TØI report 1784/2020

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The Ambitious and the Ambivalent

Sweden's and Norway's Attitudes Towards Domestic New Renewable Energy Sources

TØI-rapport
1784/2020

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ISSN 2535-5104 Elektronisk
ISBN 978-82-480-2303-6 Elektronisk
Oslo, november 2020

Tittel:	Den ambisiøse og den ambivalente: Sveriges og Norges holdninger til innenlandske nye fornybare energikilder	**Title:**	The Ambitious and the Ambivalent: Sweden's and Norway's Attitudes Towards Domestic New Renewable Energy Sources
Forfatter:	Inga Margrete Ydersbond	**Author:**	Inga Margrete Ydersbond
Dato:	10.2020	**Date:**	10.2020
TØI-rapport:	1784/2020	**TØI Report:**	1784/2020
Sider:	61	**Pages:**	61
ISSN elektronisk:	2535-5104	**ISSN:**	2535-5104
ISBN elektronisk:	978-82-480-2303-6	**ISBN Electronic:**	978-82-480-2303-6
Finansieringskilder:	Universitetet i Oslo, Centre for International Climate and Energy Policy, og Transportøkonomisk institutt	**Financed by:**	University of Oslo, Centre for International Climate and Energy Policy, and the Institute of Transport Economics
Prosjekt:	4330 Samfunnsøkonomiske metoder	**Project:**	4330 Economic methods
Prosjektleder:	Inga Margrete Ydersbond	**Project Manager:**	Inga Margrete Ydersbond
Kvalitetsansvarlig:	Askill Harkjerr Halse	**Quality Manager:**	Askill Harkjerr Halse
Fagfelt:	Samfunnsøkonomiske analyser	**Research Area:**	Economic Models
Emneord:	Sverige, Norge, ny fornybar energi, styring, bærekraft, transformasjon, innovasjon, komparative studier	**Keywords:**	Sweden, Norway, new renewable energy, governance, sustainability, transformation, innovations, comparative study.

Sammendrag:

Denne studien undersøker hvorfor Norge og Sverige i perioden fra 1960 til 2015 utviklet sin produksjon av ulike typer fornybar energi på svært ulike måter. Resultatene viser at ressursgrunnlaget, politiske beslutninger og offentlige virkemidler har hatt stor innflytelse på hvilke typer fornybar energiproduksjon som er blitt bygget ut, når og hvordan. Sverige, som har manglet tilgang til å bygge ut ny billig vannkraft etter 1970, har generelt implementert mer ambisiøse og omfattende strategier, som har ført til mye høyere produksjon av alle typer ny fornybar energi enn i Norge. Ulikheter i utbygging av fornybar energi kan forklares av forskjeller i: naturressurstilgang, langvarig satsning på forskning og innovasjon, kombinert med virkemidler som skaper markeder for slik produksjon og forutsigbar politikk. Økt produksjon av ny fornybar energi har økt energisikkerheten og stabilisert energisystemene i begge land. Inntil 2015 førte det felles grønne elsertifikatmarkedet først og fremst til økt strømproduksjon fra de allerede kostnadskonkurrerende eller nesten kostnadskonkurrerende teknologiene: småskala vannkraft i Norge og biokraft og vindkraft i Sverige.

Summary:

The study investigates why Norway and Sweden from 1960 until 2015 have developed their renewable energy production along very different paths. The results show that the natural resource potential, politics and public policies have had profound impacts on which type of renewable energy production have been developed, when and how. Sweden, lacking access to new cheap hydropower after 1970, has generally implemented more ambitious and comprehensive policies, leading to much higher production of new renewable energy of all types than in Norway. Differences in expansion of renewable energy might thus be explained by differences in: natural resource endowments, long-term research and innovation efforts, combined with creation of markets and predictable policies. Enhanced new renewables production has boosted energy security and stabilized the energy systems in both countries. The Swedish-Norwegian green electric certificate market, until 2015, mainly contributed to increased electricity production from already cost-competitive or nearly cost-competitive technologies: small-scale hydropower in Norway and bio power and wind power in Sweden.

Language of report: English

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Forord

Denne studien ble startet som et prosjekt i tilknytning til doktorgradsarbeidet da PhD Inga Margrete Ydersbond var stipendiat ved Institutt for statsvitenskap ved Universitetet i Oslo. Studien er blitt presentert på konferansene European Consortium of Political Research (ECPR) Joint Sessions i Mainz i 2013, på Renewable Energy Research Conference (RERC) i Oslo i 2014, og på en rekke ulike seminarer. En kortversjon av studien ble publisert i konferansetidsskriftet *Energy Procedia* i 2014 (Ydersbond, 2014).

Siden arbeid med denne studien ble utført i tillegg til andre prosjekter i doktorgraden, måtte det videre arbeidet med dette prosjektet vente. Målet var imidlertid alltid å få publisert studien i en utfyllende versjon slik at offentligheten skulle få tilgang til denne komparative analysen av sammenhengen mellom energisystemene og energipolitikken i Sverige og i Norge. Ferdigstilling og publisering av prosjektet i rapportformat er utført ved siden av andre oppgaver etter at forfatteren tiltrådte som forsker ved Transportøkonomisk institutt.

Forfatteren takker alle som har stilt opp underveis i prosjektet, enten som informanter, ved å gi innspill til design, analyse, og presentasjon, eller som har deltatt på ett av seminarene der prosjektet er blitt presentert. Dette inkluderer blant andre: Anton Steen, Tora Skodvin, Trond Arild Ydersbond, Amund Lie, Helle Margrete Meltzer, James Meadowcroft, Arild Underdal, forskere ved Fridtjof Nansens Institutt, personer tilknyttet det internasjonale forskningssenteret Centre for International Climate and Energy Policy (CICEP), og ansatte ved Environmental and Energy Systems Studies ved Universitetet i Lund.

Forskningsleder Askill Harkjerr Halse har kvalitetssikret rapporten ved Transportøkonomisk institutt og sekretær Trude Kvalsvik har stått for endelig layout og redigering av rapporten.

Oslo, november 2020

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Gunnar Lindberg
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Summary

The Ambitious and the Ambivalent

Sweden and Norway's Attitudes Towards New Domestic Renewable Energy Sources

TØI Report 1784/2020
Author: Inga Margrete Ydersbond
Oslo 2020 61 pages English language

The Paris agreement outlines that the world's countries are to work to attain a global warming "well below" 2 degrees Celsius and strive to achieve a warming of maximum 1,5 degrees Celsius. To achieve this, a radical reduction of greenhouse gas (GHG) emissions in all sectors is needed. These emissions stem from several sectors, including the production and consumption of energy. In the future, almost all or all energy consumed globally will thus have to stem from zero-carbon energy sources, not least from renewable energy. New renewable energy sources include the energy sources: solar energy, wind energy, geothermal energy, bioenergy and ocean energy.

Sweden and Norway have long sought to be environmental frontrunners internationally. For example, they have institutionalized policies on environmental and climate issues and have taken ambitious positions in the global climate negotiations over the last decades. With great access to domestic renewable energy sources and substantial financial and institutional capacity, both Sweden and Norway have considerable potential to become early cases of carbon-neutral societies. They can achieve this by several means, including: using renewable sources to produce electricity, heating and cooling, using renewable sources as fuel in the transport sector, as well as by reducing energy consumption.[1] Thus, it is of particular interest to focus in on these countries to further understand the factors that may stimulate and hinder the expansion of new renewable energy in affluent countries with ample renewable energy resource bases.

Sweden and Norway's energy systems featured several similarities in the 1960's, and show numerous other political and institutional similarities as well. Nevertheless, the neighboring countries for many years chose completely different paths as regards the investment in research, development and installation of production facilities for the various renewable energy sources, in particular in relation to new renewable energy sources. Therefore, this study asks:

> *Which factors might explain the large differences between the installation of facilities for production of new renewable energy in Sweden and in Norway, and what can we learn from this?*

The study focuses on the production of new renewable energy in the Swedish and Norwegian energy systems from 1960 until 2015. The method used is the comparative method of "most similar systems design." Data sources include 16 interviews with key/elite informants in Sweden and Norway dealing with energy issues, documents from the public authorities, quantitative data, previous research and other data.

The analyses show that politics and public policies, as well as the natural resource base, have made profound impacts on which renewable energy sources have been developed in Sweden and Norway, as well as when and how. Sweden, which since 1970 has lacked

[1] Other strategies include carbon capture and storage (CCS) and increasing carbon sequestration.

access to new river systems where production facilities could be installed to provide the country with cheap hydropower, has generally implemented significantly more ambitious and comprehensive policies than Norway as regards new renewable energy. By consequence, by the end of 2014, the production of energy from the new renewable energy sources like wind power and solar power in Sweden was much higher than in Norway. As of 2020, this is still the case.

Differences in energy production from these sources might be explained by differences in: natural resource endowments, long-term research and innovation efforts, combined with the creation of markets and predictable public policies. Enhanced new renewables production has boosted energy security and contributed to stabilizing the energy systems in both countries. The joint Swedish-Norwegian certificate market for green electricity, which was introduced in 2012, contributed in 2014 to the expansion of cost-competitive or nearly cost-competitive renewables technologies: small-scale hydropower in Norway and bio power and wind power in Sweden.

1 Introduction

1.1 Knowledge needs about renewable energy policy

More than two thirds of the world's emissions of greenhouse gases (GHG) has stemmed from the production and consumption of different types of energy (C2ES, 2020; IEA, 2013). Thus, a large-scale world-wide energy system transformation that significantly increases renewable energy production and consumption is paramount for achieving a reduction of GHG emissions to sustainable levels (IPCC, 2014; IRENA, 2019; REN21, 2019).

Energy policy is one of the most thoroughly regulated areas for the world's countries/nation states. The nation state is the only authority that possesses legitimate means of changing the major patterns of energy production and consumption for its citizens. Therefore, national efforts to achieve a long-term large-scale transformation to increased national production and consumption of renewable energy,[2] together with the implementation of energy efficiency measures, are crucial. In other words, most nation states need their own versions of the renown German *Energiewende*.[3]

Such large-scale energy system transformation may not only be economically beneficial in terms of lower costs of energy and the creation of new industries in the longer term, but will also lead to improved energy supply security and better living environments (e.g. IPCC, 2012; Meadowcroft, 2005, 2007). The neighboring countries Sweden and Norway were both early in setting ambitious national targets to reduce greenhouse gas emissions in 2020 and over the next decades, and aimed to be environmental frontrunners internationally. For example, they institutionalized policies on environmental and climate issues and took ambitious positions in the global climate negotiations over several decades.

Despite numerous similarities in terms of having an ample resource base of renewable energy, the neighbors have, however, developed very different energy systems from 1960 onwards, not least in terms of their capacity for production from *new renewable energy sources*.[4] New renewable energy sources are the renewable energy sources where the technologies to generate energy from them until the last years have not been regarded as technologically mature and cost competitive: wind, solar, several types of biomass energy and wave/ocean/tidal energy.[5]

Examples in case: Norway established conditions that stimulated the establishment of large-scale hydropower production in the 1900's, making it the largest hydropower producer in Europe. Sweden, however, produced and produces more renewable energy

[2] Nuclear power is also a zero emission energy source, but has numerous drawbacks, including security issues and that it is very costly technology.

[3] The German work Energiewende means energy transition, and is used for the current transition to a sustainable energy system and reduce emissions of greenhouse gases. This is attained by means of implementing numerous strategies to, for example, increase the production of renewable energy and phase out production of coal powered and nuclear powered electricity.

[4] Renewable energy sources excluding traditional biomass used for heating is called "modern renewable energy sources."

[5] Note the distinction between energy and electricity.

than Norway from all the other renewable energy sources that are beyond the prototype stage in technological development, in absolute quantitative terms in 2014, and this is still the case in 2020.[6] The total amount of renewable energy consumed in Sweden was and is also higher than that of Norway (e.g. Energimyndigheten 2020), while Norway's share of renewable energy in final energy consumption is the second largest in Europe after Iceland (see for example Figure 1 below).

By 2013, bioenergy had become Sweden's largest source of energy, wide heat pump usage previously made the country no. 3 in the world in this area, and wind power had been built out at a rapid pace (e.g. REN21, 2013). In comparison, utilization of bioenergy and wind power was rather modest in Norway. Norway was, and still is as of 2020, a latecomer internationally in terms of producing wind energy, solar energy and modern bioenergy domestically.

Therefore, this study asks:

> *What might explain the differences between the production of energy from the new renewable energy sources in Sweden and in Norway? What can we learn from this?*

The production of energy from new renewable energy sources has been heavily dependent on government interventions. Unlike in 2020 (IRENA, 2019 and 2020), such production was generally not cost competitive internationally in 2014, when all costs connected to this production were included, depending on the energy source itself and where it was produced.[7] Therefore, this study makes a historic comparative analysis of policies directed towards renewable energy, with a key focus on the period from 1960 until 2015 (i.e. until the end of 2014) in Sweden and Norway, to shed light on the factors that may influence sustainable energy system transformations.

These cases are empirically relevant to explore because both countries have achieved large shares of renewable energy compared to *all other* countries in the European Economic Area (EEA) as of 2019,[8] apart from Iceland, as shown in Figure 1, and also compared to most other countries in the world (see e.g. REN21, 2020).

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[6] See Table 2 for the situation in 2014 and e.g. REN21 (2020, e.g. p. 36) for an update on the present (2020) situation. For example, when hydropower is excluded, Sweden has the third highest renewable power generation capacity in the world after Iceland and Denmark.

[7] Grid parity: when all costs included in the installation of a new power production facility, including the equipment, installation and maintenance is similar to or lower than the similar market price of, for example, producing coal power, gas power or nuclear power. In 2019, it seems that large-scale solar photovoltaic electricity reached grid parity in Sweden (Bellini, 2019). See also: https://en.wikipedia.org/wiki/Grid_parity.

[8] All EU member states + Norway, Iceland and Liechtenstein.

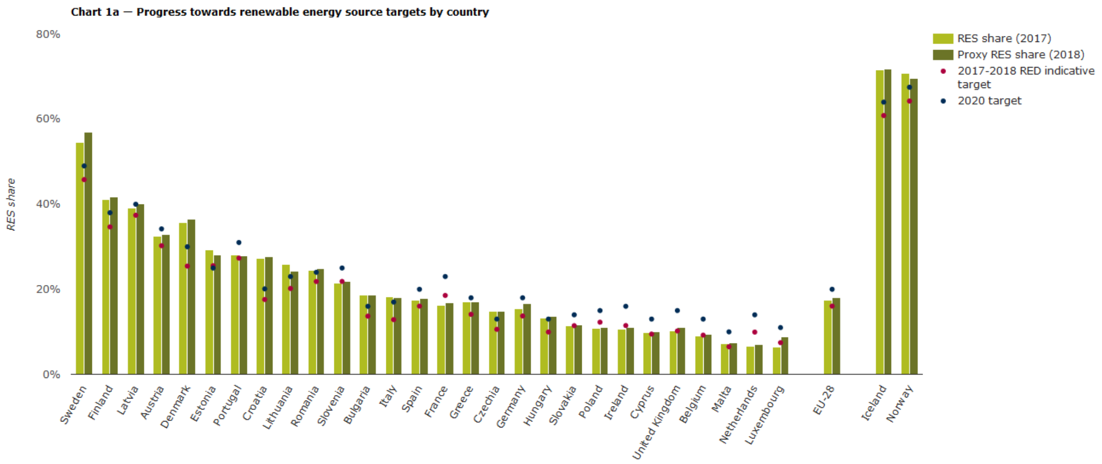

Figure 1: How the various EU member states and EEA members Iceland and Norway are progressing towards the targets set for renewable energy in the renewable energy directive. RES means renewables, shorthand for renewable energy.
Source: EEA (2019).

Moreover, both countries have exceeded the targets set in the EU Renewables Directive (Parliament and Council, 2009), a few years ahead of time. The deadline to reach their targets in this Directive is in 2020, but Sweden attained its target of 49% renewable energy of their total domestic energy consumption already in 2011. Their domestic target of 50% was attained in 2012 (Energimyndigheten, 2019). Norway's target, 67,5% of energy consumption coming from renewable energy sources, was attained for the first time in 2014 (OED, 2016; Øvrebø, 2016).

Much research literature has been studying different aspects of renewable energy policy in Sweden (e.g. Söderholm & Pettersson, 2011; Uba, 2010; Waldo, 2012), and in Norway (e.g. Christiansen, 2002; Hanson, Kasa & Wicken, 2011), while far less research attention has been devoted to comparing the energy systems in these two countries and systematically analysing these developments in relation to the politics and policies that have been implemented over several decades. Moreover, few studies have so far have analyzed Sweden and Norway from a historic and energy system transformation perspective.

Lafferty and Ruud (2008) edited a book where energy systems in European countries were compared. With the notable exception of a comprehensive report by Buan, Inderberg, and Eikeland (2010), few studies have, to my knowledge, analyzed the large differences in the development of renewable energy production in general, and in the production of new renewable energy in particular, in Sweden and Norway, over the last decades.

There are also studies shedding light on narrower aspects of renewable energy policies in Sweden and Norway, like: a) Blindheim (2015) on the relation between increased renewable energy production in Sweden and Norway and reduced GHG emissions, b) Linnerud, Andersson, and Fleten (2014) on the effect of the Swedish-Norwegian certificate markets on the timing of the licensing of small hydropower projects, and c) Boasson, Faber, and Bäckstrand (2020) and Boasson (2020), who discuss the development of support schemes for renewable energy in Sweden and in Norway from 1970's onwards.

1.2 Report structure

The report is organized as follows: Chapter two lays out the theoretical framework of Historical Institutionalism and outlines empirical expectations/hypotheses based on it and present knowledge, while the third chapter describes and discusses the methods employed: most similar systems design, in-depth interviews and document studies. Chapter four presents relevant similarities between Sweden and Norway that could affect renewable energy production, but that cannot explain the differences in production that have emerged. The fifth chapter describes the development of renewable energy production from around 1960 to 2014 in Sweden and Norway. Chapter six discusses how this development might be understood in light of the hypotheses presented in chapter two, discusses future energy system related challenges and concludes.

1.3 Abbreviations and special terms

CHP: Combined heat and power.

Bio energy: "is renewable energy made available from materials derived from biological sources. Biomass is any organic material which has stored sunlight in the form of chemical energy. As a fuel it may include wood, wood waste, straw, and other crop residues, manure, sugarcane, and many other by-products from a variety of agricultural processes" (Wikipedia, 2020a).

Electricity: related to electrical charge, the movement of electrons. Electric power is where an electric current is used to energise various types of processes (Wikipedia, 2020b).

Energy: "the quantitative property that must be transferred to an object in order to perform work on, or to heat, the object." The term for various types of energy, as energy may come in several forms, including as electricity, heat or kinetic energy (Wikipedia, 2020c).

Geothermal energy: energy from geothermal sources, like hot water stored deep in the earth.

GHG: Greenhouse gas, e.g. carbon dioxide (CO_2), methane, and nitrous oxide.

Grid parity: when all costs included in the installation of a new power production facility, including the equipment, installation and maintenance is similar to or lower than the similar market price of, for example, producing coal power, gas power or nuclear power.

TW: Terawatt.

TWh: Terawatt-hour.

GW: Gigawatt.

GWh: Gigawatt-hour.

KW: Kilowatt.

KWh: Kilowatt-hour.

LCOE: Levelized costs of energy, the same as grid parity.

Power: Means the same as electricity.

RD&D: Research, development and demonstration.

Solar electricity: Electricity made from various types of solar energy technologies, like solar photovoltaic installations and concentrated solar power (CSP) plants.

Solar energy: Energy produced from using technologies to exploit the energy from the sun, including the light and the heat.

Solar PV: Solar photovoltaic, often called solar cells.

TSO: Transmission system operator, the operator of a country's main power transmission lines, which are the transmission lines with the highest voltages.

Wind energy: Energy from wind power.

2 Historical Institutionalism

2.1 Background on the theoretical approach

This study will mainly use the theory of Historical Institutionalism. This is a relevant theory for several reasons (Steinmo, Thelen & Longstreth, 1992b). First, Historical Institutionalism enables the identification of *critical junctures*. In other words, it enables the identification, analysis and interpretation of special turning points in history. Second, comparative studies applying theories like Historical Institutionalism hold the advantage that they may identify how, for example, some factors were decisive in one country and not in the other for crucial energy policy decisions (e.g. Capoccia & Kelemen, 2007). Third, energy policy is, as aforementioned, a thoroughly regulated field in most countries and often involves decisions of investment with long time horizons, often at least three decades.[9] Therefore, the institutional setting, in terms of both which formal rules (regulations, laws, etc.) and which informal rules played out (norms, ideas),[10] when they were created, is likely to be decisive (see e.g. Steinmo, Thelen & Longstreth, 1992a).

Previously, production facilities for new renewable energy generally needed economic stimulus to be built, because of the higher construction costs than the more mature technologies, and as a result key actors' organizational ideas about how this might be achieved could be decisive. Therefore, to better understand the policies on renewable energy in Sweden and Norway, it is very important to enquire how different national governments have "thought about" and dealt with the different renewables technologies historically, and how both informal and formal rules have played out. Historical Institutionalism focuses on both formal and informal rules and is thus arguably particularly suitable as a theoretical lens.

Historical Institutionalism emphasizes that present choices are affected, and often determined, by policy choices made early in a historical process by a governmental system, that have later become institutionalized practices. The definition of an institution is: "[...] persistent and connected sets of rules (formal and informal) that prescribe behavioral roles, constrain activity, and shape expectations" (Keohane, 1989, p. 3). When an institution is first established, its structure is difficult to alter, which is sometimes referred to as institutional "*stickiness*" (Pierson, 2000). This is not least caused by the fact that public organizations establish routines called *standard operating procedures* (SOPs), and that these institutions are based on sets of ideas. Positive feedback effects make it harder to make changes in the system. Such conditioning is typically labeled *path dependency* in institutionalism (Krasner, 1984; Peters, 2005, p. 19; Pierson, 2004).

When different actors, such as organizations, adapt to an institution by committing themselves to new rules, this makes it increasingly harder for them over time to choose to

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[9] A nuclear power plant is, for example, expected to last for at least 30-40 years, and may last up to over 80 years (Office of Nuclear Energy, 2020). In 2015, an average large Norwegian hydropower plant and dam was 46 years old (Lia, Jensen, Stensby, Holm Midttømme & Ruud, 2015). Petroleum production facilities in the North Sea are expected to extract petroleum for the next decades too.

[10] Following of norms is often referred to as *logic of appropriateness*: that persons in an organization behave according to what they think is suitable and what is regarded as normatively correct within their organization.

step out of the institutions (Pierson, 2000, p. 492). In other words, not only actors' strategies, but also their goals, are heavily influenced by the institutional context, termed *institutional lock-in* (Steinmo et al., 1992a, p. 8); "By accelerating the momentum behind one path, they render previously viable alternatives implausible" (Pierson, 2000:493).

At the national and global levels, institutional lock-in is related to energy system *technological lock-in*; When authorities choose a technology for large-scale expansion and build institutions to govern it and stimulate it, such as ministries, agencies and research institutions, these initial choices may lead to an institutional lock-in, which can contribute to energy system technological lock-in. The actors and industries attached to production from the technologies that are the first to reach technological maturity may get first-mover advantages because of the large institutional, financial, physical and human resources invested into such production.

This is typically the case for petroleum extraction, leading to so called *carbon lock-in* (Unruh, 2000). However, lock-in could arguably also be the case for energy production from other types of technologies, such as for nuclear power ("*nuclear power lock-in*") or hydropower ("*hydropower lock-in*"). In the case of Norway, the institutions and groups connected to hydropower production and petroleum extraction are expected to benefit from this institutional "stickiness." While in Sweden, the institutions, such as utilities companies like Vattenfall, Uniper Sweden,[11] and others, dealing with nuclear power production and hydropower production might benefit from the institutional "stickiness" there.[12]

2.2 Empirical and theoretical expectations

As both Sweden and Norway have historically needed to expand the national production of energy to cover the increasing domestic need, including for electricity, it is natural to expect that they would opt for the "low hanging fruits" first. Facilities for hydropower production have been a mature energy production technology internationally from the beginning of the 1900's, at least. Mature here means producing power at cost competitive prices compared to other technologies. This means that Norwegian and Swedish politicians would first decide, and then respective public authorities would carry out policies to build out infrastructure for hydropower production from the 1960's onwards. Thus, our first expectation is:

Expectation 1:

> *Politicians will first opt for expanding production of hydropower in Norway and in Sweden by giving licenses to enable such production.*

When this is no longer a viable option, and energy demand is increasing, the countries are expected to develop production of other types of energy where they have large energy resource potentials that may be exploited, where the technologies are producing energy cheaply, and where the technologies have either reached a certain level of technological maturity, or clearly hold the potential to do so. This could, for example, entail developing bioenergy to produce e.g. bio power and heat from biomass. Such decisions could also

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[11] Formerly named E.On Sweden.

[12] As per 2020, nuclear electricity generates about 40% of Sweden's electricity, about the same as hydro power. However, some older reactors are to be closed down by 2020 (WNA, 2020).

include to develop other energy production facilities, such as nuclear and coal power plants. Expectations 2 and 3 are thus:

Expectation 2:

Physical resource potentials, as well as the maturity of technologies, influence the pace of expanding the production from the new renewables technologies.

Expectation 3:

When promising renewables technologies have been immature, and there has been need for enhanced domestic energy production, the governments have launched programmes for investments in research, development and demonstration to stimulate their use, and later for their commercialization.

Historical Institutionalism is generally rather weak at explaining large-scale institutional change, but posits that when institutions change their way of thinking by *policy learning*, this might contribute to change (Peters, 2005, pp. 64-70). Policy learning typically leads to small and incremental changes in public policies. However, at specific periods of time, at the aforementioned *critical junctures*, decision makers have greater than usual leeway for choice in deciding, and may then choose to initiate policies that potentially have large consequences (Capoccia & Kelemen, 2007).

One group of factors that may give political elites such opportunities (in Historical Institutionalism called "windows of opportunities") are *external shocks*. Such shocks may appear, for example, during international economic crises, geopolitical conflicts leading to for example lower energy security, nuclear catastrophe, and may bring about institutional innovation (Cortell & Peterson, 1999; Kingdon, 1984). Table 1 shows an overview of various potential international and domestic triggers of institutional change.

Table 1: Triggers of institutional change, adopted from Cortell and Peterson (1999, p. 185). The table shows a row of typical factors leading to critical junctures where politicians have the chance of deciding to change national energy policies.

International triggers	Domestic triggers
Wars	Revolutions
Geopolitical conflicts	Civil wars
Changing balances of power	Coup d'état
Technological changes	Elections/changes of government
Macroeconomic changes, dislocations, external shocks	Economic growth rates
Changes in international norms, organizations and treaties	Demographic changes
International economic crises	Social movements/conflicts
Energy crises	Energy crises

In international energy policy literature, crisis in energy supply, fluctuating oil prices and nuclear catastrophe are typical external factors (external shocks) that strongly influence national energy politics and policies (e.g. Yergin, 2006). Such external factors might lead countries and organizations like the EU to pursue policies that are more in line with the aims of creating an environmentally friendly state, to "escape carbon lock-in" (e.g. Unruh, 2002). For example, states may invest in the research and development of new renewable energy production (Lauber & Mez, 2004), leading to expectation 4:

Expectation 4:

External shocks, such as a crisis in energy supply, nuclear catastrophe and large fluctuations in petroleum and power prices, have influenced Swedish and Norwegian policies decisively, as they have made politicians and the polities aware of the risks associated with the current policies and given them incentives to stimulate production from the new renewable energy sources.

Other causal factors that may cause policy change in society are, for example, domestic socioeconomic development, including unemployment rates and diffusion of ideas (Hall & Taylor, 1996, p. 942), leading to institutional adaptation and incremental change (Cortell & Peterson, 1999, p. 178).

International triggers may include, for example, membership in international organizations. The EU has aimed to be an environmental frontrunner in the world, and has therefore put increasingly more emphasis on climate and energy related topics, such as the expansion of renewable energy (e.g. Boasson & Wettestad, 2013; Commission, 2013). Therefore, it is to be expected that Sweden, as an EU-member, is more influenced by the EU than Norway,[13] a non-EU member, in the realms of climate and energy policy. This leads to expectation 5:

Expectation 5:

Membership in international organizations, here the EU, has influenced levels of ambitiousness in renewable energy policy in Sweden, but not to the same extent in Norway, a member of the European Economic Area.

[13] Norway is, however, a member of the European Economic Area (EEA). Through this membership, Norway trades extensively trade with the EU member states and implements a lot of EU legislation, including legislation regarding climate and energy.

3 Methods and data

3.1 Most similar systems design

To investigate the topic, the method of *most similar systems design* will be employed. The method is used to compare cases that ideally are similar on all variables except for one, and have different outcomes on the dependent variable (Mill, 1843). All similar independent variables can therefore be eliminated except for the one, or the few, where the cases differ. This remaining variable(s) is(are) therefore expected to explain the outcome on the dependent variable (George & Bennett, 2005). Eliminating irrelevant variables is thus used as a strategy to enable a more focused analysis (Lijphart, 1971, 1975).

Advantages of this comparative case design further include obtaining in-depth descriptions of Swedish and Norwegian energy politics and policies, and achieving high measurement reliability and internal validity. Here, this means that a causal explanation of the evolution of the energy systems in Sweden and Norway may be enabled by combining historical process tracing with comparative analysis. This is not least caused by the fact that dual process tracing, according to Tarrow (2010, p. 244), "reduces the possibility that a supposed determining variable is as critical as it might seem from a single-case study alone."

On the other hand, such small-n studies might have problems explaining the dependent variable, because many variables might lead to the same outcome, which may be termed overdetermination (George & Bennett, 2005). Co-variation between different independent variables might also make it hard to discern exactly which variables actually affect the dependent variable, and in what way. Here, this might play out in the way that the different independent explanatory variables probably influence each other, such as the political will/commitment to stimulate growth in new renewables technologies, and the level of available natural resources for expanding production in mature renewables technologies.

To deal with this challenge, the respondents were for example questioned specifically on what role they perceived that governmental political will has had for the expansion of various types of new renewable energy, see the interview guides in Appendix 3. In addition, to attain a better assessment of the strength of governmental commitment, the analysis includes an assessment of relevant policy documents such as strategic plans and public reports on renewable energy, a review of the historical levels of funding for the stimulation of production from these technologies, and analyses of statements made by state leaders on these issues.

Small-n studies usually have a limited potential for external generalization to large populations of cases (Gerring, 2007). Generalizing from the two Scandinavian countries in this domain should, and will, thus be in the form of what George and Bennett (2005) refer to as *contingent generalizations*, i.e. carefully constructed inferences to other cases sharing specific qualities with the cases at hand. Such inferences, moreover, will necessarily be of a tentative nature. The results of this study can therefore be expected to indicate possible explanatory factors of renewables investment in similar European countries, such as in Finland (see e.g. Ericsson et al., 2004; Weckroth et al., 2011).

3.2 Cases within the cases: wind power development in Sweden and Norway

To shed light on what mechanisms have particularly influenced the investment in renewable energy sources, wind power in Sweden and Norway has been chosen as an area of particular attention in this study. Wind power is particularly interesting here, as the wind power resources in Norway have been estimated to be better in Norway than in Sweden (see Table 2), and Sweden despite of this fact nevertheless has seen a very much higher domestic investment in the production facilities from this technology. To follow up on this, the interviewees were particularly questioned about wind energy, and data collection has been particularly focused on the development within this field.

3.3 Sources of data

The study is based on a wide range of sources, including 16 semi-structured interviews with key respondents in Sweden and in Norway.[14] In order to obtain interviews that were as comparable as possible from an organizational point of view, the informants were chosen more or less "symmetrically" from Sweden and Norway so that: the ministries in charge, the national regulating agencies for electricity, the umbrella interest organizations of the renewable energy producers, and the interest organizations of wind and bioenergy would all be represented. In addition, informants were also contacted on the basis that they held key insights into the development of the energy system in their country, for example a key politician, a researcher, and a wind project leader.

Before the interviews were conducted, the Norwegian Social Science Data Center (NSD) was notified, and the project was approved. The interviewees are not anonymous, as the topics under discussion were not regarded as sensitive, and letting the readers know who has expressed what enhances the transparency of the study. Since the project lasted longer than initially planned, and NSD in the meantime had implemented new and stricter rules regarding saving of personal data, the project had to be re-applied and was, as of 2019/2020, obtaining a new approval. Thus, the interviewees also were re-asked if they would like to contribute. This request was, after a new approval from NSD, sent out at the same time as the quote checking to save time. All informants were also allowed to comment on the whole report. The informants who answered agreed with the quote checking and consented in re-use of the data. Unfortunately, a majority of the interviewees did not answer to the request for quote checking and further data use.

Three main topics were covered in the research interviews: a) drivers behind policies on renewable energy in Sweden/Norway over the last decades, b) the roles of different actors, such as the ministries in charge, and c) what might explain the differences in renewables investment between Sweden and Norway, including the different effects of the joint green certificate market that was introduced in 2012. The interviews were taped and the interview notes were systematically sorted.

Other sources of data include: government and agency reports, public statistics, research papers, newspaper articles and other relevant literature. The time period chosen is from 1960 to the end of 2014, because it was arguably mainly in this period that the two national energy systems evolved more rapidly than before in terms of changes in energy production and consumption from the various energy sources (see for example Bøeng & Holstad,

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[14] The interviewees/informants are listed in Appendix 1.

2013; Energimyndigheten, 2018). Moreover, by looking at the period from 2012 to 2015, the first effects of the joint certificate system with Sweden and Norway may be scrutinized and discussed.

Arguably, several interesting features have arisen in the energy systems after this period as well, indicating that there is also ample room to study the policies regarding new renewable energy and their effects after 2014. For example, in Sweden and in Norway, both production capacity and actual production of wind power have significantly increased since then, and in both countries, this expansion has caused significant controversy.

4 Similarities in Norway and Sweden

From an overarching perspective, Sweden and Norway are about as similar as they possibly can be in the standards of comparative country research; The countries were both ruled under the Swedish crown from 1814 until 1905. They feature similar political systems, similar party systems and generally have consensus seeking policies. Globally, both countries rank at the top in different indices of country development, such as the Human Development Index (HDI). Moreover, they feature several cultural similarities, for example in terms of language and history. The neighbors are both generous and affluent welfare states. Affluence is relevant in this context, as until recent years, investment in new renewable energy has been dependent on economic support and beneficial framework conditions due to its higher levelized costs of energy than the alternatives (REN21, 2014). In other words, until recent years, it was costlier produce renewable energy from the new renewable energy sources than from, for example coal and gas, when all costs related to the generation were included.

Sweden and Norway also share several independent features/factors (these may be called "independent variables" in small-n research) that might be linked to ambitions regarding the establishment of production facilities for new renewable energy in the energy systems. Consequentially, these independent variables must be excluded as possible explanatory factors for differences. Explanation for the large differences in new renewable energy production must thus be sought elsewhere. Here is a list of similar independent variables:

4.1.1 Similar political climate and energy targets

First, the Governments in Sweden and Norway have set similar official political targets that guide the policies that typically stimulate or influence renewables growth over the last decades. These include high targets for: the reduction of greenhouse gas emissions (e.g. MD, 2008; MF, 2009, p. 34; MSD, 2005), increasing energy security through higher domestic renewable energy production, enhancing energy efficiency. Other similar targets include becoming world frontrunners in innovation and entrepreneurship (see e.g. ND, 2008, p. 10; OED, 2012b, p. 137). Cost efficiency/a market based approach has long been an important guiding principle in the energy policies of both countries, and still is as of 2020 (e.g. IEA, 2019a; Norwegian Government, 2017).

4.1.2 Similar needs to increase energy access and improve production

Second, Sweden and Norway have both needed to increase their access to the various sources of energy and improve energy production substantially since WW2 in order to satisfy the rising domestic energy demands (for example Energimyndigheten, 2007; OED, 2012a, p. 15). Since the mid-1990s, both countries have seen years of net electricity import, as well as years of net export, caused by factors such as varying precipitation and average winter temperatures (Energimyndigheten, 2012c; OED, 2012a). In the years before 2014, however, both Sweden and Norway have, on the average, been net electricity exporters (OED, 2019; SCB, 2017), and this has continued to be the case (e.g. Rydegran, 2019; Aanensen & Holstad, 2018).

4.1.3 Ample resource bases for renewable energy

Third, to expand production from the various renewable energy sources at a large scale, an ample resource base is needed. The neighbors are also well endowed in terms of renewable energy sources, with large potentials for the production of, for example: electricity from hydropower, wind power and biomass power (e.g. Egnell et al., 2011; Førsund et al., 2008; OED, 2012a; Ramstad, 2011; Sandgren et al., 2007; Waagaard et al., 2008). For a closer assessment of the potentials for renewable energy, see Table 2. Norway's and Sweden's resources of various types of renewable energy vary, with Norway having a much larger potential for hydro power, while Sweden has a much larger potential for bioenergy than Norway.

4.1.4 Large dam storage capacities

Fourth, a challenge with some renewable energy sources (solar photovoltaic power, wind power, wave power and tidal power) is that they are intermittent, which makes electricity system management crucial, and implies that back-up power production capacity and access to energy storage may be essential. However, in Norway, there are large reservoirs for water storage, which thereby constitute reservoirs for energy. These may store energy equaling to approximately 70% of Norwegian power consumption (OED, 2016). Indeed, these Norwegian reservoirs together constitute about half of Europe's dam storage capacity, and this capacity amounts to about 86,5 TWh electricity production (see NVE, 2017). These dams function as energy storage and provide regulating power, which is used to regulate electricity production, where the regulator, the transmission system operator (TSO) Statnett, is taking into consideration uneven levels of precipitation, how much water is already stored, the power production from intermittent renewables sources (particularly wind power) and varying power prices (Killingtveit, 2012; OED, 2012a). Sweden also possesses large water reservoirs, which hold a seasonal storage capacity equaling the production of about 33,7 TWh (IVA, 2016, p. 11). Thus, while Sweden has a much lower hydro storage capacity than Norway, it still has substantial reservoirs.

4.1.5 Similar electricity markets and stakeholders

Fifth, structural features, such as the electricity supply system, might also impact the investment conditions. Sweden and Norway's electricity supply systems also share several features: Until the deregulation in the 1990's, there were power generating monopolies in both countries. At that time the large national power suppliers also owned the electricity grids. In the 1990's, these monopolies were reformed, and deregulated market based supply systems were introduced as the first in the world, first in Norway, then in Sweden. This is termed *the liberalization of the electricity sector* (Bye & Hope, 2005; Fosso et al., 1999; Högselius & Kaijser, 2010). Today, the greatest producers of electricity are still the earlier monopolists: state-owned Vattenfall in Sweden and state-owned Statkraft in Norway. Further, the central electricity transmission grids are correspondingly owned by the state-owned companies Svenska Kraftnät (Swedish National Grid) in Sweden and Statnett in Norway.

4.1.6 Similar electricity prices

Sixth, electricity prices might also affect the viability of expanding power production from technologies that were not yet mature in the period up to 2014, such as wind power. The higher the expected future electricity prices, the more lucrative it may be to invest in new generating facilities for new renewable energy. If prices are generally substantially higher in

Norway than in Sweden, for example, this may implicate that with the introduction of green certificates, it becomes more economically viable to locate plants in Norway than in Sweden. However, in reality, the differences in electricity prices probably have a somewhat limited explanatory power for the development of new renewable energy production over the last two decades (Interviews, 2013). The neighbors' electricity markets have, since 1996, been tightly connected to each other through the common power market Nord Pool. Moreover, there are several main transmission lines of electricity between Sweden and Norway, which also contribute to making the prices more equal (see Energimyndigheten, 2012b; Statnett, 2019a).

4.1.7 Similar influence from EU's climate and energy policies

Seventh, the renewable energy production in both Sweden and Norway is subject to the influence of the EU's energy policies, lately in particular through the EU Renewable Energy Directive (Directive 2009/28 EC, the Renewables Directive, RED I) (Parliament and Council, 2009). Because of their already very high share of power from renewable energy sources in their national "energy mix,"[15] both countries were required, after negotiations, to have a lower relative increase in their national targets than several of the other countries subject to the Renewable Energy Directive.

4.2 The joint green certificate market

Sweden established a green certificate market in 2003. Estimates show that it has added about 13 TWh of extra production of renewable energy until 2011/2012 (Energimyndigheten, 2012a). On January 1st 2012, Norway and Sweden launched a common green certificate market in order to reach their national renewables targets stated in the Renewables Directive. This directive requires Sweden to enhance its share of domestically consumed renewable energy from 39,8% in 2005 to 49% by 2020, while Norway has to increase its share from 58,2% in 2005 to 67,5% of energy consumed domestically by 2020 (Commission, 2009; MFA, 2011a, 2011b; NVE, 2011).

Electricity generating companies operating in Norway and Sweden are issued these certificates when they expand their production of renewable electricity. This means that those who have invested in such production will get extra revenue in addition to the payment for the electricity. One certificate is issued by the Norwegian Water Resources and Energy Directorate (*Norges vassdrags- og energidirektorat*, NVE) and by the Swedish Energy Authority (*Energimyndigheten*) per MWh of electricity produced for 15 years. All producers of new renewable electricity, including from small-scale hydropower, are eligible for such support, and no production technology is favoured. The providers of power, i.e. the power transmission companies, and certain electricity customers are all obliged to buy certificates according to a certain share of their total power consumption (MFA, 2011b; Norwegian Government, 2014/2017; NVE, 2011). This share is increased from 3% in 2012 to 18% in 2020, before it is gradually reduced and finally phased out in 2035. The price for the certificate system is paid by the electricity customers via a small fee in the electricity bill (Norwegian Government, 2014/2017).

By 2020, the two countries are, put together, to add a total of 28,4 TWh of electricity from renewable sources. Norway finances 13,2 TWh and Sweden 15,2 TWh of this target (Regjeringen, 2014). The price for this increase is to be paid almost equally by the

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[15] Energy mix means the share of different energy sources in the total national energy production.

Norwegian and Swedish electricity customers. Thus, new renewables projects have been, and will continue to be, located where it is the most profitable to invest, regardless of the country. In Norway, investments must be made before 1 January 2021 to qualify for support, while in Sweden, the green certificate market will continue to operate between 2020 and 2030, with a target of 18 TWh additional electricity (Norwegian Government, 2014/2017).

5 The development of renewable energy production from 1960 to 2015

5.1 Sweden: solving domestic needs and being an environmental frontrunner internationally

With a steadily increasing energy consumption, Swedish authorities let companies build out production facilities for hydropower in most of their remaining river systems in the 1950's and 1960's, leaving only four major rivers in the North untouched in the beginning of the 1970's. These four were protected due to concerns over nature conservation (Chen & Johnson, 2009, p. 222, Andersson, 2013). Needing higher electricity production, the Swedish Government invested large sums in developing nuclear power production. This was then viewed as an acceptable and better alternative than generating more power from coal and petroleum products.

In the period between the end of 1960 and the mid-1980's, twelve nuclear power plants were constructed and put into operation. However, the Swedish nuclear build-out created a strong and widespread political opposition in the Swedish population;[16] "The growth of antinuclear attitudes, combined with the 1973-74 oil crisis, skyrocketed the nuclear power issue to the political agenda" (Nohrstedt, 2005, p. 1047).

Thus, the environmental and anti-nuclear Swedish Centre Party (*Centerpartiet*, *Centern*) reached a record high approval in the 1976 election. Then, the large Swedish Social Democratic Party (*Sveriges Socialdemokratiske Arbetareparti*, *Socialdemokraterna*) lost power to a coalition of non-socialist parties for the first time in 44 years, led by the Centre Party. Several researchers argue that this outcome was determined by the nuclear controversy (see Chen & Johnson, 2009; Nohrstedt, 2005, p. 1047, citing Petersson 1978, Holmberg et al. 1977 and Carlsson 1999). Also within the new Swedish coalition government, nuclear power was very controversial, and the Centre Prime Minister resigned after having been defeated several times on the issue of building new reactors (Nohrstedt, 2005).

The oil crisis of 1979, again leading to higher oil prices, further increased the motivation to substitute fossil fuels with domestically produced energy (Interview Andersson, 2013). The severe nuclear Three Miles Island accident in 1979 in the United States further strengthened the Swedish nuclear resentment. Therefore, the new Swedish Social Democratic Government decided on having a referendum on the topic in 1980. The population then decided that all the nuclear reactors were to be decommissioned by 2010 (Hultman et al., 2012; Nohrstedt, 2013). This opposition was also a main driver behind the establishment of the Swedish Green Party (*Miljöpartiet de gröna, Miljöpartiet*) in 1981, similar to the background of the establishment of several other green parties in Europe (e.g. Müller Rommel, 1985). The Chernobyl accident in the former Soviet Union in 1986 sparked another rise in Swedish and European popular nuclear resentment (Chen & Johnson, 2009).

[16] And was highly unpopular among their neighbours, not least the Danes.

Photo: Protesters from Greenpeace demonstrate against the repeal of the nuclear ban in 2010 in front of the Swedish Parliament. Photo source: Wikimedia commons. Photo by Prolineserver.

To this day these nuclear power plants have been producing large amounts of power: In 2017, for example, the three nuclear power plants with their eight reactors produced 39% of Sweden's electricity (Hultman et al., 2012; IRENA, 2020; WNA, 2020).

From the 1960's onwards, large-scale district heating was gradually built out in Sweden. During the first decades, the energy here came from fossil fuels, like coal. It was likely easier to build out district heating in Sweden than in Norway, because significantly more people lived in central areas, and fewer lived in sparsely populated areas (Interviews, 2013). The penetration of such water-borne heating was consequentially significantly higher in Sweden. In 1960, 74% of Swedish dwellings featured such central heating (Fasth, 2020). The depopulation of the countryside has been much more pronounced in Sweden than in Norway until 1970 (Berg, 2005), but in the northern parts of the countries, both have experienced similar relative changes (Stein, 2017).

Heavily dependent on imported fossil fuels, constituting 77% of primary energy supply in 1970 (Ericsson et al., 2004), the Swedish authorities wanted to increase their access to power at stable and low prices and increase their energy security by having a large-scale domestic energy source (e.g. Andersson, 2013). Therefore, much like in other countries, such as Germany (e.g. Lauber & Mez, 2004), the Swedish Government launched different programs to carry out research on and development of renewable energy and other energy sources, such as constructing plants fired on peat and biomass, but also using coal as fuel. The research efforts continued at least up until the 1990's (Andersson, 2013). These research efforts on bioenergy became a world class program, according to Chen and Johnson (2009), stimulating the use of various bio energy resources significantly. From the second oil crisis in 1979/1980, an oil replacement fund supported the change of oil burning devices to devices that could use peat, coal and wood chips. Replacement of petroleum products was a major motivation for developing domestic renewable energy sources (Andersson, 2013, p. 16).

To make bioenergy more competitive with fossil fuels, energy and environmental taxes were also introduced, while biofuels were exempted, from the 1990's onwards (Bergek, 2003; Ericsson et al., 2004, p. 1713). From then on, bioenergy gradually took a larger place in the Swedish energy mix, the largest part in the form of biomass for heating in the district heating systems (Energimyndigheten, 2013a, p. 31; 2014). This was a pragmatic solution to the need to heat homes by domestic energy sources, not an environmentally motivated solution:

> *We had lots of energy in the form of wood. It was better to use it than importing coal and oil. Climate was not a part of the question back then […] (Interview Fredriksson, 2013).*

With both larger area and higher productivity, the Swedish forestry industry was significantly larger in terms of manpower, revenue, harvest, etcetera, and was also politically more influential, than the Norwegian forestry industry. However, in the 1980's, the forestry industry was not only positive to bioenergy for energy production, as it was regarded as a competitor of other uses of the product, like for producing paper (Andersson, 2013, 24). The strong role of the forestry industry may have contributed to the extensive measures implemented in Sweden to enhance domestic bioenergy production and consumption.

Swedish yearly production of wood, and, accordingly, forest-derived biomass, is 7-9 times larger than in Norway, with around 90 versus around 11 million M_3 (Interviews, 2013; Landbruksdirektoratet, 2020; Skogsstyrelsen, 2019). A significant factor contributing to the difference is that many forest areas in Norway are located in parts of the country that are very hilly and are, as a result, not as easy or cheap to harvest wood material from as the vast fairly flat forest areas of Sweden (Pöyry, 2019).

Between 1982 and 1994, the Swedish Solid Fuel Act demanded that all thermal plants producing thermal energy of more than 50 GWh should be constructed so that they could use solid fuels, which accommodated switching to bioenergy, as Ericsson et al. (2004) point out. The development towards using bioenergy for heating was further increased by the CO_2-tax on competing energy from fossil fuels in Sweden in the beginning of the 1990's, which contributed to making biomass significantly cheaper than coal from 1991, and the cheapest form of fuel for heat production (Ericsson, 2009; Ericsson et al., 2004; Nilsson et al., 2009, p. 1713). Moreover, in the 1990's, the Swedish Government ensured a market for renewable energy through investment subsidies, which in particular benefitted bioenergy. To stimulate bioenergy production and consumption, bioenergy was also exempted from most taxes.

From the 1990's onwards, the Government came up with incentives to produce electricity from bioenergy in combined heat and power plants (CHP plants) in Sweden (Andersson, 2013). Thus, electricity production from these facilities gradually increased to 15,5 TWh in 2012 (Energimyndigheten, 2013). In 2013, 116 out of 208 TWh renewable energy in the energy system, or 56%, came from bioenergy (Energimyndigheten, 2015, p. 48). A large proportion of the bioenergy in Sweden used for power production comes from timber and other forest residues (Ericsson, 2009).[17]

The developments in Sweden have been based on a political consensus over replacing fossil fuels with renewable energy, as it has been viewed as a viable substitute (Chen & Johnson, 2009; Eikeland et al. 1999; Interviews, 2013). All major Swedish parties have been (e.g. Moderaterna, 2013; Socialdemokraterna, 2013), and, judging from the party programmes, mostly per 2020 still are[18] positive to renewable energy, but the degree of enthusiasm has varied: The Center Party has been the strongest proponent amongst the traditional parties, while the Green party has proposed the strongest policies overall. Nuclear power, however, was like previously a bone of contention in 2013 (interviews Kåberger and Fredriksson 2013), and per 2020 still seems to be.

In "the energy agreement" (*Energiöverenskommelsen*), a political agreement between the Center Party, the Social Democrats and the Liberals (*Folkpartiet*) of 1991, and in 1995 between the Center Party, the Social Democrats and the Left Party (*Vänsterpartiet*), the stated goals were to substitute nuclear energy first when there were substitutes. Thus, bio-based combined heat and power was supported with 950 million Swedish Kroner (SEK), and they also aimed to build out energy production from other energy sources (Interview Andersson, 2013). The goal has been to develop a so-called "third leg" to stand on ("*et tredje ben*") in the Swedish energy system, formulated in an agreement in 1998 (Interview Borgström, 2013). This has especially been the rhetoric of the Center Party.

> *Characteristic of the Swedish energy debate is that there has been more or less total consensus on substituting oil for several decades, but none on substituting nuclear power (Interview Kåberger, 2013).*

The significant change in the composition of the energy sources behind Sweden's energy consumption from 1970 to 2013 is summed up in Figure 2, while the large change in Sweden's power production from 1970 to 2013 is illustrated in Figure 3:

[17] The forestry industry has previously, however, been heavily criticized by environmental organizations for cutting down too much of the old forests and thus violating conservation responsibilities (e.g. Hoffner, 2011)

[18] The rightwing populist party the Sweden Democrats (*Sverigedemokraterna*) seems to be skeptical towards new renewable energy in their party programme.

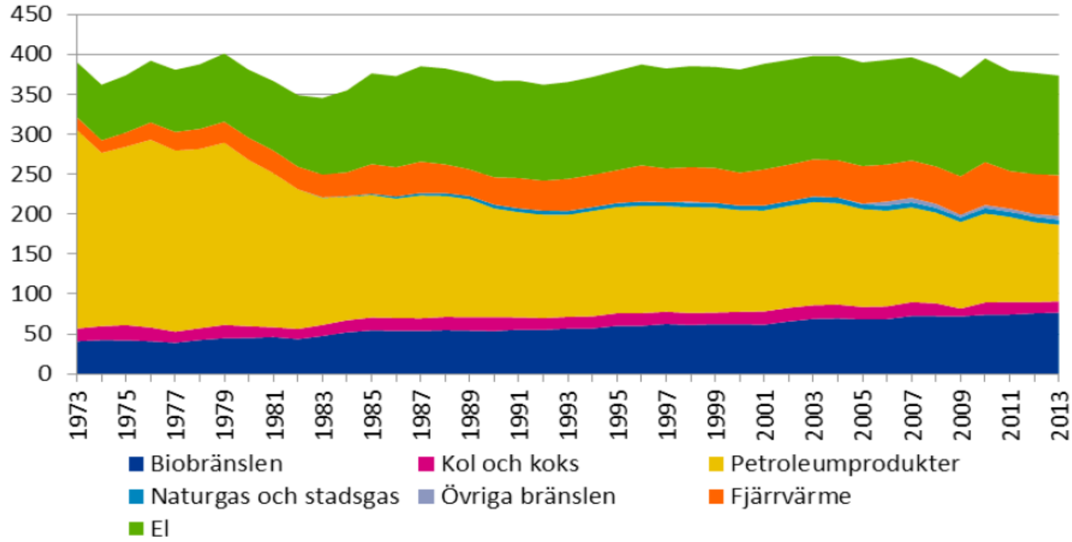

Figure 2: Total consumed energy per energy source from 1970 to 2013 (Energimyndigheten, 2015, p. 39). The dark blue field on the bottom shows the energy source consumption from bio fuel. The pink field next shows coal and coke. The yellow field illustrates petroleum products. The light blue field represents natural gas, the violet other fuels, while the orange field shows district heat. Last, the green field represents the consumption of electricity. Both bio fuels and district heat pertain to various types of bioenergy as the energy source, as more or less all Swedish district heating is fueled by bio energy.

Figure 2 demonstrates the large change in the Swedish energy mix from 1970 to 2013, not least how consumption of bio fuels (dark blue), district heat (orange) and electricity (green) increased substantially, while consumption of petroleum products (yellow) was significantly reduced, in this period (Energimyndigheten, 2015, p. 39).

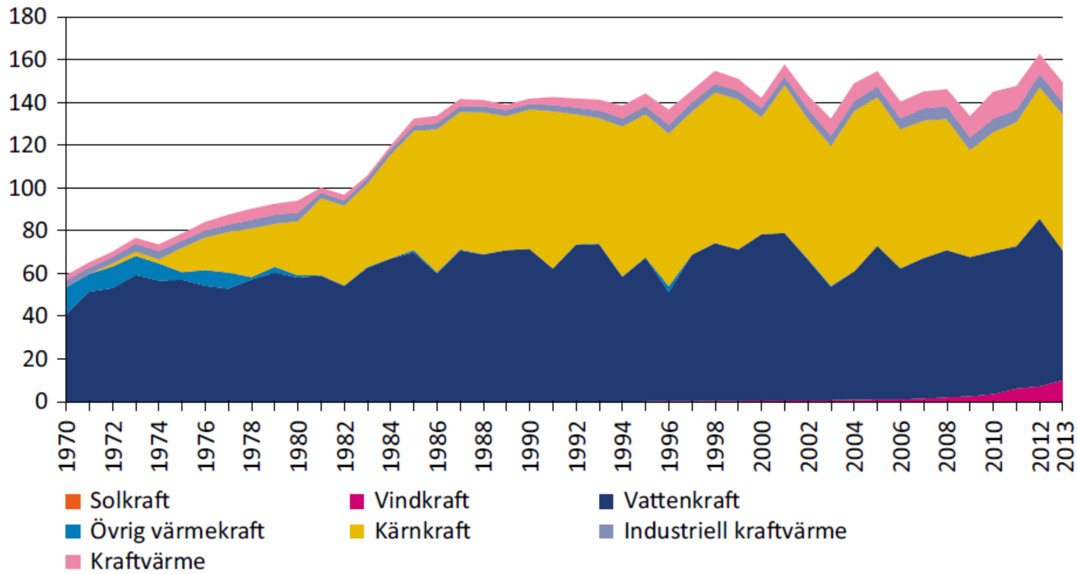

Figure 3: The development of the Swedish power generation mix from 1970 to 2013. The dark blue field represents hydropower. The dark pink field represents wind power. The blue field shows other heating power. The yellow field illustrates electricity from nuclear power. The light blue field shows other heat power, the violet field illustrates industrial power and heat, and the pink field shows combined heat and power.

Figure 3 demonstrates the large change in the composition of electricity production, as well as in the total amount of electricity, produced from 1970 until 2013. Nuclear power and hydropower were the largest sources of electricity in 2013. There was a large increase in the production of wind power (Energimyndigheten, 2015, p. 44).

The figures underscore some facts that often have been under-communicated in the popular debate about energy policy nationally and internationally. The premise that *energy production and consumption from the various sources is stable over years*, which has often been the starting point in discussions, is simply wrong. Electricity production and energy consumption have changed significantly over the last decades in Sweden. For example, electricity has become a much more important source of energy while oil and petroleum products and coal have become much less important. This is also the case in Norway (will be discussed in 5.2), for example, and in the EU's member states (e.g. IRENA, 2018, Eurostat, 2020). Moreover, renewable energy sources are increasingly important in EU's energy production and consumption (Farand, 2020).

In the 1990's, especially with the international Kyoto agreement of 1997, climate concerns became a key driver behind the Swedish energy policy, and served as an extra motivation for increasing the production of new renewable energy (Interviews Andersson; Olesen, 2013). In addition, EU membership impacted the Swedish level of ambition in climate and energy policy (interviews Fredriksson; Olesen, 2013; Grande, 2013). The increased climate awareness also contributed to making nuclear power more popular again among the Swedish conservative block (Chen & Johnson, 2009, pp. 227-229).

A Swedish green certificate market was launched in 2003 to stimulate the production of renewable energy. The green certificate market made it profitable to invest in technologies that were close to being technologically mature and competitive with other technologies in the market. The cheapest projects were built first, namely those for electricity from combined heat and power (CHP) plants (Jacobsson, 2008). Then, these certificates were used for investments in wind energy production. Thus, significant amounts of wind production capacity were added from 2006. The whole Swedish wind industry was in a large learning process. The system was also improved to speed up the licensing procedures (Interviews Ebenå; Kåberger, 2013).

In Sweden, unstable investment conditions for wind power were seemingly typical until the beginning of the 2000's. Then, the Swedish Government launched a host of different measures, general as well as specific, to further increase the production of renewable energy. These included initiatives such as: a wind pilot project, the aforementioned Swedish green certificate market, a support mechanism for solar cells, and extra subsidies for offshore wind (IEA, 2012).[19] Investments in new renewable energy projects have generally been secured by political guarantees, stable support mechanisms and compared to Norway efficient procedural practices (Buan et al., 2010; Riksrevisjonen, 2014).

Now, the electricity certificate system appears to be unusually stable and trustworthy (Interview Kåberger, 2013).

The Swedish Government thus actively pursued its ambitious long-term policy goals, among them becoming the first nation in the world to get all its energy from renewable energy sources (Buan et al., 2010; MD, 2008; Naturvårdsverket, 2012). Some projects have been uncontroversial, while others have met harsh local resistance, such as several of the proposed wind farms. The municipal veto right has stopped more than 100 Swedish wind projects, to the harsh criticism of the wind energy industry (Lundström et al., 2013; Martikainen, 2013).

[19] Look at Table 2 for further information about this.

In 2014, the laws stated that no new nuclear plants were allowed to be established, but that the 10 current reactors could be replaced where the old reactors have been standing (WNA, 2014). Several of the reactors were getting old, and had to be replaced if Sweden is going to produce the same amount of electricity from nuclear power as before over the next 2-5 decades (Interviews Ebenå; Kåberger, 2013). However, what will happen in the longer term has appeared, and still appears, to be an open question. IEA (2019a, p. 12) wrote: “Sweden is not pursuing a politically mandated phase-out of nuclear energy. Political parties also agree that nuclear power will not be subsidized,” and note that the production facilities of nuclear power “have struggled to remain competitive” caused by the low electricity prices in the Nordic electricity market and the cost of safety upgrades in the wake of the Fukushima nuclear accident in 2011.

Nuclear energy is more expensive than many other types of energy, such as wind energy, in terms of total production costs (levelized costs of energy, LCOE). Moreover, the costs of dismantling the production facilities were, and still are per 2020, extremely large. This would make nuclear power production even less competitive, if the industry had to pay the full price for all these costs, which previously in Sweden were partly incurred via a tax on nuclear power production (Interview Kåberger, 2013). This tax was, however, fully phased out in 2019 (WNA, 2016, 2020).

Different projections showed that without such nuclear decommissioning, the Nordic power market would have a significant surplus in 2020, when the 26,4 TWh from the common certificate market has been added, energy efficiency measures implemented, and other new sources of electricity have also been added after including more countries in Nord Pool (Interviews Ebenå, 2013; Kåberger, 2013). As projected, such production surplus in the Nordic power market has also become the case (Brenna, 2019b).

The alternative to replacing old nuclear reactors is expanding the production of renewable energy. In Sweden, there is very limited potential for expanding the production of hydropower (Andersson, 2013). Thus, producing more energy from the various sources of new renewable energy, including bioenergy sources, together with further improving energy efficiency, are the only options. However, establishing production facilities for intermittent renewable energy further at a large scale constitute challenges for the Swedish and Norwegian energy systems. This includes needs to: improve the transmission grids, improve technical regulating capacity, and ensure sufficient back-up capacity. Large investments in, for example, wind parks, normally require sufficient electricity grid transmission capacity to carry the electricity from the generating site to the higher power electricity grids (regional grids and the transmission grids grids), which may require considerable electricity grid investments, or alternatively to locate the wind park right next to main transmission lines of electricity.

The large dam capacity in Norway and Sweden provides large amounts of power that may either be stored, or used for power production, and thus constitutes, at least parts of the needed back-up generation capacity for such intermittent generation. Moreover, when production of renewable electricity comes from different sources, and the Nordic countries and their neighbors are closely interconnected by the electricity grids, electricity supply security is enhanced, and electricity prices in the Nordic market will on average be lower.

5.2 Norway: abundant energy resources and a “petroleum adventure”

After the Second World War, Norwegian authorities stimulated the building out of hydropower production facilities at a large scale in order to satisfy growing electricity demands in the process of electrifying the Norwegian countryside and modernizing the country, but also as a means to support Norwegian energy intensive industries by giving them access to cheap power. Often, production facilities for metals and chemicals were placed right next to sites of large-scale hydro production. Since then, Norwegian energy intensive industries have been able to purchase electricity at low prices in an international context, in part because of beneficial long-term contracts (Bøeng & Hofstad, 2013; Moe & Laird, 2013, p. 45).

In particular, the dominant Labor Party (*Arbeiderpartiet*) saw building out hydropower production and establishing corresponding energy intensive industries as a way to industrialize the country, create needed work places, and also stimulate industries that could secure large export incomes for the country. "Together with the Merchant Marine, this industry also became the main source of badly needed foreign currency" comments Midttun (1988, p. 125). Moreover, this establishment was also linked to the modernization of the country, for example would the last villages in Norway get electricity in the 1960's (Interviews Astrup; Leistad, 2013). That Norway opted for only building out hydropower in the 1970's and not also nuclear power was in the beginning far from an obvious outcome.

> *We had a discussion in the 70's about nuclear power. Then, we agreed that we had so much hydropower, which was cheap and could be regulated, and could be used to build up local industry. For a long time, there was no technology for wind power, and we had not yet found gas. Had it been discovered earlier, we would have built it out earlier (Interview Johansen, 2013).*

Hydropower production facilities and water reservoirs continued to be established at a rapid pace in the 1970's and the early 1980's because the resource base was still ample, the technology was mature, and a solid hydropower technological competence had been established in Norway, including as a strong competence on the topic among the governing agencies and ministries dealing with environment and energy issues (Interviews Flatby; Hegg Gundersen; Hersvik, 2013).

Cheap electricity, together with the oil crises of 1973 and 1979, led to gradual substitution of petroleum driven heating systems with electric panel ovens to heat new buildings in Norway (Havskjold, 2001). Central heating systems were often modified to use what was at the moment cheapest of electricity and oil. Electric ovens became the dominant way of heating buildings (Bøeng & Hofstad, 2013, p. 31; Statnett, 2019b). The large resulting electricity consumption over time became increasingly controversial. From the end of the 1960's, the environmental movement started to protest against the large projects because of the environmental consequences in terms of, for example damage to landscapes.

Especially when the Alta-river system and its landscape was severely modified by the construction of a large-scale hydropower plant in the period from 1979-1981, popular protests peaked. The protesters included a wide range of participants, not least from the environmental movement and from the Sami people, making it a symbolic event of popular resistance to protect nature against the state. The following picture shows some of the protesters, including Sami people in their traditional costumes among them:

Photo: National Archives of Norway.

According to Midttun (1988, pp. 128-130), hydropower over-expanded: The construction was frequently more expensive than what had been estimated, and the markets for energy-intensive products were already saturated, leading to widespread and strong criticism, also from economists. After intense protests from the growing Norwegian environmental movement in the 1970's and 1980's, protection plans were established, gradually protecting several large watercourses (Persen & Ranum, 1997). The first protection plan was decided on by the Norwegian Parliament in 1973 (Regjeringen, 2003).

In 1991, the Norwegian Government launched the fourth, and so far last, main version of the "General plan for the river systems" (*Samlet plan for vassdrag, NOU 60, 1991-92*), which outlined which watercourses could be built out first, based on economic and environmental considerations, and which should be protected. In 1993, about 130 new watercourses were protected by the Norwegian Parliament. This reduced the controversy related to hydropower, but the environmental movement continued fighting to protect some of the remaining large river systems, and a supplement to the plan, protecting 46 more watercourses, was established by the Norwegian Parliament in 2005, which meant that altogether 341 river systems were protected against building out of hydropower (Regjeringen, 2003).

In the 1970's, nuclear power for commercial purposes was also discussed as a solution to projected large future energy needs. Therefore, The Norwegian Water Resources and Energy Directorate (NVE) proposed building out nuclear reactors at several sites and presented their plans in 1972. The Government in 1974 followed up and proposed to establish commercial nuclear power plants.[20] This caused great controversy, not least in the

[20] Norway has, however, had two nuclear reactors for research purposes, one in Kjeller and one in Halden. The Halden reactor was closed in 2018, and in 2019 it was decided to close the last reactor in Kjeller (Haugstad, 2019).

local communities where the plants were supposed to be constructed. In 1979, after the Three Miles Island Accident, the Norwegian Government preliminarily decided to abandon these plans, even though a committee had already recommended it earlier (Sejersted, 2014). Since then, the topic of building out nuclear power plants for commercial purposes has not been discussed seriously in the Norwegian Parliament or Norwegian Government.

In 1973, the international oil crisis also hit Norway, leading to investment in research on new renewable energy sources, similar to in Germany and Sweden. In particular, wave power received significant attention, as a dense type of energy that could over time potentially contribute significantly to the Norwegian energy supply (Christiansen, 2002).

The short term energy supply was, however, to a large extent to be based on Norwegian fossil resources. The first site of petroleum extraction opened in 1971 with Ekofisk, and over the following years new reservoirs were steadily discovered, leading to a rapid increase in petroleum production. This started what has frequently been dubbed the "the Norwegian oil adventure" (*Norges oljeeventyr*), that made Norway one of the World's largest exporters of oil and gas in 2014.[21] The petroleum industry gradually became more important for Norway's export revenues and public finances. It also employs a large number of people both directly and indirectly, estimated to be 165 000 persons, but with approximately 79 000 directly in petroleum and the rest in the related industries, in 2014 (Æskeland, 2014). Indeed, in 2012 and 2013, there were record investments in the petroleum industry on the Norwegian continental shelf, while other industries experienced all-time low investments (SSB, 2012, 2014a).

The petroleum industry also takes up a large share of Norwegian human capital by employing a lot of highly skilled people both directly and indirectly. This arguably contributes to considerable intellectual capacity building, but also employs the "brain power" that also has been, and arguably is also sorely needed in other sectors (see e.g. Hansen & Steen, 2011; Johansen 2012). In addition, significant resources have until 2015 been, and still are in 2020, allocated to petroleum research. Far more research was in 2014 connected to the petroleum industry than to renewable energy (Moe, 2012).

This affluent industry significantly contributes to making Norway one of the wealthiest countries in the world, for years constituting the largest part of the gross domestic export income (SSB, 2014b, 2020b). Steady governmental support has stimulated, and continues to stimulate, both private and public investment in the petroleum industry.[22] This might arguably be viewed as a symptom of a type of carbon lock-in, namely that the Norwegian society at large is "locked in" petroleum production.

Critics, such as the environmental movement, several members of the academic community, the Confederation of Norwegian Enterprise (NHO), and the renewables industry have viewed, and continue to view, this development of continuing dependence on one sector as worrying (see e.g. Bjørnland, 2013; Kjær Vidnes & Gjengedal, 2014). For example, a Norwegian wind energy manager stated in our interview:

> *We have become blinded by the speed in our petroleum sector. The large investments there have led to pressure in our national economy (Interview Hersvik, 2013).*

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[21] In 2019, Norway was the world's 15th largest petroleum producer according to Wikipedia (https://en.wikipedia.org/wiki/List_of_countries_by_oil_production).

[22] Through numerous policies, including: allocating large resources to research, giving the petroleum sector beneficial taxation regimes, supporting export through export guarantees such as guaranteed export credits from the state (GIEK), etc.

Investments in hydropower production, transmission and research gradually declined from a peak in the 1960's until the 1990s. Until 1991, the price of electricity was politically decided. Frequently, the same local and regional companies produced power and owned the electricity transmission grids and had long term contracts with the industry. The liberalization in 1991 meant that these companies had to be split. After this, the electricity grid companies no longer had the same large incentives to build out the grid as before, and for several years there was low investment in the Norwegian transmission system, leading to different electricity prices in different regions and vulnerability to shortages (Løvås, 2011).

In 2001, the Norwegian Prime Minister Jens Stoltenberg in a famous speech said "We have now come to the time, where the time for large-scale building out of river systems is over" (Stoltenberg, 2001). Still, there were significant quantities of small-scale hydropower that could be exploited commercially, and NVE had made a plan of stimulating such production (Interview Hegg Gundersen, 2013). Expansion of small-scale hydropower production facilities could typically benefit land owners, such as farmers, who could earn significant extra revenues from producing electricity.

Very cold winters in 1997 and 2002/2003, combined with little precipitation, led to a shortage of electricity, which created a peak in 1997 and high electricity prices in 2002/2003 (plus some of the subsequent years) (e.g. Bakker 2018; Bøeng, 2014). The Norwegian Government was, thus, severely criticized, on several grounds. At the same time, the major river systems were to be protected. Thus, political attention was given to the alternatives gas fired power and wind power. In 1998, in a white paper (*Om energipolitikken*), the stated target that production facilities generating 3 TWh wind power should be built by 2010, and that other measures, such as enhancing energy efficiency, and improving access to heating power from other sources than electricity should also implemented (MPE, 1998). All parties, apart from the Conservative Party (*Høyre*) and the Progress Party (*Fremskrittspartiet*) supported the wind target (Hager, 2014, p. 27).

To achieve a more stable electricity production, it was decided that two gas fired power plants would be constructed. The centrist Government led by prime minister Kjell Magne Bondevik tried to prevent this in 2000, on the grounds that gas fired power production would lead to increased GHG emissions, and they thus demanded CO_2 capture. The Bondevik Government had to resign because it did not obtain a majority in the Norwegian Parliament on this issue. Gas-fired power plants started producing electricity in 2007 and 2007/2008, but they were not very profitable, and they never contributed significantly to the Norwegian power supply (Norwegian Wikipedia, 2020). The environmental movement protested strongly against these plants, and demanded that there be no construction unless there was a carbon capture and storage (CCS) of all emissions.

To resolve the issue, the new Norwegian Labour Party Government, led by Prime Minister Stoltenberg, launched a plan to cleanse the emissions by establishing facilities for full-scale carbon capture and storage (CCS) at Mongstad. This was a prestige project, and the so-called "moon landing" (*månelanding*) received billions Norwegian kroner in investment support (Stoltenberg, 2007).

Still, the CCS plant did not manage to solve the challenge within the set time frames, and was postponed several times with mismanaged costs. This was harshly criticized by the Office of the Auditor General of Norway (*Riksrevisjonen*) (Riksrevisjonen, 2013). The ambitions and investments were, thus, scaled down significantly in the fall of 2013, and the whole project was re-launched as a technology development center. As of 2020, Mongstad is still a technology development center and will run until 2023, while CCS might be established at the landfill Klemetsrud in Oslo and in the cement factory Norcem in Brevik (Technology Centre Mongstad, 2020; Vermes, 2020).

In 2001, Enova SF was established to support the transformation to more environmentally friendly consumption and generation of energy in Norway. Until 2012, it was the agency that decided which renewable energy projects that would be publicly funded. At the end of the 1990's, Norway's first small wind parks were established. Establishment of parks with wind turbine technology was still expensive compared to building out more hydropower production facilities, and much like most of/all the other new renewables technologies, it had to get state support to be economically attractive to invest in for investors.

The Norwegian Government from the 2000's onwards launched several policy instruments to increase production of renewable energy from these new renewable energy sources. However, these have generally been weaker and have been introduced later than in Sweden (see e.g. Buan et al., 2010, see also Table 2).

One example is the "Strategy for increased build-out of bioenergy" (*Strategi for økt utbygging av bioenergy*), which was launched in 2008 (IEA, 2012; OED, 2008). Traditionally, district heating, which may use bio energy as an energy source, has not been used much in Norway, in contradiction to in Sweden. The main use of bioenergy in Norway has been for local heating in wood stoves. This has changed rapidly in recent years, with district heating established in several Norwegian cities, but was in 2014 still comparatively small (e.g. Energimyndigheten, 2015, p. 45; Energifakta Norge, 2019; SSB, 2011, p. 9; Aanensen & Fedoryshyn, 2014).

> *As long as we have more than enough "cheap kilowatt hours," as with the electricity certificate system, we will not have the same incentives to build out with new technologies (Interview Hjørnegård, 2013).*

The changing consumption of various types of energy products from 1990 until 2011 in Norway is illustrated in Figure 4:

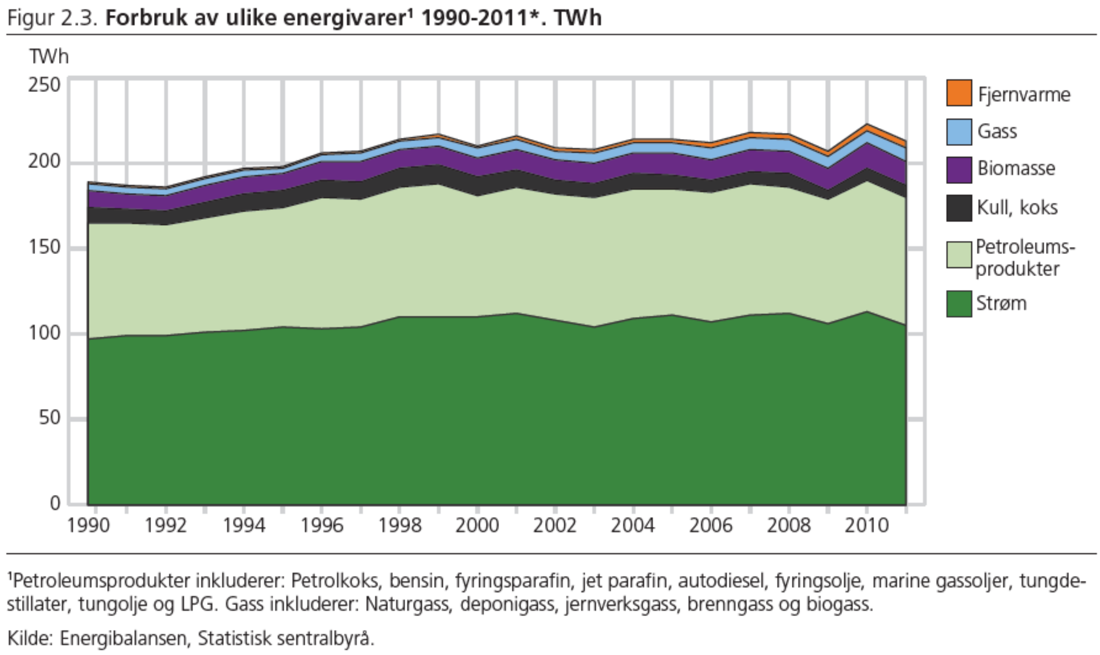

Figure 4: Total consumed energy per energy source from 1990-2011. Here, the dark green field represents electricity, the light green field petroleum products, the black field coal and coke, the purple bio mass, the light blue natural gas, and the orange district heat. Close to 100% of the Norwegian electricity has been generated from hydropower the last decades, and was previously on average 141 TWh a year. Currently (2020), the average Norwegian electricity production has increased to 151 TWh yearly in the wake of a significant increase in wind power production. The remaining power production as of 2020 comes from wind power and heat power (here, the sources of energy are municipal waste, industrial waste, oil, natural gas and coal), with a very small amount of solar power.
Sources: Bøeng og Hofstad (2013, 13), Energifakta Norge (2019), NVE (2020), Statistics Norway.

Figure 4 shows that the composition of the energy consumption in Norway the last decades seems to have changed significantly less than the Swedish. There has been a net increase in the consumption of electricity, little changes in the use of petroleum products, lower use of coal and coke, and increased use of natural gas and district heat.

In 2005, despite a large parliamentary majority for introducing international trade of green certificates with Sweden, Prime Minister Stoltenberg rejected joining in the Swedish certificate scheme (Interviews, 2013; Hager, 2014). Still, the political negotiations with Sweden continued at the ministerial level (Interview Hjørnegård, 2013). It was first when it was clear that Norway had to implement the Renewables Directive (Parliament and Council, 2009) in the summer of 2010, that the Norwegian Government ultimately, in 2011, decided to join the Swedish certificate scheme and thereby created the world's first international green certificate market (e.g. Gullberg & Bang, 2014).

Establishing increased wind power production in this period proved very difficult for the wind energy industry. There were several obstacles for investors: They experienced large insecurity regarding future support mechanisms. Licensing procedures were very long, caused by protests from communities where wind farms were planned ("not in my backyard"-factors, NIMBY-factors) and environmental organizations,[23] as well as the long public procedural practices. Initially, the funding levels from Enova SF were also low (interviews Hersvik; Leistad; Hegg Gundersen and Flatby, 2013, and also pointed out by

[23] NIMBY: "Not in my backyard," e.g. many people favor renewables projects such as wind turbines, but only as long as they do not affect them directly by for example disturbing their local landscape, producing noise, disturbing local wild life, etc. See for example Karlstrøm (2012).

Blindheim, 2013; Buan et al., 2010; Buen, 2006; Gjerald, 2012; Hager, 2014, p. 32; Lie, 2012a; Pettersson, Ek, Söderholm & Söderholm, 2010, p. 3118).

For a period, the power prices were low, making it less beneficial economically to invest in new production facilities for renewable energy (Interview Johansen, 2013). Electricity grid access was another barrier, as electricity grids were not prioritized for several years (Interview Hjørnegård, 2013). Supporting new renewable energy was by viewed, by several people, as being "uneconomic." Other types of obstacles for new renewable energy were public attitudes, such as the notion that "new renewables are expensive," "we should rather wait until the technologies are mature, then it will be cheaper for us to invest" (the "wait-argument"), extensive negative media attention about wind power[24] and the attitude that "Norway has enough power." Therefore, the 3 TWh-target was not met. Instead, total production was up at 2,1 TWh electricity from wind power in 2012 (Interview Leistad, 2013), which had increased to 5,5 TWh, contributing to about 4% of the electricity production in 2019 (NVE, 2020b).

Generally, the public discourse in Norway was also marked by a weak understanding of the vulnerability of being dependent on a very varying source of electricity production, hydropower. Production of hydropower over the last decades has fluctuated significantly because of the large variation in precipitation and temperatures each year, and fluctuations seem to have increased with larger average precipitation (SSB, 2020a).

Photo: The Alta hydropower plant. Photo source: Wikimedia commons, Blair 175.

[24] This is also often the case as of 2020 (e.g. Brenna, 2019a). Wind power is an issue of large contention in the public debate and among e.g. Norwegian parliamentarians. For example, an organization working against the establishment of wind power production facilities, Motvind, has been established.

Consequentially, Norwegian companies working with onshore and offshore wind mainly targeted their attention to the European market (e.g. Hansen & Steen, 2011; Steen & Hansen, 2018, p. 197). Furthermore, an increase in electricity supply combined with subsidization mechanisms, like green electricity certificates, could lead to a reduced net profit from existing state- and community owned hydropower plants, which could make new renewable energy projects less popular (Hager, 2014, p. 25-26; Interview Hersvik, 2013).

Some of these tendencies, for example the fact that support mechanisms and political signals have been unstable, also seem to have existed for the other new renewable energy technologies in general, at least until the joint, and technology neutral, green certificate system with Sweden was introduced 1 January 2012 (Hager, 2014; Interview Isachsen, 2013). Norway's first biodiesel plant, Uniol in Fredrikstad was, for example, closed a couple of years after it had been opened, because the Government changed policy from stimulation by tax exemption to withdrawal of this support, which made investors unwilling to invest more in the company, leading the company to lack the needed means for continuation (White et al., 2013, p. 102).

Until the joint market with Sweden was launched in 2012, Norway was more or less the only country in Western Europe to not have any regular support mechanisms for renewable energy, as Wicken (2011) points out. However, where the investment support has been adequate, and the market conditions and legal framework have been supportive, Norwegian private persons and enterprises have invested in new renewable energy. For example, after Enova SF introduced investment subsidies to heat pumps, there was a very rapid and widespread growth of private and public heat pump installations and heat generation (Enova SF, 2011).

Unstable support policies, combined with a level of subsidies that has been fairly low, and inconsistent political signals probably influenced large Norwegian renewables companies for some years to direct their attention abroad in terms of investment in the new renewable energy sources. For several years, Norwegian Statkraft, Europe's no. 1 producer of renewable electricity, has, for example, invested large-scale in offshore wind in Scotland and England, and in onshore wind in Sweden. However, in 2014 Statkraft only owned three established Norwegian wind production projects through its company SAE Wind, which it owned together with Agder Energi (Statkraft, 2014).[25]

A primary focus on the export market was, in 2014, also the case for the Norwegian solar PV component industry and other PV related industries. The Norwegian Government and public authorities have supported RD & D and expansion in the Norwegian solar PV component industry through various measures (Klitkou & Godoe, 2013). It seems as though most "Norwegian PV" over the last decade has been constructed in various African countries (e.g. Valmot, 2019).

5.3 The joint green certificate market

During the first two years when the common certificate system was running, far more certificates were attributed to supporting production in Sweden than in Norway (Energimyndigheten, 2013). In Sweden, wind energy and bio energy projects were the main receivers, but also small-scale hydro projects and solar energy received support through the

[25] Since 2014, a number of wind farms have been established in Norway, however, and the generation of power from wind in 2018 reached a new record level of 3,87 TWh (Gilje, 2019).

green certificate system. In Norway, the recipients of the green certificates were in the beginning, almost exclusively small-scale hydropower projects. As several Norwegian wind projects applied for certificates, and the Norwegian wind industry was learning, the situation was expected to change in the years to come (Interviews Ebenå; Hegg Gundersen, 2013). This also turned out to be case: there was large expansion of wind power production in Norway in the years after 2014 (Gilje, 2019; NVE, 2020c). There has been issued more production licenses than there has been established wind power production facilities.

5.4 The strikingly different outcomes

Regarding production of bioenergy, in particular, the results of different government policies are striking. According to public data, Sweden produced 120,3 TWh of energy from bioenergy, while the total production in Norway was about 14-15 TWh in 2010 (Energimyndigheten, 2012e; OED, 2012a). In relation to the other sources of renewable energy, Sweden has also outpaced, and continues to outpace, Norway by far. Total Norwegian wind production onshore reached 0,9 TWh in 2011, while the Swedish had a sharp increase to 5,6 TWh. Norway has extremely large potentials for offshore wind due to the long and windy coastline and large territorial waters (see e.g. NVE, 2012; Sandgren et al., 2007 and Table 2).

The existing projects were only pilots because the Norwegian Government first wanted to have a comprehensive study of the effects and consequences of such projects (see e.g. Norwea, 2011). For example, the existing regimes for support were unable to make the first planned offshore wind park in Norway, Havsul, profitable. Therefore, this project was ended (Gillesvik, 2012). Still, Norway, as of 2020, has no commercial production offshore wind farms, and there is pressure to license floating offshore wind farms as of spring 2020 (Durakovic, 2020). As late as in April 2020, the Norwegian Government approved Equinor’s (previously called Statoil) plans to establish floating offshore wind power production. These facilities are estimated to start producing power in 2022, to supply power to petroleum installments in the North Sea (Lorentzen, 2020).

By contrast, several offshore wind parks have already been installed in Sweden, generating 0,5 TWh in 2011 already. These trends regarding investment also seem to be typical for the other types of renewable energy technologies that have reached a certain developmental, “maturity,” e.g. solar power (Energimyndigheten, 2012f; OED, 2012a; REN21, 2012; Statoil, 2012; Weiss & Mauthner, 2011).

This pattern seems to be less typical when looking at innovation in renewables technologies that are still at the development stage and therefore are very far away from grid parity. For example, Norwegian Statoil developed the world’s first floating wind turbine, the 2,3 MW Hywind (Statoil, 2012), and the World’s first non-commercial floating wind turbine was planned for research purposes in Norway (Seehusen, 2013). In addition, Statkraft developed the world’s first demonstration osmotic power plant (Statkraft, 2012). This is not, however, the case for all types of ocean energy. While Fortum planned what will be the world’s biggest wave power plant in Sweden (Fortum, 2012), wave power received little attention in Norway, according to Edvardsen (2012) in Norwea. What might explain these striking results?

Table 2 gives an overview of the estimated production from the various sources of renewable energy and the estimated potential capacity for producing energy from these sources, from a number of different sources, in 2014. The average yearly production of hydropower in Norway used to be around 141 TWh. Table 2 clearly shows the large differences between Norway and Sweden regarding energy potentials and production from all renewable energy sources, not least hydropower, bio energy and wind energy. The numbers regarding the potentials are derived from the existing sources in 2013, so if all available sources today (2020) were used, the numbers presented would likely be somewhat different.

Table 2: The different previously estimated potentials and production of renewable energy in Sweden and Norway, in 2012.

	Hydro-power (TWh)	Wind power (TWh)		Bio-energy (TWh)	Geothermal heat and power (TWh)	Photovoltaic power (TWh)		Ocean power (TWh)			
		Onshore	Offshore			Solar cells	Other solar	Wave energy (TWh)	Tidal currents (TWh)	Salt/osmotic power (TWh)	SUM
Sweden's theoretical potential capacity	90	540		Forest: 125-135, 7-8 of existent crops, 10-18 if all land used for land fallow and grass is used							760
Capacity minus protected areas											
Estimated production in 2012	78,5	7,1	0,46	130,8	13,8 (heat), 5****	0,0019	??	0, the world's largest plant was being built	0,1		197,20
Estimated extra technical potential capacity	2,7						??				
Norway's theoretical potential capacity	600	1636	14000******, 996 in areas up to 60 metres depth	425**	55***	4,4	??	600	2	250	17332,40
Total capacity minus protected areas	549,6						??				549,6
Estimated production in 2012	144	1,57	0,01*	14-15	3,5			3 prototype plants	1 prototype plant is being built, 1 full scale plant is planned	1 prototype plant	145,90
Estimated extra technical potential capacity	163,6	480		26-35	54,5		5-25	12-30*****	1	12	

Sources: Energimyndigheten (2012d), Statoil (2012), OED (2008, 2012a), MF (2009); Miljøverndepartementet (2009), Söderholm and Pettersson (2011), Førsund et al. (2008), SINTEF and KanEnergi (2011), Pettersson et al. (2010), Sandgren et al. (2007), Rosen (2012), Tjus and Fortkamp (2011), Statkraft (2012), Ramstad (2011), Energimyndigheten (2013b), NVE (2012).

*This came from a single project: Hywind.

**425 total, 325 on land and 100 from biomass in water.

***Estimated heat consumption in 2030, all heating can potentially be covered by geothermal heat in Norway.

****Heat pumps here refer to large heat pumps for district heating.

*****Dependent on their energy efficiency. The estimate is based on an estimate of using 10-25% of the wave power potential.

******797 TWh on depths up to 60 meter in areas that are not close to the coast.

6 Analysis, discussion and conclusion

6.1 What might explain the large differences between the energy systems in Sweden and in Norway?

Expectation 1:

Politicians will first opt for expanding production of hydropower in Norway and in Sweden by giving licenses to enable such production.

Expectation 2:

Physical resource potentials as well as the maturity of technologies influence the pace of expanding the production from the new renewables technologies.

The data and analyses clearly support the first two expectations. Norwegian and Swedish energy authorities issued licences to construct hydro power plants in Norway and Sweden accordingly, as hydropower was technologically mature in Scandinavia earlier than all other sources of renewable electricity. The analyses demonstrate that the Swedish and Norwegian Governments have had physical resource potentials on their minds when deciding on policies to promote first hydropower and then bioenergy in the Swedish case, and expand hydropower production and use electricity for industrial development and heating in the Norwegian case.

Sweden’s large development of various types of bioenergy up until 2015 came about as a result of several factors playing out over the last decades, including: improved resource use in the large forestry-based industries, sustained research and development efforts, creation of markets for bio fuel through taxation of fossil fuels, building extensive district heating systems, stimulation through green certificates and other means. It is the combination of all these efforts that have created the significant Swedish bioenergy industry and made bioenergy one of the countries’ largest energy sources.

Moreover, Swedish politicians, lacking access to additional hydropower that could be used for new production facilities, instead opted for the establishment of nuclear power plants after the second World War. The construction of the first nuclear power plant started in 1966 (Oskarshamn I, closed in 2017). For several years, nuclear power contributed about 40% of the country’s electricity, dropping to 30-35% in 2019-2020 after increased contributions from bioenergy, wind and solar and decommissioning of several older nuclear reactors - mostly for economic reasons (Swedish Wikipedia, 2020).

Despite significant production facilities already in operation, for Norway, electricity from hydropower held the potential to contribute to be a large and abundant electricity source also from 1960 onwards, if further hydropower production facilities could be established at a large scale. Having access to abundant and cheap hydropower has meant that generation of energy from other renewable energy sources (apart from firewood) have (generally) been comparatively expensive. Still, it was not clear that hydropower would be the single dominant source of electric power in the beginning of the 1970's. Mostly for economic reasons, but also influenced by negative public opinion, the Norwegian Government decided to abandon the plans for nuclear reactors in Norway in the 1970's (Hofstad, 2019).

Expectation 3:

> *External shocks, such as a crisis in energy supply, nuclear catastrophes and large fluctuations in petroleum and power prices have had decisive effects on Swedish and Norwegian policies, as they have made politicians and the polities aware of the risks associated with the current policies and given them incentives to stimulate production from the new renewable energy sources.*

The analyses also give support to expectation number three. The oil crises of 1973 and 1979 can be viewed as typical external shocks. They influenced both the Norwegian and Swedish energy policies in the 1970's, leading to more research on alternative energy sources, such as on different types of renewable energy, and other measures to enhance energy supply security. In Sweden, it was also a major motivation to stimulate long-term programs to promote bioenergy, while in Norway, it catalysed the ongoing large-scale substitution from petroleum products to electricity as an energy source.

Moreover, nuclear catastrophes can, as aforementioned, also be perceived as being external shocks. Such catastrophes certainly influenced energy policies in Sweden and Norway. The Three Miles Island accident of 1979 cemented the decision to abandon the development of commercial nuclear power in Norway, while Sweden at the time already featured several operating nuclear power plants. This accident was the prima facie reason for the Swedish Government's decision to arrange a referendum on the usage of nuclear power in 1980. Here, the Swedish people voted that nuclear power in Sweden should be abandoned within 2010. The Chernobyl accident in 1986 moreover strongly increased Swedish nuclear resentment and strengthened motivation for development of alternative sources of electricity.

Later, events that may also be perceived as (smaller) energy crises, namely the periods with very high electricity prices caused by cold winters and little precipitation in 1997 and 2002/2003 in Norway, boosted ongoing Norwegian energy efficiency programs, improved cross border electricity trade and investment in the development of alternative ways of supplying energy. The first energy crisis and other factors were, thus, important for the Norwegian Government's motivation to coordinate and stimulate work on better use of energy through a central institution. The governmental agency Enova SF was thus established in 2001. It supports alternative energy sources, including wind power, heat pumps, and other investments to attain a sustainable energy system transformation (Johnsen et al., 2019). Hence, such crises seem to have opened windows of opportunity for politicians and other "political engineers" who have wanted to change the energy systems by, for example, giving legitimacy to introducing targeted support mechanisms for renewable energy (see also Hager, 2014).

Expectation 4:

> *Membership in international organizations, here the EU, has influenced levels of ambitiousness in renewable energy policy in Sweden, but not to the same extent in Norway, a member of the European Economic Area (EEA).*

The interview data (Interviews, 2013) also provides some support for the fourth expectation. Some informants mentioned that the EU had made Sweden's climate and energy policies more ambitious in general. Norway, as an EEA member, is also strongly affected by the EU's policies in this field, as shown when Norway implemented its first support mechanism for renewable energy when the EU's Renewables Directive was to be implemented.

In practice, the two countries have had to comply with rather similar requirements from the EU, but the Norwegian approach has been much more passive than the Swedish, reflecting the different potential for policy impact. As a net effect, the EU's influence on Sweden seems larger than what it has been on the Norwegian environmental and climate policies, and has probably made Swedish climate and energy policies somewhat more ambitious and proactive. The exact effect is hard to assess. For example, Sweden has launched a national target that has been higher than those outlined in the EU's Renewable Energy Directive, and this domestic renewables target was already exceeded in 2012 (Energimyndigheten, 2020). Moreover, Sweden has been a promoter of ambitious environmental targets in the EU for a number of years (Ydersbond, 2018a, 2018b).

EU's influence on Sweden has seemingly also influenced *the type of policy measures* implemented to stimulate increased production of renewable energy. Åstrand (2005), Bergek and Jacobsson (2010), and the interviewees of Boasson et al. (2020) have argued that the EU influenced the Swedish approach to stimulate increased production of renewable energy, by supporting the idea that technologically neutral green certificates were a cost-effective way to attain enhanced renewables production and consumption. In Norway, sceptical attitudes towards green certificates have been widespread (e.g. Lie, 2012b; Linnerud, 2012).

6.2 Within case-case: Differences in wind power expansion under the joint green certificate market

That more wind power production was established in Sweden than in Norway under the green certificate market, despite the fact that the wind conditions are generally better in Norway, is a result of several factors. First, the Swedish wind industry matured earlier through a decade of experience after the certificate system was introduced, while the Norwegian wind industry was still learning (Interviews Ebenå; Flatby; Fredriksson; Pedersen, 2013).

Second, with the expansion of these technologies, this scaling up has pressed down the prices for installation and other processes in the supply chains, leading to lower total costs of installing wind power production facilities in Sweden, than, for example, in Norway (Interviews, 2013). Third, the electricity prices in Sweden have generally been higher than in Norway (Interviews, 2013), which may stimulate for the expansion of technologies where the levelized cost of energy is higher than for hydro power.

Fourth, Norwegian projects met additional obstacles, such as insufficient grid capacity and long licensing procedures caused by public protests, to a larger extent than the Swedish projects (Interviews Hegg Gundersen; Isachsen, 2013). Fifth, different taxation rules contributed to making Swedish projects more economically attractive (Interviews Hersvik; Isachsen, 2013). In the fall of 2013 and in the spring of 2014, the wind industry in both countries still experienced unstable investment conditions, caused by the combination of low electricity prices, low certificate prices and low prices in the EU Emissions Trading System (e.g. Interviews, 2013).

Sixth, there were many Norwegian hydropower projects that became profitable with the support from the green certificates, in practice competing with wind power projects. Being economically marginal, this could demotivate strong support for land-based wind power, which emerged as a future strong competitor (e.g. NVE & Energimyndigheten, 2018). As a possible seventh factor, it may be pointed out that the Norwegian energy policy for many years included gas-fired power plants as an important element.

6.3 What more can we learn from this analysis?

6.3.1 Regulatory stability is essential

The interview data (2013) and previous research (e.g. White et al., 2013) also demonstrate that another factor that might be decisive for investment is *regulatory stability*, i.e. giving investors the safety and motivation to invest in renewables projects by providing stable and predictable policies. This factor has played a part in the case of investment in wind energy in Norway, for example. When this factor is not present, many investors will not take the risk of investing in new renewable energy projects because of the large financial risk their investments then face.[26] Regulatory stability also pertains to knowledge and understanding of what is legal according to the international laws that affect Norway, for example the EU's Climate and Energy State Aid Guidelines, which were operational from 2014 onwards (Commission, 2014).

In Norway, economical arguments have for decades dominated the discussion about energy and environment, nurturing the doubts about regulatory stability, as the conditions for optimal cost-effectiveness may change rather quickly (e.g. Bruvoll et al., 2012). That regulatory stability is essential to secure renewables investment, has also been shown in numerous previous studies (e.g. Holburn, 2012). The need for "push-factors," such as stable support mechanisms to expand the production from the new renewable sources has, for example, been pointed out by Gross et al. (2012).

6.3.2 Other drivers of new renewables investment: the job market argument, declining technology costs and political decisions

Internationally, one of the big drivers leading to the creation of support mechanisms that result in renewable energy investment is the creation of domestic industries that provide jobs (Ydersbond & Korsnes, 2016). However, with very low rates of unemployment in Norway over the last decades, this argument has seemingly not carried much weight for Norwegian decision makers. When the oil and gas prices were falling, and it seemed that the oil reservoirs in the North Sea were going to be depleted in the 2000's, offshore wind in particular received increased attention as a source of industrial opportunities. When new, large, Norwegian petroleum fields were found in 2010, this led to less attention being paid to and investment in offshore wind (e.g. Furdal, 2011; Norsk Olje & Gass, 2017).

However, in 2020, the future of Norway and what the citizens will live from when the petroleum age is over, is a much debated topic. Here, arguments about green industries are much present as a solution and way to create new sustainable industries. In Sweden, the "job market argument" for stimulating increased production of bioenergy has been present in at least some phases, for example in the decisions to stimulate increased use of bioenergy from the 1980's onwards.

Some of the new renewable energy technologies have seen sharp cost declines the last decades, and particularly the last years. This is, for example, the case for solar PV and wind

[26] This has also been mentioned by interviewees representing the European renewables industry in previous studies that the author has conducted.

energy (IRENA, 2019, 220). The lower costs have come about as a result of several factors: the scaling up of production in the wake of beneficial conditions and investment decisions globally, higher rate of innovation following higher demand, and competition between various manufacturers. Typically, these technologies have presented a "learning curve," which is defined as unit cost reduction per doubling of installed base, of 15-25% or more.

Which renewable technology at any moment is costly or less costly on the global market, depends on several circumstances, including national investment conditions. The short-term cost digression curves for solar PV in 2014 were steep (Frankel et al., 2014), and continued to be so during the following years, also on the Norwegian market, as expected. This contributed to larger investments from businesses and personal consumers alike in Norway (Martiniussen, 2019), even though investments in Sweden have been significantly larger.

Different developments in renewable energy production have also been crucially influenced by the political decision makers in government, for example the Stoltenberg Governments' abandonment of green certificate schemes with Sweden in 2005, and confirmation and the extension of the earlier protection plans requiring that no large new river systems should be dammed up to produce hydropower. National energy politics and policies are inherently *political* in nature, and when national decision makers experience energy crises, they might choose several different paths. There has been no such perception of imminent crisis in Norway since 2010, as increased precipitation, technical upgrades of existing hydropower plants, many new small hydropower projects and an increasing contribution from wind power has made the country a relatively stable net exporter of power.

Increased renewables production has come about as a result of the combination of various measures. Both Sweden and Norway have in different periods set aside significant resources for research on renewable energy. Swedish authorities, lacking the same access to new, cheap hydropower, have launched wide-reaching and extensive support programs (i.e. push factors), and other supportive measures for the different types of new renewable energy. These acts combined ultimately led to much larger penetration of production facilities utilizing the new renewables sources in Sweden than in Norway in 2014, and this also seems to be the case in 2020 (e.g. Energimyndigheten, 2019). Norway, as opposed to Sweden, is at a high carbon risk

6.3.3 Norway, as opposed to Sweden, is at a high carbon risk

Rapid technological change has occurred since 2014, with wind power and solar power becoming competitive sources of power globally (IRENA, 2019, 2020). When such rapid technological changes happen, this development might put Norway at a carbon risk, especially, as so much of the economy has been, and is, tied to the petroleum sector. It may well be that in the future, the global use of petroleum products will significantly decline, as steadily more energy is produced from renewable sources, ever more countries are planning for climate neutrality within 20-50 years, and the global fleet of vehicles gradually electrifies and thus may need much less diesel and gasoline than before (IEA, 2019b). Over the next decades, businesses such as aviation may also be running on electric motors fuelled by electricity and/or hydrogen (e.g. Avinor & Civil Aviation Authority, 2020).

The European petroleum sector has lobbied against legislation that will lead to enhanced production of renewable energy at e.g. the EU level (see Ydersbond, 2018b). Until 2014, and still, as of 2020, large resources in Norway are still "locked-in" to the petroleum industry, including physical infrastructure, investment and intellectual capacity. The petroleum industry in Norway, not least the state-owned giant company Equinor, also possesses a strong structural power to influence decision making in its own interest, which has the potential to hamper, a transition to a more sustainable society. In contradiction, the previously largest petroleum company in Denmark, state owned Ørsted (previously named DONG Energy), has quit its investments in petroleum and has solely opted for renewable energy instead, which has been a great economic success so far (Ørsted, 2020).

6.4 Final comments and discussion

Knowing which technologies will be successful in the future is very hard, if not impossible, particularly with respect to technologies that are in the infant stages of development. All sources of power generation and other types of energy have impacts on nature and climate to varying extents, including the production of renewable energy. Therefore, to some degree, renewable energy also gives rise to trade-offs between different targets, such as the need for increased energy production together with the potential harm to nature such as the loss of biodiversity and changes in landscapes.

The building of large small-scale hydropower production facilities in Norway and Swedish bio power industry are cases that illustrate this: both enhance energy production, but both may also negatively impact nature. On the other hand, renewable energy production in Norway and Sweden generally has minor consequences for the environment and nature compared to fossil fuel extraction and the generation of energy from fossil fuels, including their ensuing greenhouse gas emissions, local pollution following the use of combustion engines and oil spills from the production facilities of the petroleum products.

Based on their respective resource and economical situations, Norway and Sweden have adopted different paths to de-carbonization. Sweden, being much richer in resources for bioenergy than Norway, has also exploited these resources much better, while Norway has stuck to its hydropower-based approach. It should be noted that Norway, in spite of a huge production of fossil fuels, has not increased its domestic use correspondingly, and the attempt at developing gas-powered electricity production 1998-2008 was an economical failure.

While cooperating closely with neighbouring countries on power exchange has long traditions in Norway, cooperation on resource utilization was virtually non-existent until EU requirements more or less forced the country into cooperation with Sweden on green certificates.

We do not really know what society's demand for energy will be in the future. Thus, only projections are possible. Moreover, there are numerous ways to create sustainable energy systems. How should we create the best sustainable energy systems, not knowing what the future will look like in terms of economic capacity, maturity of different technologies and domestic needs? Yergin (2013) comments:

> *There is no question that we are at a turning point in world energy. But then we are often at a turning point. Just as everybody gets comfortable with what they expect to happen, a big change comes along that undercuts existing assumptions.*

The noted differences between the two countries may be based mostly on differences in resources, policy differences being secondary. If Sweden had possessed large-scale domestic petroleum resources, Swedish authorities would probably have stimulated businesses to make heavy investments in this sector, which would most likely have made Sweden more similar to Norway. Similarly, had Norway lacked the large-scale petroleum resources, Norway would likely have been more similar to Sweden. However, also research and development has been important, such as for the efficient utilization of Sweden's large bioenergy resources.

Sweden has for several years been more "future-proof" than Norway, and rapid technological change might put Norway, especially, at a (further) disadvantage over the next decades, as so much of the economy is linked to Norway's petroleum sector. This may be exemplified with the worldwide economic crisis caused by the virus SARS-CoV2, which causes the disease Covid-19: As economic activity around the world has slowed down and transport is significantly reduced, the petroleum prices reached all-time lows spring 2020 (ICAO, 2020; Salmon, 2020). This has had a major negative economic impact on the petroleum industries around the world. Norway has thus suffered from a double economic depression: one caused by the negative economic effects of the disease, and one caused by the very low petroleum prices. However, Norway, with very solid state finances, has also been economically capable of making strong stimulus packages to rescue the different industries and sectors that have been hard struck by the Covid-19 crisis.

The same is probably the case for many other large petroleum producing and exporting countries. The Norwegian petroleum dependency might be perceived as a typical energy system lock-in, where it is hard to change the system because of several factors. These include: All the resources that are tied to it, including physical, economic, and intellectual ones, all the competence that has been created within the system, the large number of persons attached to it, as well as the fact that it is an industry contributing to large parts of the Norwegian export income. The Norwegian petroleum industry also possesses considerable structural power to influence decision making in its own interests, likely obstructing or delaying a shift to a more sustainable economic structure.

The continual stimulation of the petroleum sector through for example the large refunding for searching and beneficial taxation rules is probably, as pointed out by numerous researchers, intellectuals, politicians and analysts, a risky strategy for the Norwegian society in the longer term ("putting all eggs in the same basket"). With the Covid-19 crisis, the Norwegian Parliament issued rescue packages to the petroleum industry that were better than what they asked for, contributing to prolonging the Norwegian petroleum dependency.

However, energy revolutions do happen, and the dynamics of energy system change are probably underestimated in Norway today. The energy systems are, as demonstrated, *not* stable entities regarding production and consumption of various types of energy. The increasing electricity market share of renewables, supported by steadily increasing investments in various types of sustainable assets, this puts a number of Norwegian businesses, not least those connected to the petroleum industry, at a climate risk that increasingly is independent of climate concerns. Investors increasingly evaluate climate risk before they invest their assets. Moreover, the EU, Norway's largest customer of gas, has outlined increasingly ambitious paths towards carbon neutrality, and is planning to reduce its gas consumption in the coming decades (e.g. Commission, 2020; Fink, 2020; Pletten, 2020; Ramnefjell, 2020).

The overall picture seems clear. Due to staunch investment, leading to innovation and declining prices due to economics of scale, the prices of various renewable energy technologies have dropped significantly over the last decades, not least in recent years. The large majority of solar and wind power to be commissioned in 2020, for example, "should provide lower-priced electricity than the cheapest new coal-fired, oil or natural gas option" (IRENA, 2019). This has also been the case (IRENA, 2020).

This strong renewables growth, together with switching from coal to gas and higher production of nuclear energy, has contributed to making global CO_2 emissions from the energy sector flatten out in 2019 after several years of general increase (IEA, 2020).

Another ongoing revolution is the electrification of the transport sector. Steadily more types of transport are electrified, demand for petroleum products to give them energy decreases. Electric cars are for example expected to be cost competitive around 2025 (BloombergNEF, 2019).

These are examples of turning points in energy production and transport with major impacts on energy production, consumption and greenhouse gas emissions. Both renewables technologies and various types of electric vehicles contribute to lower demand for petroleum products globally. For example, in Norway, which had the highest share of electric vehicles in the world per August 2020, with about 11%, there has been a significant decline in the sales of gasoline and diesel (Elbilstatistikk.no, 2020; Statistisk sentralbyrå, 2020). Countries with high investments in wind power and solar power, like Denmark, Germany and The United Kingdom, see steadily longer periods where all the power generated comes from these renewable energy sources (e.g. Andersen, 2020).

An argument in the public debate has been that if Norway waits a few years, Norway will also benefit from the technological developments without paying the higher price before the technology is cost competitive. Offshore wind is an instance of this. In contrast to Sweden, Denmark, Germany, the United Kingdom, the Netherlands, and a number of other countries, Norway has (2020), no established or licensed offshore wind farms, despite:

a) significant potentials for it
b) that Norwegian industries could develop further in the field with the establishment of domestic projects. This has been the case for other countries developing new renewable energy industries
c) that Norwegian companies are already involved in some of the largest offshore wind energy projects in the world in other countries
d) population growth

This may be taken as yet another example of Norwegian ambivalence, but the full picture is somewhat more complex: In spite of the ongoing phasing out of fossil fuels, most of the time there is still a considerable electricity surplus in Norway, and there are not efficient mechanisms in place to handle large surpluses over time, market-wise. And there is currently a focus on floating offshore wind, which is far from technologically mature, but has huge potentials if costs can be kept down.

Hywind Tampen is an ongoing project of this type that is intended to make significant contributions both to decarbonization and commercialization of floating offshore wind. The projected effect of 88 MW is well into the effect range for small commercial wind farms. Furthermore, Norwegian companies are active developing different types of wind projects around the world. The situation has recently changed a little: Spring 2020, there was opening up for offshore wind in Norway, at 4,5 MW installed capacity. From January 2021, developers may apply for licences (Offshorewind, 2020).

In spite of these modifying arguments: When considering the gross imbalance between investments in increasingly risky fossil projects and increasingly important offshore wind projects, there should be little doubt that the current investment and development policy likely is way too passive. When renewable giant Iberdrola bought into the Swedish offshore market in 2020, a project portfolio of 9 GW was included – in the same order of magnitude as the projected Swedish nuclear power production in 2021.

The “wait-argument” for investing in offshore wind, in other words, has major weaknesses. For example, it will most likely continue be the case also in the future that many large changes in energy systems will not come about without stimulation of various kinds. Moreover, by not investing in creating markets for new renewable energy technologies, the national producers of these will not get a domestic market where they can develop their products and thus potentially get first-mover advantages.

In other words, for a large-scale energy system transformation to take place, a host of different types of regulatory measures, as well as different types of support mechanisms and an expansion of the relevant infrastructure, is usually necessary. While we may hope for the best in terms of technological innovation, this study has shown that changes in the heavily regulated field of energy have often come about through government interventions and regulatory stability, coupled with innovations, research and falling costs of technology. Acting now has positive consequences, such as domestic businesses gaining foothold within an industry that is developing rapidly, creating jobs, and also, of course, to help reduce GHG emissions. However, offshore wind does not come without its own challenges, including that it may be viewed as disturbing by the fishing industry and others.

Exactly how Norway and Sweden should change their energy systems further is not obvious, as there are numerous pathways to sustainable energy systems and no blueprint. Each country has unique resources and needs to find its own way. One thing seems clear, however: In order to increase renewable energy production and consumption further in Sweden and Norway, general measures to stimulate research, in combination with the creation of commercial domestic markets to bridge the technological “valley of death,” and long-term regulatory stability, will remain essential. Only comprehensive measures will lead to the required energy system transformation within the time scale needed.

Researchers, newspaper commentators, government representatives and others argue that the present economic crisis caused by the global Covid-19 pandemic of 2020 gives a golden opportunity to change systems and make the Norwegian economy less oil dependent and much better geared for a zero-emission future. Sweden has much lower greenhouse gas emissions and higher energy efficiency than Norway, and is a climate frontrunner internationally (e.g. CAN Europe, 2018). On the other hand, Norway is an international frontrunner as regards the electrification of the transport system, which illustrates how policy dependent the development and expansion of various types of environmental technologies are.

Appendices

Appendix 1: List of interviewees and their formal affiliation at the time the interviews were carried out

Andersson, Kjell, Svebio (Sweden)

Astrup, Nikolai, Høyre (Norwegian Conservative Party) (Norway)

Borgström, Truls, Näringsdepartementet (Ministry of Enterprise, Energy and Communications) (Sweden)

Ebenå, Gustav, Energimyndigheten (Swedish Energy Agency) (Sweden)

Flatby, Rune, Norges vassdrags- og energidirektorat (NVE), (Norwegian Energy Resources and Water Directorate) (Norway)

Fredriksson, Gunnar, Svensk Energi (Swedish Energy) (Sweden)

Hegg Gundersen, Mari, Norges vassdrags- og energidirektorat (NVE), (Norwegian Energy Resources and Water Directorate) (Norway).

Hersvik, Rune, Norsk vind ("Norwegian Wind") (Norway)

Hjørnegård, Sigrid, Energi Norge (Energy Norway) (Norway)

Holm, Marius, Zero (Norway)

Isachsen, Øyvind, Norwea (Norway)

Johansen, Øivind, Olje og energidepartementet (OED) (Norwegian Ministry of Petroleum and Energy) (Norway)

Kåberger, Thomas, Chalmers University; former CEO in Energimyndigheten (Swedish Energy Agency) (Sweden)

Leistad, Øyvind, Enova (Norway)

Olesen, Johanna, Svensk Vindkraftforening (Swedish Wind Power Association) (Sweden)

Pedersen, Carl-Arne, Svensk Vindkraftforening (Swedish Wind Power Association) (Sweden)

Appendix 2: Letter of information

Kjære informant,

Jeg er en stipendiat ved Institutt for statsvitenskap ved Universitetet i Oslo, www.sv.uio.no/isv, og holder på å gjennomføre en studie der jeg sammenlikner politiske virkemidler for utbygging av fornybar energi i Sverige og i Norge. Dette arbeidet er en del av et større forskningsprosjekt som heter Strategic Challenges in International Climate and Energy Policy (CICEP), www.cicep.uio.no. Jeg er tilknyttet arbeidspakke 4 i CICEP, 'European climate, energy and technology policies: opportunities and constraints for Norwegian actors', som ledes av Per Ove Eikeland.

Det foreløpige navnet på studien er 'The Ambitious and the Ambivalent, Sweden and Norway in Promoting New Renewable Energy Sources', og den vil sannsynligvis bli publisert i et internasjonalt fagtidsskrift. Et utkast til studien ble presentert på den internasjonale konferansen ECPR Joint Sessions of Workshops i Mainz i mars 2013, og i etterkant ble de beste bidragene i min gruppe invitert til å delta til et spesialnummer av tidsskriftet Policy Sciences. Metodene som vil bli benyttet er studier av offentlige dokumenter slik som utredninger, annen forskningslitteratur og avisartikler, intervjuer og noe statistisk behandling av data om for eksempel volum i produksjon av fornybar energi fra de ulike fornybarkildene i Sverige og Norge.

I den sammenheng tar jeg kontakt med deg, siden du har verdifull kunnskap om prosessene rundt utbygging av fornybar energi i Norge. Jeg ønsker et intervju med deg i løpet av september og lurer på om du har mulighet til å stille opp? Jeg er meget fleksibel med tanke på tidspunkt og sted, men jo snarere det kunne vært, desto bedre, siden tidsfristen for innlevering av manuskriptet er 15. oktober. Intervjuet vil bli tatt opp på bånd, og du vil få mulighet til å sjekke alle sitater i etterkant. Intervjuet vil vare rundt en time. Emner jeg tar opp er blant annet hvilke politiske virkemidler staten har brukt for å fremme fornybar energi, hvordan de har fungert, og hva som generelt fremmer og hemmer at Norge og Sverige skal nå de målene som regjeringene har vedtatt, og som også er pålagte gjennom EUs fornybardirektiv.

I tråd med de nasjonale forskningsetiske retningslinjene er deltakelse i prosjektet frivillig, og du kan derfor trekke deg når som helst uten å fortelle grunnen til dette. Endelig sluttstrek for prosjektet vil først bli satt når spesialnummeret av Policy Sciences er utgitt, men jeg må altså sende inn et utkast til tidsskriftet allerede 15. oktober 2013. Opplysningene vil bli lagret på et sted med passordbeskyttelse, og de vil utelukkende være tilgjengelige for undertegnede. Data vil etter prosjektets slutt 01.7.2017 også bli lagret på et sted med passordbeskyttelse frem til 01.7.2021 der kun undertegnede har tilgang, og dataene vil følge meg som forsker hvis jeg da eventuelt blir ansatt ved en annen institusjon. Jeg vil ta kontakt ved slik eventuell gjenbruk eller overflytting av data. Hvis du ikke hører fra meg, vil data bli anonymisert innen 01.07.2021. Målet med denne lagringen er bruk til eventuelle oppfølgingsstudier innenfor samme område. I publikasjonen vil intervjudeltakerne være gjenkjennbare gjennom navn, stilling/vev og arbeidssted. Prosjektet er meldt inn til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Hvis du er villig til å delta eller har videre spørsmål, ta kontakt med meg på +47 92019154, eller inga.ydersbond@stv.uio.no eller alternativt leder av CICEP, professor Arild Underdal på +47 22855241, eller arild.underdal@stv.uio.no.

Beste hilsen
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Appendix 3: Interview guides

Background questions:

- What is your role?
- How long have you worked here?
- Where have you worked previously?

A3.1 Interview guide to the Norwegian interviewees

Questions about renewables targets and the achievement of them in Norway:

- Why have we built out hydropower in Norway at relatively large scales the two last decades, despite protests from environmental organizations? Expertise? Traditions?
- Why was Norway far behind the previously set targets of 3 TWh of electricity from wind energy by 2010?
- Which role do the Norwegian support mechanisms for renewable energy or lack of thereof have in this context?
- Why is the lead time from project start to construction much longer in Norway than in Sweden?
- Which factors would have to be changed to promote more wind and the other renewable energies in Norway?
- Stability and consistency of support policies?

- Why, in your opinion, has there been a far more rapid expansion of a) wind energy, offshore wind b) bio energy and c) geothermal energy in Sweden than in Norway, despite both countries having significant potentials?
- And why does Sweden now have several offshore wind farms, while the one that was planned in Norway has been cancelled?
- Why is there a much broader portfolio of renewables technologies in Sweden that are applicants for green certificates from the common Swedish-Norwegian market than in Norway?
- Why, in your opinion, has the common certificate market so far led to more extra terawatt hours of electricity in Sweden than in Norway?

- Which role do the legislative frameworks have in this context?
- And different roles of the ministries in Sweden and in Norway. Which role does the Norwegian Ministry of Petroleum and Energy have in this context?
- What is your impression, which role has “political will” had?
- And the role of political parties?
- And the fact that Norway is a large petroleum exporter? – Expertise to other sectors, investment in other sectors, need for ensuring energy security.
- Why is there seemingly fairly much innovation in Norway, like making the world’s first floating wind mill, the world’s first osmosis based power plant, while there is little commercialization of these technologies?
- Why are politicians steadily talking about investing in research and innovation, but not in commercialization of renewables technologies?

- What, in your opinion, has been the effect of a population and industry being used to low power prices for renewables policies, especially supporting immature technologies?

Other keywords:

- Lock-in in dominant technologies
- Mixes of policy measures
- Energy potentials
- Research and development
- Stability and consistency of support policies

A3.2 Interview guide to the Swedish interviewees

Questions about renewable energy and the achievement of targets in Sweden:

Questions on the general development:

- What have been the main drivers behind the Swedish policies on a) bioenergy, b) wind power, c) geothermal energy, d) wave power and e) solar power
- Which role do the Swedish support mechanisms for renewable energy had in this context?
- How has the achievement of the Swedish renewables targets been in these domains?
- And the achievement of Swedish climate targets? What are the numbers today on this issue?
- To which extent has the growth in production of renewable energy from different sources been achieved in a sustainable manner?
- Which factors would have to be changed to promote even more wind and the other renewable energies in Sweden?
- And what have been the largest hindrances for renewables expansion the last decades?
- What have been the largest controversies in Sweden connected to renewable energy?
- What could possibly halt the present development of rapid renewables expansion?
- How is the stability and consistency of the different Swedish support policies today and how has it been previously?

Questions on the roles of different actors:

- Which role does the Swedish Ministry of Enterprise, Energy and Communications have in this context?
- What is your impression, which role has Swedish ‘political will’ had for expansion of renewable energy the last decades?
- And what is the role of the political parties? E.g. the Conservatives? The Greens? The other parties?
- And what is the role of traditional industries for creating new renewables industries, for example the forestry industry for creating a biomass industry?
- Which role has energy security had for Sweden’s strategy of producing more renewable energy domestically?
- How has the issue of nuclear power impacted on Swedish policies in renewable energy?
- To which extents are, in your opinion, Swedish politicians occupied about commercialization of technologies when talking about investing in research and innovation?

- And to which extent is public policy aimed at commercialization of technology from the so called 'new renewable energy sources'?

Questions on the differences between Sweden and Norway:

- Why, in your opinion, has there been a far more rapid expansion of a) wind energy, offshore wind b) bio energy and c) geothermal energy in Sweden than in Norway, despite both countries having significant potentials?
- And why does Sweden now have several offshore wind farms, while the one that was planned in Norway has been cancelled?
- Why is there a much broader portfolio of renewables technologies in Sweden that are applicants for green certificates from the common Swedish-Norwegian market than in Norway?
- Why, in your opinion, has the common certificate market so far led to more extra terawatt hours of electricity in Sweden than in Norway?
- Would you know; why is the lead time from project start to construction much longer in Norway than in Sweden? What have you done to shorten the lead times in Sweden?
- According to a recent report by the Norwegian consultancy firm Thema, the tax regulations for wind power are more beneficial in Sweden than in Norway. Is this correct, do you think?

Thanks for participating in my study!

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