Nordic Economic Policy Review

A Nordic Green Flexible Energy System: Barriers and Opportunities

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Abstract

The current transitions in Nordic countries' energy sectors form part of the green revolution towards a future with a decarbonized energy system that focuses on system integration costs, reliability and sustainability. Ambitious climate and decarbonization targets have been set that involve the massive deployment of variable renewable energy such as wind and solar power.

The Nordic region has profiled itself as a frontrunner in the green revolution and in reducing CO2 emissions. However, energy policies in most Nordic and Baltic countries are still dominated by a traditional policy framework concerned not only with environmental issues but also with security and the cost of supply, while lacking policy awareness of energy-system flexibility, a prerequisite for a successful transition to a clean energy system drawing on a variety of sources.

This paper discusses climate and renewable-energy targets and the challenges involved in creating a future energy system dominated by variable renewable energy. Four possible scenarios for how the market might develop are surveyed and discussed with respect to future Nordic energy cooperation, and the advantages and disadvantages of a flexible energy system are highlighted.

The paper takes further a recent high-level report issued by the Nordic Council (Ollila, J., 2017: *Nordic Energy Co-operation: Strong Today – Stronger Tomorrow*) on the need for greater flexibility by coming up with possible scenarios for targeting Nordic energy co-operation.

Introduction

The current transitions in Nordic country's energy sectors form part of the green revolution towards a future with a decarbonized energy system that focuses on system integration costs, reliability and sustainability. Ambitious climate and decarbonization targets have been set that involve a massive deployment of variable renewable energy (VRE) such as wind and solar power.

In the Nordic energy community, we know we can reach higher by standing on each other's shoulders than by stepping on each other's toes. Our shared attitudes and our trust in each other form the firmly grounded pillars for good Nordic collaboration (Ollila, 2017). However, what makes this collaboration even stronger is our differences in, for example, the energy technology mix. We use these differences to create win-win solutions across national borders and are bold in exploring synergies.

Thus far, for many people the common electricity market is synonymous with successful Nordic energy co-operation, whereas the heat, gas and transport sectors have mainly been driven by national policies and regulations. This has created differentiated and more complex policy arrangements that challenge the future coordination of the decarbonization and electrification of these sectors in the Nordic area.

There are many good reasons to strengthen energy co-operation through the introduction of focused and coherent Nordic policies. The main questions are where to set the focus and how much effort is needed? Should we focus on cooperation in the existing electricity market, trusting that we have already encouraged a market that can cope with the flexibility challenges that a future energy system with a large share of variable renewable energy (VRE) requires? Should we strengthen Nordic co-operation over electricity by reforming the existing market design and adding greater transmission capacity between Nordic countries? Or should we explore flexibility options that can be realized by introducing stronger connections between sectors through the enhanced electrification of the heat, transport and gas sectors? These different policy areas require different regulatory changes and the removal of barriers in order to be realized.

This paper starts with a review of current climate and renewable energy targets. Then we discuss the challenges of a future energy system that is dominated by variable renewable energy (wind and solar). The political framework is then discussed, followed by a section on possible energy co-operation scenarios in the Nordic area. Finally the paper discusses barriers to the Nordic green revolution and offers policy recommendations for its acceleration.

Climate and renewable energy targets

The Paris Agreement of 2015 sets the scene for the reduction of greenhouse gas emissions worldwide. The aim of the Agreement is to keep global warming well below 2^0C compared to pre-industrial levels and if possible to stay below 1.5^0C. This creates strong pressures on the future of greenhouse gas (GHG) emissions. In total global GHG emissions were estimated at 51.9 $GtCO_2e$/year in 2016, an increase of 0.5% over 2015. However, the growth rate is slowly falling (Emission Gap Report, 2017).

By October 2017, 168 countries had ratified the agreement, covering approximately 88% of total global GHG emissions. All the larger GHG emitters have signed up to the Agreement, though the USA has left. Looking at the goal for the 2^0C level by 2030, a GHG reduction of approximately 17 $GtCO_2e$/year is required compared to the current policy trajectory. The National Determined Contributions (NDC) reported by participating countries account for approximately one third, leaving a gap in the Unconditional case of approximately 13.5 $GtCO_2e$ and in the Conditional case of approximately 11 $GtCO_2e$ to be reduced in addition in order to reach the 2030 target. Of course, to reach the 1.5^0C level the gap is even higher. In the words of the Emissions Gap Report, "*The gap between the reductions needed and the national pledges made in Paris is alarmingly high*" (Emission Gap Report, 2017).

GHG reduction goals and measures in the EU

For a number of years GHG reductions have been at the core of the EU's energy policy. Back in 2009 the EU launched goals to be achieved by 2020, the so-called 20-20-20 targets:

- 20% GHG reductions compared to 1990
- 20% of final energy consumption to be covered by renewable energy
- 20% in increased energy efficiency to be achieved compared to a reference date.

According to a number of criteria these targets were distributed to the individual member states, and overall there is no doubt that they have had and continue to have a considerable impact on their own energy policies. It therefore now seems plausible that the EU will fulfil its 2020 targets. GHG reductions are well on the way, mostly helped by the economic crisis, though the EU's emissions trading scheme (ETS) has been less efficient. Most member states will also achieve their own targets for renewable energy (see Figure 1 below, showing a sub-set of EU countries). Three Nordic countries, Sweden, Finland and Denmark, have already achieved their 2020 renewable energy targets.

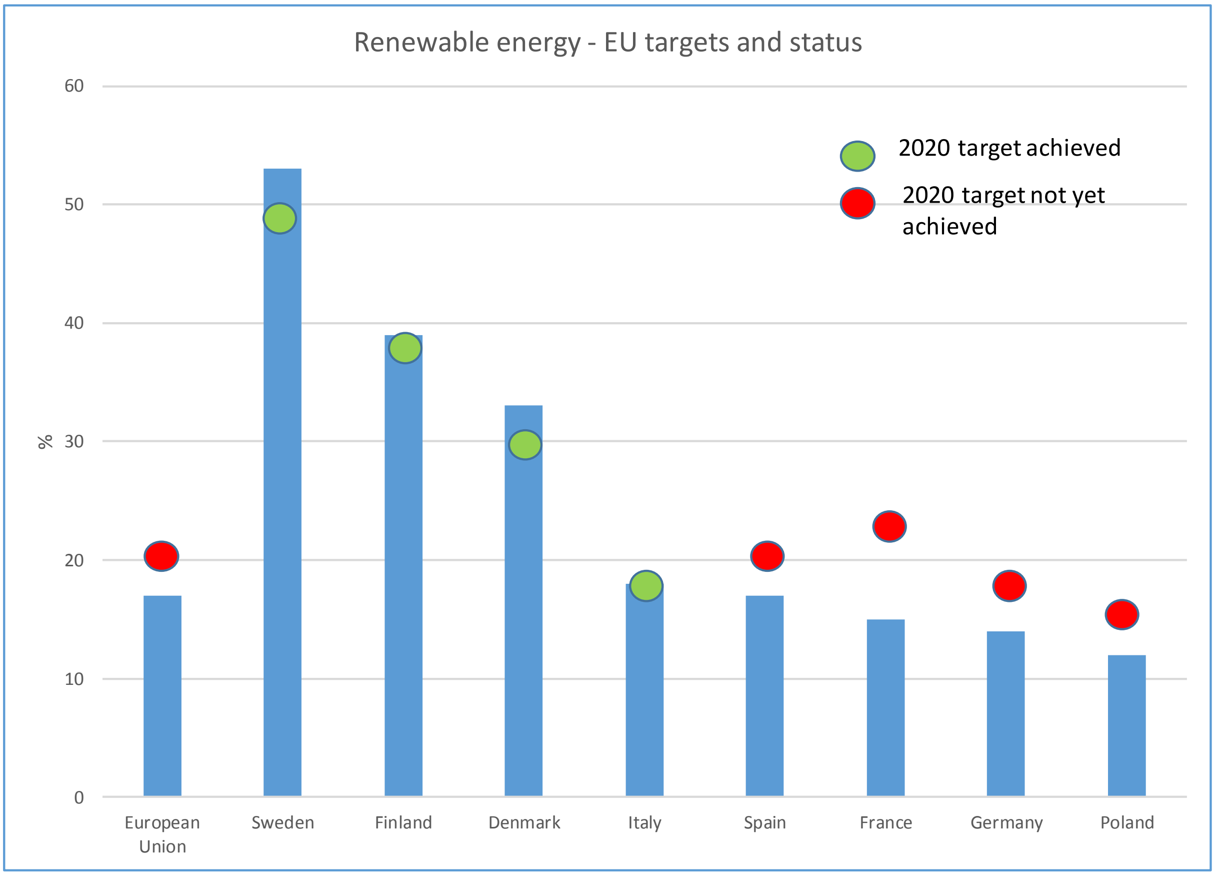

Figure 1. 2020 targets and status (2015) for the deployment of renewable energy in selected EU countries. Source: Eurostat.

Recently, the EU has agreed to adopt new targets for 2030:

- Greenhouse gas emissions reductions of 40% compared to 1990
  - Within ETS, 43% compared to 2005
  - Outside ETS, 30% compared to 2005

- Renewable energy to cover 32% of the EU's gross energy consumption
  - Technology-neutral or technology-specific auctions
  - Possibility for cross-border support systems (open to other EU countries)

- Transport: renewables to account for 14% by 2030
  - Maximum of 7% in conventional biofuels (food-related sources)
  - 3.5% in advanced biofuels by 2030
  - Electricity: Roadx4, Railx1.5

Targets for GHG reductions outside the European Trading System are distributed to member states, but renewable targets are not distributed, the expectation being that they will be reached across the EU by means of national and EU policies.

The Nordic countries' emphasis on renewable energy

The Nordic countries have a strong agenda in reducing GHG emissions and have set ambitious targets to do so (NETP, 2016):

- Denmark to be independent of fossil fuels by 2050

- GHG emissions to be reduced in Finland by at least 80% by 2050
- Iceland's net GHG emissions to be reduced by 50-75% by 2050
- Norway to be carbon neutral by 2050
- Sweden to have no net emissions of GHGs into the atmosphere by 2045

At the same time, the Nordic countries have an abundance of renewable energy sources, including hydro-power, wind power and biomass, and renewable technologies are expected to play a large part in achieving their respective GHG reduction targets. The Nordic countries are strongly interconnected, making it possible to transfer large amounts of electricity to one another and also to the European continent. In 2017 net power exports from the Nordic countries were 11 TWh, with Norway exporting 15 TWh and Sweden 20 Twh (Nordic ETP, 2016). The large amounts of hydro-power in the Nordic area go well together with variable renewable energy (VRE) sources like wind power and photovoltaics. The steadily increasing economic competitiveness of wind and solar power paves the way for the strong deployment of these technologies, increasing the need to balance services from, for example, hydro-power, gas and biomass. Table 1 below lists the main current energy-system characteristics of the Nordic countries, showing that, although we are neighbours, large technology mix differences nonetheless exist, making it clear that the Nordic countries supplement each other in the provision of energy and that close collaboration is mutually beneficial.

%	Denmark	Finland	Iceland	Norway	Sweden	EU28
Oil	39	30	20	39	29	42
Coal	9	10	3	3	3	10
Gas	15	7	-	6	3	26
Biomass	24	33	0.5	6	33	10
Hydro-power	-	5	39	44	15	2
Wind power	8	0.8	-	0.8	3	2
Nuclear	-	8	-	-	12	6
Geothermal	0.2	-	37	-	-	0.3
Other	4.8	7	0.5	1.2	2	1.7

Table 1. Characteristics of the Nordic energy system 2015. Source: Nordic Energy Technology Perspectives (NETP), 2016.

The carbon intensity of the Nordic electricity system is below 60 gCO2/kWh, compared to a global average of over 500 gCO2/kWh. This means that the Nordic electricity sector is well ahead of required global decarbonization. The main future Nordic challenges are therefore how to decarbonize the other sectors while replacing the remaining fossil fuel-based electricity generation with renewable sources of energy.

The abundance of low-carbon electricity options in the Nordic region provides a stepping stone to the mitigation of emissions from the more challenging sectors of heat, gas, transport and industry (Nordic ETP, 2016). This will require changes to the market for electricity, as well as in how it is linked to the other sectors. In addition, it will challenge the system's flexibility to integrate more variable sources, where centralized, fossil fuel-intensive electricity generation is being replaced by decentralized renewable energy.

The Nordic countries have large unused renewable energy potential, especially in wind and solar power, since additional hydropower expansion is restricted by spatial regulation, and biomass is a limited resource. At present wind power is the fastest growing technology being deployed in the Nordic countries. Denmark has the highest proportion of wind power in the world, which provided 43.4% of total annual Danish electricity consumption in 2017 – a world record–more than 50% in western Denmark (Figure 2). These figures are expected to rise in the years to come. Like the rest of northern Europe, the other Nordic countries are deploying large amounts of wind.

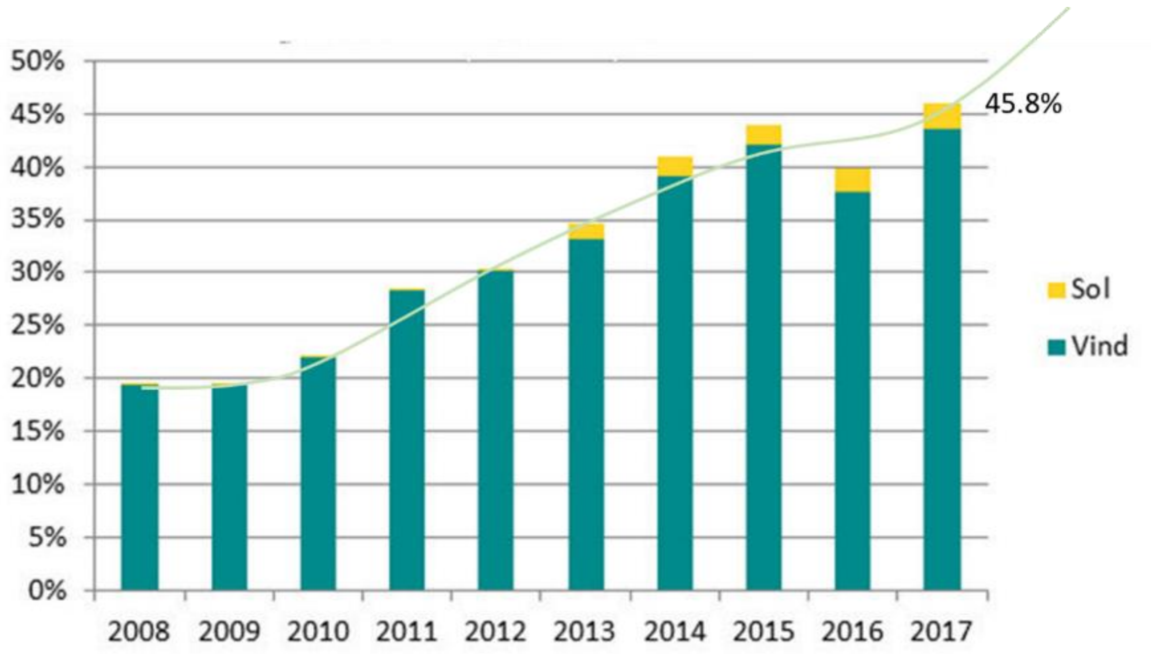

Figure 2. Share of wind and solar in annual electricity consumption in Denmark: 43.4% wind and 2.3% solar.

By nature, the temporal supply of VRE is highly variable because it depends on weather conditions, which affect balancing costs and therefore also forecasting errors (Smith et al. 2007, Obersteiner et al. 2010, Holttinen 2011, and Hirth et al. 2013). VRE is also location-specific, as the primary energy source cannot be transported, unlike coal or biomass (Borenstein 2012, Hirth et al. 2015). This may increase the cost of distribution and transmission networks (Brown & Rowlands 2009, Lewis 2010, Hamidi et al. 2011 and Baker et al. 2013). In addition, VRE influences the cost of firms' reserve capacities, implying lower utilization rates, and it also causes more cycling and ramping of traditional plants (Ueckerdt et al. 2013). At high VRE penetration rates, the overall integration costs could be substantial (Ueckerdt et et al. 2013, Hirth et al. 2015, and IEA 2014).

Simultaneously with an increasing share of VRE, the traditional, flexible and highly responsive fossil fuel-based peak generators are being decommissioned, increasing flexibility challenges in accordance with the depletion of these ramping capabilities. Figure 3 illustrates the variation in VRE generation for one week in western Denmark in 2015.

Without further flexibility, even the Nordic power market mechanism will come under pressure, possibly leading ultimately to a breakdown in the Nordic electricity market and preventing the spread of a common energy market throughout the EU based on the principles behind NordPool.

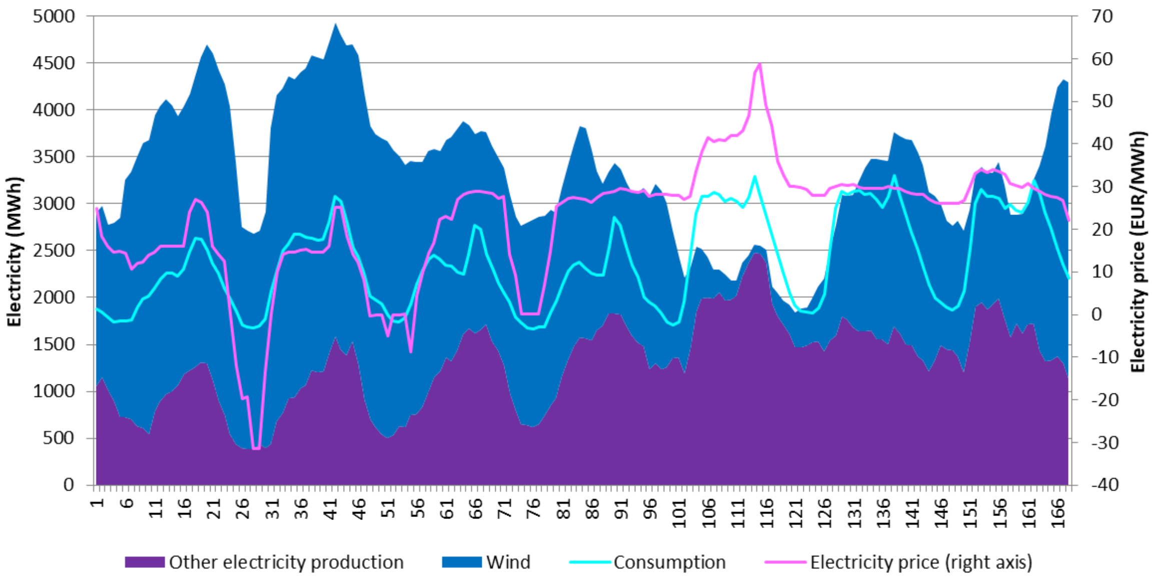

Figure 3. Electricity production, demand and price, for western Denmark: first week of 2015. Source: Nord Pool spot.

Consequently, cost-effective integration of VRE has become a pressing challenge in the energy sector, giving rise to additional needs for flexibility and co-operation in turn to ensure stable, sustainable and cost-efficient energy systems. In general, successful transformation to a low-carbon energy system requires improved systems and market operations (IEA, 2013 and 2014). Increased flexibility may reduce integration costs and elevate the economic value of domestic VRE. In addition, market integration may expand the potential for low-cost flexibility and thereby contribute to an increase in the socio-economic value of VRE.

The future Nordic power market will be the central arena for achieving increased system flexibility. It can be linked to the heat, gas and transport sectors through co-generation, power-to-heat, power-to-gas and power-to-transport fuels, and e-mobility measures. These linkages can all increase the flexibility provided by electricity generation, power transmission, storage and demand-side management. How future Nordic energy markets are to be integrated will depend on framework conditions and the degree of co-operation achieved through focused and coherent Nordic energy policies.

Nordic energy policies

Decarbonization targets and the EU's vision of an internal energy market and an energy union are influencing the green transition. Therefore future Nordic and European energy systems should be consistent with the threefold political targets of improving competition, reliability and sustainability (see Figure 1). Nord Pool, like other existing power markets, is tailored according to the Internal Energy Market and corresponding EU Directives, which facilitate low consumer prices through competition and reliability by matching the supply and demand for electricity (EU Directives 96/92/EC and 2009/72/EC). However, these market designs might have to be adapted to the green transition so that they enable the necessary short- and long-term flexibilities in the system.

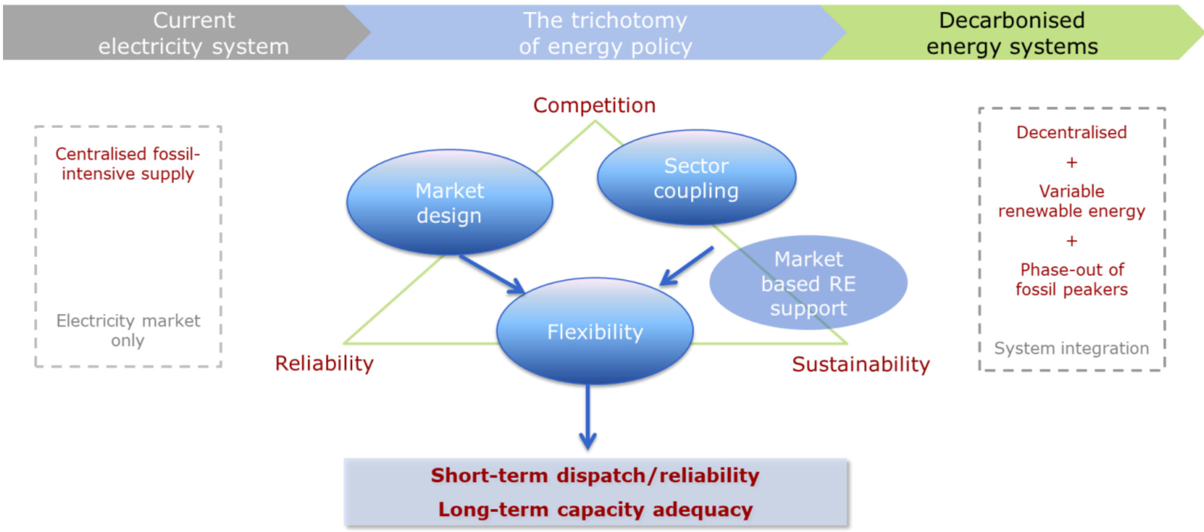

Figure 4. Policy goals and framework in the green energy revolution towards the future energy market.

So far the creation of the Nordic and the EU's internal electricity markets has concentrated on finding a market design that ensures low consumer prices and a reliable electricity supply (left blue oval box in Figure 4). In the Nordic case, the Nord Pool wholesale market has demonstrated its efficiency in creating competition while maintaining its high current level of security of supply in the electricity system.

Simultaneously, the political trend for support is moving towards the market-based deployment of renewables (e.g. auctions and green certificates), as well as a degree of sector coupling that allows the sustainable decarbonization of all energy sectors in a cost-effective and competitive way, for example, by electrifying the heat, gas and transport sectors (right blue oval boxes in Figure 4).

As mentioned above, the green transition towards a sustainable system with a large share of VRE increases the challenges to flexibility in maintaining a reliable energy system (lower blue oval boxes in Figure 4).

We argue that an appropriate market design, smart sector coupling and the right design of support can generate enough flexibility in the system to produce a future decarbonized energy system that fulfil the political targets. However, how this is done will depend on political conditions. In the following section, we present and discuss our suggestions regarding different policy scenarios.

Nordic Energy co-operation scenarios

It is uncertain to what degree future policies will target the decarbonization effort sector by sector, rather than using a holistic approach through sector connection (coupling). Likewise it is also uncertain to what degree future policies will target flexibility directly.

The main questions therefore remain to what degree Nordic energy co-operation will develop in the future and what will be its focus. Consequently, our two scenario parameters for the future of Nordic energy co-operation scenarios are the ***degree of market coupling*** and the ***focus on ensuring flexibility***.

We base our scenarios on a common long-term vision of a decarbonized system by 2050 realising the Nordic targets mentioned above with a high share of VRE. We define four scenarios with different degrees and focuses in Nordic energy co-operation. The scenarios depict different approaches to the enabling of flexibility in the electricity system. The scenarios differ notably in the degree to which they target the two scenario parameters:

- incentives for (specific) flexibility resources
- degree of coupling/connectivity between the different energy sectors/areas.

Four possible long-term scenarios are described below.

Scenario 0. Continued Electricity Market Co-operation (Business as Usual)

In this scenario, Nordic energy co-operation focuses on the electricity market only in the belief that the Nordic electricity market has proved so successful with its current framework conditions that the expected future high share of VRE can be integrated in an efficient and effective manner.

Current main initiatives, such as the harmonization of the market's rules between the Nordic and Baltic countries, will be completed. However, no additional policies will be implemented to focus on promoting sector coupling or providing additional flexibility. Accordingly, it is expected that hydropower, biomass and demand-side management will provide the main sources of flexibility.

This scenario works as a "business-as-usual" scenario (or reference scenario) in which existing electricity market co-operation is continued and energy policies are implemented sector by sector.

Scenario 1. Extended Electricity Market Co-operation (Transmission)

The horizontal integration of the Nordic and north European electricity markets is developed further by adding additional transmission capacity.

In this scenario, Nordic energy co-operation focuses on the common electricity market and the need for additional flexibility by improving exploration of the synergies between electricity technology mixes and load profiles across national borders. This is done by removing bottlenecks in the electricity grid by expanding the transmission capacity between and within the Nordic countries, as well as through additional coordination between the power exchanges in order to facilitate bi-national trade.

The electricity network is dimensioned beyond the current Nordic and Entso-E network developing plans in order to benefit from diversified installed generation capacities. This will allow consumers to benefit from low-cost renewable generation in other regions and from flexible resources such as hydropower plants in order to balance variable generation in other regions.

This scenario increases the trade in electricity in northern Europe and enables flexibility at the systemic level. The ideology behind it builds on the general view of many people that the electricity market is synonymous with Nordic energy co-operation, since historically it has been a great success, is clearly defined and is easy to develop further.

Energy policies for the other energy sectors are implemented sector by sector.

Scenario 2. Coherent Energy Market Co-operation (Targeted/Coordinated Markets)

In this scenario, targeted markets are developed that solve specific problems. Examples are

- markets for renewable energy
- reliability or capacity markets
- local community markets.

Nordic energy co-operation works across these markets in order to ensure coherent linkages with the common electricity market.

Decentralized markets operated by a local system operator or community manager which allow small scale trades might have the objective of facilitating peer-to-peer trading in the spirit of the community or ensuring distributed grid adequacy and reliability. By coordinating the linkage to the electricity market, Nordic countries can benefit by using both local and regional resources in order to release the low-hanging fruit of flexibility options and thereby obtaining a low system cost overall.

Separate markets for renewables exist today, such as the Green Certificate market and the auction markets for renewable energy deployment. These market-based support schemes are being promoted by the EU, the auction schemes apparently being especially favoured by many EU member states. Due to the near-zero marginal short-term costs of many renewable energy technologies, it seems beneficial to have competitive auction markets ensuring a certain capacity deployment at the lowest cost while ensuring that the long-term costs are recovered for renewables.

The split between an electricity (energy-only) market and the renewable energy auction markets could imply a new role for the former, especially with a future system based mainly on renewable sources of energy. The auction markets would provide the system with a certain capacity, while the residual electricity market would become a "flexibility" (price-elastic) market with a generally low price level in hours with abundant electricity supply compared to demand – and vice versa, with high prices in hours of scarce supply.

By co-ordinating their renewable energy markets, the Nordic countries can create a level playing field for renewable energy capacity in order to reduce the costs of variations in the hourly supply (and thereby also electricity price variations) by creating a large geographical market.

Likewise, another possible future split between the markets could be initiated from the consumption side, as a large number of them have almost price-inelastic demand, so that they are more interested in a reliable supply than in a price-sensitive electricity market. A "reliability" market could be organized as a market for "inflexible" generation and demand with more long-term price-setting, leaving the electricity market as a residual price-elastic market. As with the renewable energy market split, in this case the electricity market would also have more volatile prices, providing incentives to flexible actors to adjust their consumption and generation. However, in this case both the consumption and generation sides can hedge a stable total price by taking a large portion of their demand or supply from the reliability market.

Nordic co-operation between these markets would ensure larger markets and thus more stable prices and lower overall costs. Since the targeted markets would be created in order to solve specific problems, other future markets could occur alongside or instead of the examples mentioned above.

Scenario 3. Smart Integrated Energy Co-operation (Sectoral Integration)

This smart energy co-operation scenario for the Nordic area targets a fully-integrated internal energy market *across* sectors and countries. A level playing field across sectors is provided where energy can flow freely without any technical or regulatory barriers, and where energy providers compete freely and provide cost-effective energy prices.

Flexibility from all energy sectors (electricity, heat, gas, transport) is maintained on the same basis. The energy sectors act as a single internal market in order to avoid sub-optimal sectorial, national solutions. This results in benefits from synergies at the interfaces between the different energy sectors.

In this scenario, the general belief is that a fully integrated Nordic energy system with coherent energy policies and market signals in the different energy markets is able to provide appropriate, least-cost and technology-neutral incentives for the operation of and investment in sources of flexibility.

Thus, the future of Nordic energy cooperation should be based not on the perspectives of the traditional electricity sector, but rather on an integrated decarbonized energy system in which electricity becomes a cornerstone of the sustainable energy transition for other energy sectors – such as heat and gas – as well as for transport and other service sectors with a large degree of reliance on electrification (Skytte, Pizarro and Karlsson, 2017). The progressive connection (coupling) between the electricity sector and the other sectors will increase the volumes traded on the electricity market, as well as competition that will ultimately benefit consumers. If sector coupling is done in a ‘smart’ way, it also may increase the flexibility of the system – especially on the demand side – by unleashing the potential for electrification via flexible load units with ramping capabilities such as electric boilers in heating systems, electrolysers in power-to-gas or the smart charging of electric vehicles (Skytte et al., 2017a; Ropenus and Skytte, 2007).

Scenario overview

Although, because of cross-sectoral or market connections, increased flexibility will play a key role in reaching decarbonization targets, appropriate policies for Nordic Energy cooperation will be required in order to ensure a high level of short-term reliability and long-term capacity adequacy at the lowest cost.

The required political focus differs between the scenarios. Table 2 below gives an overview of the characteristics of each scenario compared to Scenario 0, Continued Electricity Market Co-operation (Business as Usual).

Scenario	Coupling/ connectivity	Incentives for flexibility	Driver	Impact
0. Business-as-usual	-	-	-	-
1. Transmission	Geographical connections	Price differences between regions	Different technology mix	Increased imports and exports
2. Targeted markets	Market coupling	Price volatility in the electricity market	More actors	Differentiated pricing
3. Smart integration	Sector coupling	Price differences between energy sources and technologies	Increased business opportunities	Increased national demand

Table 2. Scenario properties compared to scenario 0, Business as Usual.

As shown in the table, the three scenarios are compared to Business as Usual, evaluated according to four criteria:

- *Connectivity*: the aspect of the connection or coupling of areas
- *Incentives for flexibility*: how price regimes differ in promoting flexibility
- *Driver*: the driving force that generates these price differences
- *Impact*: the impact on the energy system

The three scenarios differ substantially in how they merge (connect) areas and thus in how they induce increased flexibility:

1) The first scenario, with increased transmission, expands the power market geographically, induces more power price variations because of different regional technology mixes, and leads to increased exports and imports between regions (e.g. countries).
2) The second scenario, with targeted markets, makes possible new market configurations. We might see the emergence of local markets, separate markets for renewable sources and/or separate markets for "reliable" (firm) power. In most cases this will imply a "residual" and more limited power market, in which prices will be more volatile and the power market will be the main means of providing hour-to-hour flexibility. However, depending on how the market is set up, we might also see more differentiated prices for products and in markets, inducing more actors to allow more flexibility. By participating in different markets, actors' total costs might fluctuate less than the price for power on its own.

3) The third scenario on smart energy integration couples the sectors for power, heat, gas and transport. In this way synergies are generated in the interactions between energy carriers, technologies and markets, taking advantage of the different characteristics between, for example, power and gas, where gas can be stored while power cannot. This will generate energy price differences by inducing new business opportunities with flexibility and the increased demand for power.

Different motivations might exist for supporting one scenario rather than another. Further and deeper quantitative research will be required to find the socio-economically optimal choice, and it is likely that a mixture of the different scenarios will unlock the need for least-cost flexibility in order to create a Nordic clean energy system based on variable renewable energies. It is therefore important to identify the barriers that must be lifted in order to facilitate the various scenarios.

Nordic barriers and policy recommendations to facilitate the scenarios

The different scenarios mentioned above require changes to energy market frameworks and Nordic energy cooperation. The present barriers, and hence future policies to facilitate the scenarios and thereby increase energy system flexibility, are numerous.

Scenarios 0 (Business-as-Usual) and 1 (Transmission) both build on the existing Nordic power market where the framework conditions already have been adjusted to serve the common electricity market. Expansion of transmission capacity have been done several times in the Nordics during the last decades. The main barrier for new expansions are the large investment costs and the public acceptance of the transmission lines.

Scenario 2 (Targeted markets) as well as scenario 3 (Integrated sectors) have the challenge of different actors being active at two markets/sectors simultaneously. The main policy challenge is to create framework conditions that facilitate business models for different flexible actors at the power market. This is very different from the traditional "planning" policy in scenarios 1 and 2. It is further complicated by existing framework setting for the secondary market.

An example of this is the existing regulation of district heating where tax exemption for biomass as fuel in some countries makes it more profitable to use biomass based heat boilers than to use heat pumps or electric boilers (power-to-heat) which pay electricity consumption tax and grid tariffs in addition to the electricity price. In that way, the uneven frameworks for biomass and power-to-heat technologies undermine the business case for power-to-heat and *counteract* the sector coupling between electricity and district heating (Skytte et al. 2017).

Another example is the market for green certificates, which does not give the renewable energy suppliers incentive to curtail their generation in case of excess supply of electricity at the power market - unless the power price is more negative than the revenue from the green certificates. A negative power price indicate that there is a surplus of electricity supply compared to the demand. There is a negative marginal value of suppling additional power that create additional system integration costs.

While recognizing the regulatory role of both European and Nordic policies in respect of any development in the energy sector, including energy system flexibility, the Flex4RES project (Karimi, Lund, Skytte and Bergaentzlé, 2018) has surveyed barriers in the Nordic and Baltic markets, which would require the attention of policy-makers, decision-makers and key stakeholders, when striving for a *maximum* share of renewable energy in future electricity markets. There are several barriers of varying importance, but two of these stand out above all:

B1 Insufficient market signals for some stakeholders
B2 Uneven frameworks for different renewable energy resources.

Seven policy recommendations (R1-R7) were identified in the Flex4RES project to respond positively to the barriers addressed as follows:

R1 Create a level playing field for all RES technologies across sectors through consistent fiscal policies
R2 Implement electricity grid tariffs, which allow market signals for flexibility to reach end-users
R3 Dynamic taxation of electricity (e.g. restructuring levies and taxes)
R4 Encourage VRE operators to act flexibly using short-term market-based incentives
R5 Abolish RES support during negative price periods
R6 Enhance electrification by removing the limitations on using electricity for heating
R7 Tackle investment risks in flexible individual heating through new financing and private ownership models.

Recommendations 1-7 form a market-based policy framework for decision-makers, which could be used in a strategic context such as updating national climate-energy policies or in reforming policy measures to reflect changing boundary conditions in the market, such as price falls and growth of the market for renewable electricity.

In comparing the barriers across the Nordic and Baltic countries, common barriers were found, as well as specific conditions that need to be taken into consideration. The set of recommendations needs to be applied selectively to take into account the specific conditions of each country (Table 3).

Recommendations	Related barrier(s)	Denmark	Norway	Sweden	Finland	Estonia	Latvia	Lithuania
R1	B2	■			■	■	■	
R2	B1	■	■	■	■	■	■	■
R3	B1,B2	■	■	■	■	■	■	■
R4	B1,B2	■				■	■	■
R5	B1,B2			■		■		■
R6	B2	■						
R7	B2	■		■	■	■		

B1 = Insufficient market signals for some stakeholders;
B2 = Uneven frameworks for different renewable energy resources

Table 3. Nordic barriers. Source: Karimi, Lund, Skytte and Bergaentzlé, 2018.

The Flex4RES findings (Table 3) suggest that scenario 2 (Targeted markets) as well as scenario 3 (Integrated sectors) require substantial changes to overcome the barriers. The countries differ with respect to technology mix (Table 1), the need for flexibility as well as with respect to framework conditions at the regional and local levels. A heuristic view needs to be taken to target low-cost, high-potential sources of flexibility from other sectors or from different markets that can be released by removing specific barriers. For example, the flexibility provided by other sectors is facilitated by the redesign of regulations in the direction of a targeted and coherent framework aimed at transmitting the correct electricity price signals, for example, by redesigning grid tariffs. In doing so, a greater degree of electrification is made possible *across* sectors while ensuring that the electricity sector benefits from unlocked sources of flexibility.

This, for instance, concerns the removal of sector-oriented policy mechanisms distorting the price signals from one energy source to another with detrimental effects on electrification and subsequent flexibility from large consumers, including power-to-X, for example, the redesign of incentive-based grid tariffs.

It is important to make **coherent changes** to market designs, regulatory framework conditions and the coupling of markets. For example, improvements to the regulatory frameworks of those sectors – heat, gas, transport and electricity – that can supply flexibility must occur along with the growth of VRE in the electricity supply in order to develop coherent Nordic energy markets. This will require well thought out market designs and framework conditions implemented in a timely fashion. Otherwise, integrating energy markets with very different framework conditions (e.g. heat vs electricity) may prevent the transition towards integrated energy systems and increased flexibility.

So far, energy policies in most Nordic countries are still too focused on the traditional policy framework dominated not only by environmental issues, but also by considerations of security and cost of supply, while lack policy awareness of energy system flexibility, a prerequisite for a successful transition to a clean energy system (Figure 4). However, flexibility has recently received attention in the Nordic area. In a high-level report from the Nordic Council (Ollila, J., 2017: *Nordic Energy Co-operation: Strong Today – Stronger Tomorrow*), the need for greater flexibility is emphasized as a necessary aspect of increasing the share of VRE in the region. Consequently, this paper adds to this report by reviewing some of the challenges involved and by drawing up possible scenarios for what this future might look like and where Nordic energy co-operation should be targeted.

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