase by approximately 110 TWh to 160 TWh by 2040 (2019b, 14). The reason why the increase in wind power production is higher than the net increase in power production, is because the latter number considers the decommissioned nuclear and fossil power production (2019b, 6). The NCES predicts between 173 TWh and 233 TWh of power production from wind resources by 2040 (Wråke et al., 2021). Even the very lowest of the NCES scenarios predict more than 10 TWh above the NVE projection, although NVE specifies that their number has a leeway stretching from 154-172 TWh (2019b, 14) (which almost overlaps with the CNB scenario).

NVE predicts that Nordic wind power will continue to develop in all Nordic countries. NVE (2019b, 14-15) predicts that Norwegian wind power construction (which grew rapidly in the years before the report was published) will continue to grow. However, this report was published before Norwegian onshore wind plans were scrapped, or at least paused for the time-being (Solberg, Skei & Befring, 2019). NVE (2019b, 16) puts forth three scenarios of low, medium, and high wind power deployment in Norway, of which the low scenario currently seems to be the one materialising (19 TWh of wind production established by 2025, with no growth until 2040). Currently, no new onshore wind projects are planned (NVE, 2021b). The prospects of offshore wind are possible, but still uncertain (2019b, 17).

In Sweden, a rapid increase in wind production is expected in the years until 2040. A tripling of current production numbers to a total of 60 TWh is expected to be necessary in order to reach Swedish energy policy development goals - of which one-third will be offshore (NVE, 2019b, 18). In Denmark, wind power production has a long history, but as turbine technology has developed rapidly in later years, plans are in motion to replace older turbines with fewer and larger turbines. A total of 22 TWh is expected to be produced from onshore wind, and as much as 31 TWh offshore by 2040. Finnish wind power production is also expected to increase to around 18 TWh by 2040 (NVE, 2019b, 18-19). Although NVE predicts a rapid growth in wind power, it is still considerably lower than the NCES.

6.2.3 Solar power

NVE (2019b, 20) finds that solar power will also grow in the Nordics and will reach a modest 20 TWh by 2040. The NCES also predicts a modest increase in solar power and a small variation between the different scenarios (28-30 TWh), however higher than NVE (Wråke et al., 2021). The modest predictions of solar power by both NVE and in NCES are obviously attributed to the fact that the highest power output from solar generation occurs at the times of lowest demand. In the Nordic region heating in the winter is a major source of energy demand, whereas in warmer regions demand is high during the summer due to the need for cooling.

6.2.4 Nuclear power

Currently, around 80 TWh of nuclear power is produced in Finland and Sweden. NVE emphasises that nuclear energy will play an important balancing role in the Nordic electricity system also towards 2040, but production will decrease to 46 TWh in 2040 (23 TWh in Sweden and Finland each). Swedish nuclear power appears to be eventually discontinued, but there is no political decision yet - although the goal is for electricity production to be 100 percent renewable by 2030 (NVE, 2019b, 23). Two reactors (Ringhals 1 and 2) were decommissioned by the end of 2020 (Vattenfall, n.d.) and if the existing reactors are not decommissioned before their operational lifespan requires it, the final reactors will be decommissioned before 2050 (NVE, 2019b, 23-24). In Finland, two new reactors are expected to start up before 2030 (Olkiluoto 3 and Hanhikivi 1). All reactors are expected to be decommissioned after the end of their technical lifespan, which means four reactors will be closed down before 2040. Only the two newly constructed reactors will be operational in 2040 (NVE, 2019b, 24).

The NCES expect nuclear power production to remain at current levels, as all plants are operational for their technical lifetime. The difference in nuclear power production between NCES and NVE is because the NCES projects technical lifetime *extensions* of the current nuclear fleet (NER, 2021b, 168), whereas NVE sees a gradual phase-out with no extensions. The CNN and the CNB scenarios expect nuclear power production to be at 78 TWh in 2040 (47 TWh in Sweden, 30 TWh in Finland), while the NPH expects 87 TWh (47 TWh in Sweden, 40 TWh in Finland) (Wråke et al., 2021). This is assumed to be due to different projections regarding Hanhikivi 1 (see NER, 2021b, 168). The balancing role of nuclear in the Nordic power system and the challenges that can occur if it is decommissioned is recognised in both NCES and NVE (NVE, 2019b, 23; NER, 2021b, 167).

6.2.5 Bioenergy

Bioenergy is important in the overall energy mix of the Nordic countries, especially in transport and combined heating and power production. Of the total energy consumption in Finland, Sweden, and Denmark, approximately 25 percent comes from biomass (peat excluded) (NER, 2021b, 92). However, it is not included in the NVE analysis towards 2040, because it is not significant in the electricity sector. The NCES sees an important, but shifting role for bioenergy towards 2050, as presented in 6.1.2, from electricity and heat production to transport and industry. Bioenergy is considered important for facilitating a renewable energy transition, and is the largest source of renewable energy in all three countries (Energistyrelsen, n.d.; Energimyndigheten, 2019; Ministry of Agriculture and Forestry of Finland, n.d.). In Denmark, Finland and Sweden, district heating systems utilising bioenergy are the most common form of heating (NER, 2021a, 37). The NCES favour electrification over bioenergy for power and heat because it is more efficient (although it can still be used for these purposes demand is high) (NER, 2021b, 92).

NCES claims biomass is an abundant (although not unlimited) resource in the Nordics (NER 2021b, 93-93). At the launch event for the report, this was criticised by climate-policy expert Oras Tynkkynen who claimed *sustainable* biomass is indeed a scarce resource in the Nordics, and that large quantities of biomass are already imported. This may implicate an “export” of the environmental impact, i.e., the carbon-neutral Nordic region relies on increasing emissions elsewhere in the world – recall from 1.3.4 that Sovacool (2017) also found this to be a key concern related to energy justice in the Nordic region. Additionally, increasing the demand for biomass can lead to higher biodiversity loss, and decreasing carbon sinks, meaning fewer negative emissions. The response from the NER was that a sensitivity analysis has found that the Nordics can manage without importing biomass (NER, 2021c, from 45:10). As has been previously discussed, (5.2.1.2), the feedstocks used to produce biofuels are oftentimes imported, sometimes with dubious sustainability characteristics.

6.2.6 Grid expansion

The NCES consider grid expansions to be crucial for reaching carbon-neutrality in the Nordic region and find an increase in exchange capacity of 60 to 70 percent between Nordic bidding zones to be necessary (NER, 2021b, 21). The need for grid investments is also recognised by the Nordic transmission system operators (TSO). The Nordic Grid Development Plan 2019, a joint report by the four Nordic TSOs, finds there to be both a significant need, and significant socio-economic benefits in expanded interconnector capacity in the Nordic region. The gradual replacement of steady and predictable power generation (nuclear, in Sweden mainly), with weather-dependent and fluctuating generation (notably wind power) is a major driver for grid investments (Statnett, Fingrid, Energinet & Svenska kraftnät, 2019, 4, 7).

Nordic TSOs plan to invest more than 15 billion euros in the grid before 2029 (historically high). This is done to increase transmission capacity, reduce bottlenecks, and to facilitate integrating more renewables, of which primarily wind power (Statnett, Fingrid, Energinet & Svenska kraftnät, 2019, 3, 9). Updated plans will be published every other year, because closer cooperation in grid planning, as well as knowledge and data sharing, has been recognised to be a benefit for the Nordic interconnected region (Statnett, Fingrid, Energinet & Svenska kraftnät, 2019, 43). Also, Tenggren et al. (2017, 155) point to the importance of joint planning in grid development.

6.3 Key differences and conclusions from this chapter

What becomes clear from these numbers is that current policies are not following the pathways of the Nordic Clean Energy Scenarios - all production numbers are consistently lower. Only from these numbers we can deduce that the current development is closer to the lower consumption scenario (CNB) than the higher consumption scenario (NPH). However, looking solely at power production does not say much about whether the Nordic region is on track in achieving carbon-neutrality following the CNB scenario pathway. Recall that this scenario reaches carbon-neutrality through behavioural change which ultimately lowers energy demand. Based on this analysis there is no proof that this is currently happening in the Nordics. It is more likely that the direct electrification and consequent increased electricity demand and power production that is the core of all three NCES scenarios, is not developing as fast as necessary to achieve carbon-neutrality by 2050.

Nuclear and hydro are emphasised as important balancing capacities by NVE and play a larger role in this report than in the NCES. This can at least in part be explained by total power production being lower, so they have a bigger share of the total. Neither NVE nor NCES sees any significant increase in hydropower production, or in nuclear power production. The NCES still sees the continuing important role of bioenergy toward 2040, but as neither NVE nor national authorities forecast production numbers towards 2040 (complicated by bioenergy only partly being used for power production), we do not have numbers for comparison. However, the important role of bioenergy in the future is firmly recognised by all national authorities as well, but it is less clear whether the changed use from power and heat to transport and industry that the NCES favours is compatible with national strategies.

The NCES sees no fossil fuel power production in the Nordics by 2040 (Wråke et al., 2021), NVE estimates approximately 15 TWh of fossil power production in 2040, largely because domestic peat replaces coal and oil in Finland (NVE, 2019b, 25-27). However, the Finnish goal of reaching carbon-neutrality by 2030 came after this report, and there are currently proposed plans to cut the use of peat in power production to reduce emissions. This is a delicate subject in Finland as peat production is a large employer (Yle, 2021). Recall a corresponding argument from Sovacool (2017) on energy justice and loss of jobs as a barrier for the Nordic low-carbon transition. Regarding grid expansion, the national TSO's seem to see the value of closer cooperation, as the NCES – but recalling the discussion on public acceptance, the key barrier to grid expansion does probably not lay at the TSOs.

The second research question "How compatible are national strategies with the regional vision on renewable energy in the interconnected Nordic region?" has now been answered. Again, it must be emphasised that Iceland is excluded in this analytical chapter. This chapter has shown that there are considerable differences in predicted electricity generation based on current policies, and with the level necessary to reach carbon-neutrality according to the NCES. In conjunction with the insights from the former chapter, many potential tensions arise between the regional vision on the one hand, and the national strategies and security situations on the other. These discrepancies will be explored further in the next and final chapter, with the help of Scholten & Bosman's (2016) two scenarios for renewable strategies.

Chapter 7: Conclusions: Security approaches, renewable energy, and the new energy security

This chapter begins by an exploratory analysis of the Nordic renewable strategies through the use of Scholten & Bosman's (2016) two scenarios. Based on the insights from this thesis, five assumptions on the conceptualisation of renewable energy security will then be presented. It is further discussed whether these insights from the Nordic region can be employed elsewhere, along with implications for further research and policy. The final conclusive subchapter ties it all together.

7.1 Security approaches and renewable energy

Scholten & Bosman's (2016) thought experiment will be used as a framework for analysis to discuss further the different approaches to RES deployment and its relation to security perceptions. Recall that the technical characteristics of renewable energy sources and the market implications these have, ultimately lead to two different approaches on how the international renewable energy system could materialise. The National scenario emphasises security of self-sufficiency in domestic energy supply, and the Continental scenario emphasises cost-efficiency and imports. It was discussed in 4.5 how these scenarios can both have beneficial effects for energy security, and that the chosen strategy is affected by security and strategic considerations. The aim is not to characterise energy policy, but to explore the approaches in light of these scenarios. This theoretical experiment is considered to illustrate important aspects of how renewable energy strategies and security perceptions adhere. It will therefore be used in this final conclusive analysis of the five Nordic countries.

7.1.1 Denmark

Denmark has left behind fossil fuel exports and aims to become a significant exporter of renewable energy. Especially the planned offshore wind parks (the energy islands) emphasise this goal, as they are directed straight at exports and not to cover domestic needs. The approach taken by Denmark seems to be leaning towards the continental scenario, even recognising the potential to take a leading role within this scenario. Denmark has abundant wind resources at sea and aims to exploit these to export electricity and perhaps also electrofuels. The planned offshore wind exports may even bypass the increasing challenges of public acceptance of wind power, which may become a challenge for further developments onshore. Additionally, Denmark is importing the resources they are lacking (or at least where domestic supplies are not cost-competitive), such as a large share of their biomass. Biomass is an in important energy source in Denmark, but domestic supplies are low, as discussed in 5.2.1.2 and 6.2.5. This also points to a more continental-leaning approach to renewables, where cost-efficiency is favoured over the security in domestic supplies.

7.1.2 Finland

Finland is the most import-dependent of the Nordic countries. Imports are largely from Russia, the country they share the most complicated history and contemporary security issues with. Bioenergy is Finland's largest source of domestically produced renewable energy. However, biofuels may be imported, as discussed in 5.2.1.2. Bioenergy (from domestic forestry residues) is considered to increase Finnish self-sufficiency in energy (Ministry of Agriculture and Forestry of Finland). It is not unlikely that the high biomass ambitions in transport are a means to decrease the dependence on Russian oil imports. However, the NCES sees a changing role for bioenergy, entailing that Finland should use less bioenergy for electricity production or heating, and install more windmills (and even rely on imports). Although it can be more cost-effective, this may conflict with the aim to become more self-sufficient.

The continued use of peat in replacing coal and oil as predicted by NVE (see 6.3), is difficult to see as anything but a means of increasing self-sufficiency. While the peat industry is a large employer in Finland and a source of domestic energy to replace imports of fossil energy, it is highly uncorrelated with the climate goals. Currently, climate goals seem to prevail, and peat production is decreasing. Finnish nuclear fuel is largely imported from Russia but can in theory be imported from other uranium producers, so nuclear energy in Finland is not really a dependency issue. Still, the ownership challenges of the Hanhikivi 1 NPP (5.2.1.1.) illustrate how Russia wants to maintain an influence over Finland. This case might illustrate well the pragmatic role Finland has had to take ever since the 1940's. The approach taken by Finland seems to be leaning towards the national scenario, favouring security in self-sufficiency over cost-efficient imports. This can easily be seen as a product of the security situation and as a means of decreasing dependence on imports. However, an ambition for self-sufficiency would have to be balanced against actively going against Russian interests. Additionally, independence in renewables is perhaps less safe than interdependence (as discussed in the introduction of chapter 5).

7.1.3 Iceland

Iceland is distinctive in the Nordic region, because of its isolation from the Nordic grid. It makes less sense to talk of a specific approach to renewable energy deployment, as Iceland obviously does not have the option to choose between importing or producing domestically. The same goes for the autonomous regions of Faroe Islands and Greenland. Although domestic sourcing of RES has the potential to decrease import-dependencies of fossil fuels, the isolation makes renewable imports (and exports, for that matter) impossible, except for potentially electrofuels. Electrofuels are an unlikely solution for imports however, due to their high cost. The isolated regions in the Nordic are therefore in a "forced" national situation where they cannot choose cost-efficient imports. This makes it less relevant to discuss any type of approach to renewable energy in relation to Scholten & Bosman's (2016) theory.

7.1.4 Norway

Although Norway is a rather significant exporter of renewable electricity, the Norwegian approach is arguably more national than continental. Norway can produce renewable electricity cheaply and efficiently. Thus, there is potentially a large export revenue to be generated from electricity, or electrofuel exports. According to current policies, hydropower has limited increased potential, and only the very lowest of the NVE projections of wind power is looking to materialise. Onshore wind power is very contested, and there are no fixed plans for large-scale offshore wind production unlike in Denmark. And as discussed in 5.2.1.3, high electricity prices in the autumn of 2021 were attributed partly to electricity exports and international interconnectors. Recall that the NCES require that Norway become the "powerhouse" of the Nordics, even Europe. Although Norway is highly connected to the Nordic neighbours, and through several interconnectors to Europe, Gullberg (2013) and Moe et al. (2021) do not see Norway becoming Europe's balancing capacity as politically feasible (see 5.2.1.3).

The Norwegian approach seems to lean towards a national approach, aiming to not rely on either import or export of renewables. This is facilitated by already being self-sufficient in renewable electricity (although imports take place in times of low supply). The Norwegian case brings about an aspect that is not addressed in Scholten & Bosman's (2016) theory: what determines whether a resource-rich country chooses to take a leading continental role. In Norway, keeping electricity prices low seems to be favoured over the economic gains of export.

But there may also be other dynamics in play that shapes this decision which have not been investigated in this thesis.

7.1.5 Sweden

Sweden seems to take a more continental-leaning approach of exporting renewable electricity, similar to Denmark. Sweden is a significant electricity exporter, and has been so for years, having the stability in hydropower, nuclear and bioenergy, combined with efficient wind power. On the other hand, exporting surplus energy alone can hardly be seen as a continental approach, as the Norwegian case illustrates. As far as this analysis has shown however, Sweden seems less reluctant than Norway regarding exports.

One can see the Swedish debate around nuclear energy in light of these two scenarios. Should Sweden eventually phase-out nuclear energy, as both the NVE report and the NCES predict, Sweden will no longer be self-sufficient in electricity. That is unless enough wind power is constructed to replace it. And as wind energy is variable, balancing capacity from other countries might be increasingly necessary in times of high demand and low domestic production. Deciding on a nuclear phase-out lean towards a continental approach, where costs are favoured over self-sufficiency. However, hydro power also provides an important domestic balancing source, making the situation in Sweden different than in for example Finland.

7.1.6 Summary

First of all, this part of the analysis ought to be seen as exploratory. A more in-depth analysis of the specific energy policies of the five countries would be necessary to make an accurate classification in the Scholten & Bosman (2016) scenarios. Still, some interesting topics can be drawn out of this exploratory task:

First, within the continental scenario of the framework by Scholten & Bosman, countries may indeed take on different roles. Forecasting that renewable production will happen smoothly where it can be done most efficiently and cost-competitively, seems to be too simple when explored in practice. Countries may choose not to be a provider of renewable energy even if they have a great potential. This seems to be the case of wind power and interconnections Norway. There is not just a ‘make or buy’ decision to be made, as has been discussed before. There is an additional ‘trade or keep’ decision for the countries in which this is applicable. This is a consequence of the technical traits of electricity trade and the redistributed benefits discussed in 4.1.2.1. Electricity exports affect the home market, differentiating them from for example oil exports. The Scholten & Bosman theory seems to lack an understanding of the mechanisms shaping the actions of exporters. Additionally, the authors expect that taking the national approach has little or no international geopolitical tensions (2016, 280). However, there may be new tensions arising from countries that refuse to 'share' through further expansion of production and infrastructure. This may even result in it becoming infeasible to isolate.

Additionally, in all countries, increased production of renewable energy (especially onshore wind) may be delayed or hindered by domestic public resistance. This shows how it is more than the available resources and the security situation that determines the renewable energy strategy. The same goes for interconnectors. It should be noted that with the interconnections that are already established in the Nordic region, taking an extreme national approach is not possible, as no countries (Iceland excluded) are isolated from the regional grid. Because of the high level of interconnectedness, a decision regarding exports made in one country will to some extent affect all other members of the grid-community. Thus, it will have little effect in practice if Norway aims to not export to Europe, but Sweden does (this is perhaps irrelevant since Norway is already exporting but shows the complexity of this issue).

Lastly, it should be considered that the NCES are inherently 'continental' in their approach, and it is taken for granted that the Nordic countries will take the same approach for the success of the carbon-neutral Nordic region scenarios. It is additionally assumed that within each scenario, all Nordic countries will pursue the same scenario, which is of course not necessarily the case (NER, 2021b, 131). As discussed in chapter 2, one can assume regional cooperation is favoured in the NCES. The lack of understanding of the possibility that some countries may favour a national-leaning approach is a key criticism of the NCES. This can be important barrier to the realisation of either of the carbon-neutral scenarios. In order for the Nordic region to become carbon-neutral, the Nordic countries would have to make decisions that sometimes would favour the region over the nation. This may pose challenges. Altogether, while the Scholten & Bosman (2016) theory does not explain everything, testing their approach has been a useful exploratory task that has provided interesting points and new questions for discussion and research.

7.2 The renewable energy security

The following subchapters will use the insights gained from the theoretical background and the empirical investigation of the Nordic region to answer the final research question:

> In which ways can the Nordic case inform about the ways in which renewable energy sources can change and affect the concept of energy security?

The aim is not to define energy security, but to explore the concept. This analysis has raised potential issues that may arise with increased renewables in the Nordic region, and certain insights can be taken from this:

1. **Regional**

As the literature predicts (Scholten & Bosman, 2016; Hancock, Palestini & Szulecki, 2020), this study of the Nordic region supports the prediction that the renewable energy system will be a regional one. Many of the challenges related to the widespread inclusion of variable energy sources are overcome in the Nordic region because of interconnection and cooperation, which facilitates making use of a variety of energy sources. Additionally, as the literature presents, the technical characteristics of electricity prevents it from being transported for long distances due to energy loss, which is why regional energy markets make more sense than global markets in the renewable system.

One could further argue that the interdependent character of (renewable) electricity trade makes *trust* a necessary base. This implies that countries may favour connecting to countries in which they trust, for example because they also cooperate on a range of other issues. For this reason, one might expect it to be more likely that countries will limit energy trade to the closest neighbours – if one is lucky enough to trust them. Trust among stakeholders is important if a regional electricity market is to succeed, as emphasised by Ollila (2017, 29). Countries that do not have established trust among their neighbours may therefore have a challenge in the making of a renewable energy system. The Norwegian scepticism towards interconnectors to Europe seems to be higher than connection with Nordic neighbours – this supports the argument on the role of trust in electricity trade. Therefore, renewable energy systems may be characterised by smaller regions, and not continental regions.

2. Liberalised

One may also argue that a liberalised electricity market such as the Nordic, in which the nation-state does not decide the flow of electricity (it flows wherever there is a demand and the price is high) gives a great deal of supply security and stability in a renewable energy system. It allows for the whole Nordic region to reap the benefits of efficient wind power and the flexible balancing mechanism of hydro power and nuclear. Having everything within the boundaries of one country seems infeasible, amplified by land use challenges, geographic distance between production and consumption, and level of public acceptance for renewable production and infrastructure. The renewable energy system may therefore be characterised more as conflicts within nations, than between nations.

This may entail that the role of the state changes from being the entity that supplies energy, to taking a more regulatory role while letting the market supply. This requires the state to give away a degree of autonomy of the energy supply, which may be a hard pill to swallow in some countries. This analysis has also shown the negative aspects of the liberalised energy market – such as when the state cannot exercise control over whether domestic supplies or cheaper imported supplies can be used. For example, in Finland, where it is a politically decided objective to become more self-sufficient by the use of bioenergy - and then market mechanisms prevail and biomass is imported because it is cheaper. The same principle goes for electricity trade. After the interconnector is established, the electricity flows freely, and the state can hardly control where it flows – which ultimately also means that the electricity prices for Nordic consumers are dependent on prices on the European continent. The Nordic region has the potential to be self-sufficient, but sometimes also becomes an importer from Europe when it is cheaper. This is of course not only a downside, but also a significant benefit for end-users who get a lower electricity bill. But ultimately this means less state control over imports and self-sufficiency - if that is a desired goal.

Tenggren et al. (2016) found that while the transmission grid is a state-owned entity in Sweden, power production is commercial. Moreover, the lack of coordinated planning between the state and market actors leads to the grid not always developing where it is most needed (for example where production is expanded). They advise the state to take a more prominent role among these different actors (2016, 154). Market organisation may therefore not always be efficient.

The limitations of chapter 2 briefly addressed the two trends of renewable energy deployment introduced by Johansson (2013b), the large-scale centralised power production, and the small-scale decentralised deployment of e.g., solar panels on houses, which may create tensions with centralised or state-owned power producers and grid companies. This is also listed as one of the market implications of renewables in Scholten & Bosman (2016, 278-279). When the market decides, cost-efficiency and profit prevails, such as larger wind farms and taller turbines. As the Danish case shows, public acceptance to wind power declined as the cooperative model was replaced with industrialised, larger units. Market rule may not allow for small-scale RES production – and large-scale RES production can find barriers in public acceptance. This trade-off is perhaps under-estimated, if even considered.

Although the market may play a larger role in supplying energy in the renewable energy system, it does not mean the state can withdraw completely. Certain energy technologies, such as hydropower production and especially nuclear power, will probably continue to be state-controlled because of high security risks. Additionally, the Nordic electricity market is liberalised, but all countries still have national transmission system operators (TSO), national state-owned companies that operate and monitor the national grids - so the essentials are still in control by the state.

There are many benefits of a liberalised electricity market, and the Nordic case shows it can be good for the supply security and cost-efficiency in a renewable energy system. Nevertheless, the negative aspects discussed here should be kept in mind.

3. Interdependent

The nature of both electricity and renewable energy sources creates interdependent trade relations, rather than the one-directional dependent trade relations of fossil energy. The intermittent nature of renewables means virtually all countries will at some point require balancing support from neighbours, creating interdependent relations. When countries and regions are connected, everyone will have an interest in the well-functioning grid. This means that cut-offs and other challenges we know from the fossil energy system become less likely. This can be seen as an improvement from the fossil energy system.

The other side of it, is that since domestically sourced renewables can be considered as means for increased independence and self-sufficiency, interdependence can also be seen as negative if it displaces the prospects of independence. The above discussion of Finland may support this argument. Also, the role of trust among stakeholders, as discussed above, must be reiterated here. Interdependent trade relations are likely to be more feasible if the trade partners have established trust in each other.

4. **The decisive role of public acceptance**

The role of public and political acceptance is not usually included in energy security literature. This analysis has shown that the acceptance of both energy production facilities, infrastructure and interconnectors is an overarching principle that must be present both for the success of the carbon-neutral region, and for increased renewables on a national level. The lack of acceptance can be an essential barrier to the deployment of sufficient capacity that is necessary to secure a stable supply of renewable energy. Recall from 1.3.4 that Sovacool (2017, 578) found political contestation to be an important barrier for the Nordic low-carbon transition. But if one commits to a fossil fuel phase-out, renewable (or low-carbon) energy is the only alternative. Public acceptance may therefore also be a barrier to energy security if it hinders establishing sufficient production and transmission capacity. The renewable energy security concept should therefore not be kept separate from public acceptance, at least not in democratic societies where the people's opinion have influence. This shows the relevance of the interpreted security concept by Buzan et al (1998) in investigating the renewable energy system. This latter point is discussed further under the next feature of renewable energy security.

An additional point that has not been discussed in this thesis but is worth mentioning, is who will pay for the establishment of more power production facilities and enforcements of the grid. The latter bill may have to be picked up, at least in part, by end-users or taxpayers. This can add additional challenge for public acceptance.

5. **Contextual**

As has been the underlying principle throughout the thesis, security is a dynamic and context-dependent concept, and renewable energy security is arguably even more so than its fossil counterpart. The available domestic supply, the at any time public acceptance to production and infrastructure, which neighbours you have and what kind of relations you have with them, and how the market is organised, will all influence how energy security in renewable energy is both interpreted and achieved. Again, this shows the relevance of the interpreted security concept by Buzan et al (1998) in investigating the renewable energy system. The contextual security concept emphasise interpreted security and the role of the audience (people). It is distinct from the realist approach and traditional security studies that are focused on the state as primary actors, and where interpretation has little relevance (see 3.1). When energy security is dependent on people's acceptance, as in the renewable system, people's interpretation are put centre stage.

7.3 The Nordic story as a recipe for others

There are many aspects of the Nordic countries that are distinct. These are well-developed democracies with high levels of welfare and relatively low population numbers. The region is also closely connected in culture, politics, values, and even languages. Sovacool (2017) concludes that certain elements of the Nordic low-carbon transition are unique and a result of the specific Nordic context, and therefore does not function as a blueprint for others to follow (2017, 581). Although I would argue (as above) that renewable energy security will be contextual and that there is no fit-for-all solution, I believe there are still lessons to be learned from the Nordic recipe.

This relates not least to that the Nordic region has already reached great success in the integration of renewables in the energy mix. The Nordic region, while not perfect, can to some extent be seen as a blueprint of what a future well-functioning renewable energy region may look like. It is interconnected, there is a high degree of cooperation on energy issues, and it relies on many different renewable (and low-carbon) energy sources that both offer efficiency and flexibility. These measures are ways to overcome the technical challenges of renewable energy sources that were presented in chapter 4 – which will be present in all regions. This does of course not mean that the Nordic way is the only way, but it is *one* way.

The study of the Nordic region also shed light on the significance of acceptance. This is likely to be a challenge also elsewhere and can be a significant barrier to renewable energy deployment in all democratic societies.

Although the Nordic region is often grouped together and sometimes even treated as one, the analysis of chapter 5 showed that much separates them as well. The aim of emphasising this is not to claim that regional cooperation is futile, but to show that despite the many benefits of regional cooperation and integration, and no matter how much you trust your neighbour, governments want to have a degree of control of energy. Exactly how and to what degree, may vary from country to country, but its importance cannot be ignored because it has the potential to be a barrier for further integration of renewables.

7.4 Implications for further research and policy

7.4.1 Research

Investigating tensions between the region and the nation proved to be a useful way of structuring a study to get insights into the ways in which energy and security affect each other and learn more of the importance of national priorities in the energy transition. A similar study on the European Union could be particularly interesting. Either with a focus on EU initiatives and legislation meeting national priorities - or focused on sub-regions as these may be more feasible grid-communities given the characteristics of electricity trade.

A larger study with a wider scope, could for example test the results of this thesis further. It could investigate the Nordic states' energy and security situation more in-depth, maybe even do a number of interviews to gain further insight into the interpreted security situation. This could potentially enhance theory on energy security. Although interviews were, as discussed in chapter 2, discarded as a method in this thesis, they may be fruitful in building on the insights of this thesis. Further, studying the dynamics of niches, regimes and landscapes in the Nordic renewable transition using Geels' multi-level perspective as mentioned in 2.2.3 could also be a possible extension of this study.

This thesis has in certain parts had to exclude Iceland and the autonomous island states of the Nordics as they are not connected grid-wise, but these regions are highly interesting in themselves. Another type of study could investigate the role of renewables in the quest for energy independence in disconnected island communities. Islands are interesting cases in the study of sustainable energy transitions, and have become popular sites of research and testing of new solutions (see e.g. Skjølsvold, Ryghaug & Throndsen, 2020). This is because they are compact and geographically limited regions, often with less complex energy systems, and have generally had to rely on (expensive) imported energy. The energy transition of islands may therefore act as examples for mainland regions to follow (Child, Nordling & Breyer, 2017, 49).

For a long time, there has been a research focus on finding the solution to an energy system with little or no climate-harmful emissions. The technical solutions are now well advanced. Now, focus must be on the societal solutions – because the technical solutions have no value if we cannot implement them. For example, people are not necessarily against wind power in general, but the ways in which wind power is now installed might bring resistance. For example, Denmark is seeing increased resistance as the cooperative organisation model was replaced with large-scale industrialised production. We need more social science focused research on renewable energy in order to get ahead in creating low-carbon societies, and we need more studies on renewable energy and energy security. Energy security can be both a driver and a barrier for renewable energy deployment. With the future health of our planet being dependent on the world successfully *and* fairly transforming the energy sector, we need to learn more about these dynamics.

7.4.2 Policy

Two things will be emphasised. Firstly, the Nordic region could perhaps benefit from more than a joint declaration on carbon-neutrality. The regional path can as shown be highly fruitful, but as the NCES and others also point out, joint plans and agreements are necessary. The Nordic countries, perhaps particularly the countries that seem to favour a national-leaning approach (Norway and Finland), could benefit from including more regional thinking in national energy policy. Furthermore, certain challenges of public acceptance, such as interconnectors and electricity prices in Norway, would perhaps be alleviated if the benefits of a regional approach to energy are emphasised and communicated more clearly.

Secondly, as in research, it should be recognised that the main obstacles ahead lie in society. There should be a shift in focus to the social aspects of renewables – which this thesis has only touched upon. Building policy on a technological or a profit-focused basis can fail to notice what is important to the people involved. Acceptance is key for energy security in renewables and for succeeding in a socially fair energy transition. This is a challenging barrier to overcome and efforts by policy-makers should therefore be put here.

7.5 Conclusive remarks

This thesis has investigated energy and security of renewables in the Nordic region, and this analysis had at least two outcomes. It made it possible to make assumptions on how renewable energy security can look like, and it revealed barriers for the realisation of the carbon-neutral Nordic region that all Nordic prime ministers agreed on in 2019. This thesis also aimed to show that energy security is a multifaceted concept, about more than just security of supply and affordability. Supply security and affordability are obviously still essential parts of the concept, but of a changing character. Holding a constructivist approach to security, emphasising context and interpretation, proved particularly useful. It is now time for original and creative thinking around the energy security concept and not to continue on the path laid by fossil energy security studies.

This thesis illustrates the continued relevance of a security approach when studying the field of energy, also the renewable energy system. This revealed barriers for the realisation of the carbon-neutral Nordic region, and gave more insight into what drives energy policy in the Nordics. But energy is a policy area also involving economic, environmental, and social dynamics and policy, so one cannot view energy solely from a security approach. That does not mean the security approach is redundant. Security is one side of the energy security concept, arguably an overarching one, that has the potential to steer energy policy.

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Cover photo: Power lines in the Helsinki bay. Photograph from personal collection.

[8] In the following analysis, only the "Power Production by Energy Source" has been used, found under the tab "Power & DH". Data from each scenario (CNB, CNN, NPH) was consequently retrieved from the left tab, as well as the country selection (Iceland was excluded).