Flex4RES

Flexible Nordic Energy Systems

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Policy brief - Key Recommendations

August 2019

Nordic Energy Research

Flex4RES project summary

The Flex4RES project investigated how intensified interaction between coupled energy markets supported by coherent regulatory frameworks can facilitate the integration of high shares of variable renewable energy (VRE) into Nordic-Baltic energy systems, thus ensuring stability, sustainability and cost-effectiveness.

Through a holistic systemic approach based on coupled energy markets in the region, the potential costs and benefits of achieving flexibility in the Nordic-Baltic electricity market from the heat, gas and transport sectors, as well as through electricity transmission and generation, were identified. Flex4RES developed and applied a multidisciplinary research strategy that combined technical analysis of flexibility needs and potential, economic analysis of markets and regulatory frameworks, and the modelling of energy systems, which quantifies impacts.

Flex4RES identified transition pathways to sustainable Nordic energy systems through the development of coherent regulatory frameworks and market designs that facilitate market interactions which are optimal for the Nordic-Baltic conditions in an EU context. Flex4RES results will be of high relevance to stakeholders from governments, industry and civil society for better market designs for achieving a sustainable energy system in the Nordic-Baltic region.

WHY: To ensure that a future decarbonised energy system is possible, in line with climate concerns, national decarbonisation targets and the UN's SDGs.

HOW: By increasing energy-system flexibility to accommodate high shares of variable renewable energy such as wind power.

WHAT: Identifying and assessing regulatory and technical pathways towards coherent Nordic energy systems.

More information regarding the Flex4Res project can be found at www.Flex4RES.org or by contacting project coordinator Claire Bergaentzlé clberg@dtu.dk

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Nordic Energy Research

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Act fast and cooperate in the Nordics while paving the way to carbon neutrality

The energy system must undergo deep decarbonisation by the middle of this century to mitigate climate change and meet the targets set in the Paris Climate Accord. According to several international studies, the transition ahead will mainly rely on renewable and efficient energy solutions. **The Nordic region is well positioned to meet this challenge** through its already high share of hydropower, bioenergy and district heating, well-established and efficient power markets and grids, and ambitious national climate targets and policies.

The results from the Flex4RES project strongly indicate that **large-scale deployment of clean energy needs to take place as early as in the 2020s to hit the unique window of opportunity** opening up in the Nordics that leads to zero CO_2 emissions by 2050. The analyses conducted as part of the Flex4RES project unambiguously show that, within the next ten years, most of the key policies, market mechanisms and regulatory frameworks need to be in place to enable the optimum investments required for the clean energy transition.

The results of the Flex4RES project also show **that the Nordic electricity and heat sectors could be carbon-neutral as early as the 2030s**, leading the way towards the decarbonisation of both the other sectors of the economy and the energy systems of other European countries, expected to be completed by 2050. This is supported by sector-specific decarbonisation targets, the present technology mix and, especially, the rapid deployment of wind power in the Nordics.

When following a market-based and least-cost trajectory, the **best strategy leans on a major scaling-up of renewable energy, notably wind power, and increased electrification of other sectors**. Spatial integration through increased power transmission capacities, both within the Nordic region and with third countries in Europe, supports this strategy. In addition, the Nordics have a large potential to provide energy-system flexibility through sector coupling in heat, gas and transport, enabling the integration of large shares of variable renewable electricity into the energy system.

To realise these opportunities, however, major policy reforms are necessary. There are currently two barriers above all, namely insufficient market signals for key stakeholders, and uneven frameworks for different renewable energy resources. Therefore, a level playing field is needed for all technologies, which requires the elimination of policies that are too technology-specific. Dynamic tariff and tax structures are also necessary to strengthen the new business models needed in the change.

However, our central message is a **call for stronger collaboration in the region**. As so many times before, when facing threats, Nordic cooperation could have a unique value for the Nordic countries when tackling climate change, the great challenge of our time. Our analysis shows that by combining our efforts we can be much more effective in finding solutions than if we act alone.

Flex4RES provides a blueprint for the way forward. But we need to act fast.

Recommendations

The clean-energy transition can be framed in different ways, with different priorities leading to different solutions. The Flex4RES project contributes a set of important observations, conclusions and recommendations, which are summarised in this brief. Flex4RES not only touches upon deep decarbonisation of the electricity sector, but also on district heating. Extending decarbonisation efforts to the heating sector is crucial, as heat represents the largest share of final energy demand in the Nordics, as well as in the rest of Europe. The project's analyses also consider the transport sector through the electrification of vehicles.

A CO_2-free energy sector is possible, but Nordic countries need to speed up their actions

The results of Flex4RES show unambiguously that a CO_2-free, least-cost and reliable energy sector can be achieved in the Nordics. However, to reach such a challenging goal, the Nordic countries **need to act fast**. Postponing measures would require even steeper emissions cuts in future years and would also mean missing **a unique window of opportunity** which is opening up for the Nordic countries in terms of new investments and revenue creation in the coming decade. Missing this opportunity would require much costlier solutions to be adopted in the future. In practice, a **large part of the energy transition needs to occur as soon as in the 2020s** through more investments in clean energy production. This is also in line with many of the international recommendations for reversing the upward trend in CO_2 emissions.

Basically, all key elements for a carbon-free energy sector would need to have been put in place in the 2020s. The policies would need to move even faster to enable optimal framework conditions. The Nordics would need to focus already in the 2020s on sector coupling and market approaches, remove regulatory barriers and allow business cases for flexible actors.

Nordic cooperation enables more efficient solutions without ignoring national needs

The results presented here highlight the benefits of collaboration in the search for solutions for the energy sector. The evident benefits of stronger sector and geographical coupling confirm the importance of good Nordic cooperation.

Creating Nordic solutions does not exclude national specificities, but rather draws upon these to design integrated responses to the common energy challenges in the region. **Being different but acting together provides a comparative advantage for the Nordics**.

Norwegian and Swedish hydropower, for instance, combined with district heating in Denmark, Sweden, Finland and the Baltics, can provide much of the flexibility that is needed in the system for large-scale operation of wind power in Denmark and

Sweden, thus providing cheap renewable energy from which the whole region benefits.

Nordic trust and cooperation: Exploiting differences, but acting together provides a comparative advantage for the Nordics.

The policy recommendations contained here do not necessarily aim to harmonise national policies, but to provide coherent frameworks and policies, leaving the scope for individual incentives and solutions that also benefit the common targets.

Stronger Nordic cooperation would improve outcomes for our societies by increasing the economic benefits and strengthening a common voice in the EU when updating joint European low -or zero- carbon policies in the coming years. Nordic solutions could also serve as global 'lighthouse projects' to guide other countries in their paths towards zero-carbon energy systems.

The Nordics may play an important role in decarbonising the EU and beyond

By moving fast towards carbon neutrality, the Nordic region would benefit from the **consolidation of a pioneering position worldwide**. In particular, the large-scale, cost-efficient, systemic solutions presented here could create major business opportunities to pave the way to deep decarbonisation.

Interestingly, the scenarios in Flex4RES linking the Nordic and continental European energy systems indicate that, due to more cost-efficient clean-energy solutions, exporting electricity could actually be a good business opportunity for Nordic utilities. The expected revenues of electricity exports could be in the range of €5-10 billion a year in the period 2030-2040. In addition, the Nordics could, through a more flexible energy system, also provide increasing flexibility to the EU energy sector. This would facilitate the energy transition in the whole Union.

If developed early, a Nordic electricity sector based on renewables can act as a catalyst for the decarbonisation of other sectors such as heat and transport, as well as for the green transition in other European regions.

A market-based approach helps to unlock flexibility through better market coupling

There are comparative advantages in combining different energy markets in the Nordic region to promote flexibility, as well as to explore synergies and reduce costs. The Nordic power market has so far functioned well. Our results show that a market-based energy transition with an emphasis on market coupling is a cost effective way of unlocking flexibility to accommodate a large amount of wind and solar power.

Importantly, the markets send the **correct signals to market actors, encouraging them to operate flexibly and to invest in flexibility-enabling technology**. These investments could rely heavily on sector coupling (e.g. power-to-heat). By creating a level playing field, removing regulatory barriers (e.g. by changing to flexibility-friendly grid tariffs) would reinforce the incentives to invest while ensuring that they are not distorted by technology-specific measures.

New market solutions may arise at Nord Pool or in parallel to the organised market places

In the Nordic power market, Nord Pool, we might see more trade closer to real time as the share of wind power increases. In addition, **market participants are likely to find efficient solutions in parallel to Nord Pool, such as power purchase agreements (PPAs) and similar market-based contracts, hedging against price risks and securing investments**. With a large share of power being traded through these fixed-price contracts, the residual markets at Nord Pool are likely to be used more for flexible energy trading, with more volatile prices than we see today.

Technologies are mature, but their deployment need to be accelerated

The analyses in Flex4RES clearly show that the transition to a carbon-neutral energy sector in the Nordics can be based on well-proved and cost-efficient technologies, but will require scaling up to become the foundation of the energy system. The Nordic pathway could mainly rely on existing technologies, minimising the risks and uncertainties associated with the energy transition. This represents a more realistic future option for decision-makers in the region. Using existing technology in a smarter way, as depicted in Flex4RES, eliminates the need for major technology disruptions in the Nordics to reach zero-carbon levels in the energy sector.

> *Water as storage and flexibility provider - flushing batteries away. Combining flexible (smart) operation of thermal water storage in district heating systems with water storages in hydropower dams yield large and cheap flexibility options - eliminating the need for major technology disruptions in the Nordics.*

In terms of energy production technologies, fossil-fuel-based power and heating plants must disappear from the Nordics in the 2030s to reach national energy and climate policy targets. The technical supply side focus could be shifted to hydro and wind power, supplemented by bioenergy-based combined heat and power (CHP), which has an important local role.

The main change required in the energy sector is a much stronger electrification of other sectors, notably in heating, but also to some extent in the transport sector. This kind of sector coupling linking power to other energy sectors as well (referred to as power-to-X or P2X) is a key strategy for the deep decarbonisation of the energy sectors as a whole. As more than half of all final energy use in the Nordics is in the form of heat, coupling the power to heating plays a central role in activating a major

source of new flexibility. In practice, power-to-heat (P2H) conversion is carried out via electric boilers and heat pumps, which are already in large-scale use in the Nordics. To maximise the flexibility potential, heat storage, which is a cheap and reliable way to store energy, can be utilised on a much larger scale than at present and be more tightly linked to the P2H schemes. Short-term heat storage in district heating is already a mature technology, but moving towards long-term storage solutions may require additional investments in RD&D to reduce uncertainties and costs.

None of the scenarios investigated in Flex4RES indicate the need to expand electricity storage (batteries) in the Nordics. The flexibility of the large amount of hydropower with dams in combination with flexible (smart) operation of thermal water storage in district heating systems yield large and cheap flexibility options, thus eliminating the need for major technology disruptions in the Nordics. However, batteries may be deployed in other regions of Europe that do not have these alternatives.

Carbon capture utilization and storage (CCUS) technologies, which still encompass maturity uncertainties, are not needed in the Nordics in order to reach carbon neutrality in the energy sectors, but they could be useful in other sectors such as carbon-intensive industries. However, if the energy sector needed to be pushed beyond carbon neutrality towards negative emissions, carbon capture would be required in the energy sector as well.

Step-by-step roadmap to decarbonising the energy sectors first and then expand to the EU as a basis for carbon neutrality

The Flex4RES project identifies the necessary steps for a swift and cost-effective decarbonisation pathway (see Figure 1). This includes not only the necessary technological changes, but also the required reforms in markets and regulatory frameworks.

The Carbon Neutrality Roadmap comprises three distinctive phases, corresponding roughly to each of the next three decades. The first phase, called "Energy Transition", would take place in the 2020s. It features a sharp turn to decarbonising energy (especially through wind power), simultaneously requiring massive investments in new energy and sector coupling in order to hit the unique window of opportunity that the Nordics will enjoy as frontrunners.

Optimal framework conditions for smart sector coupling and decarbonisation need to be in place by the 2020s to allow for market-based flexibility across sectors. This implies the removal of regulatory barriers and the creation of level playing fields for different fuels and technologies, as well as flexibility-friendly taxes and grid tariffs, enabling business models for flexible actors.

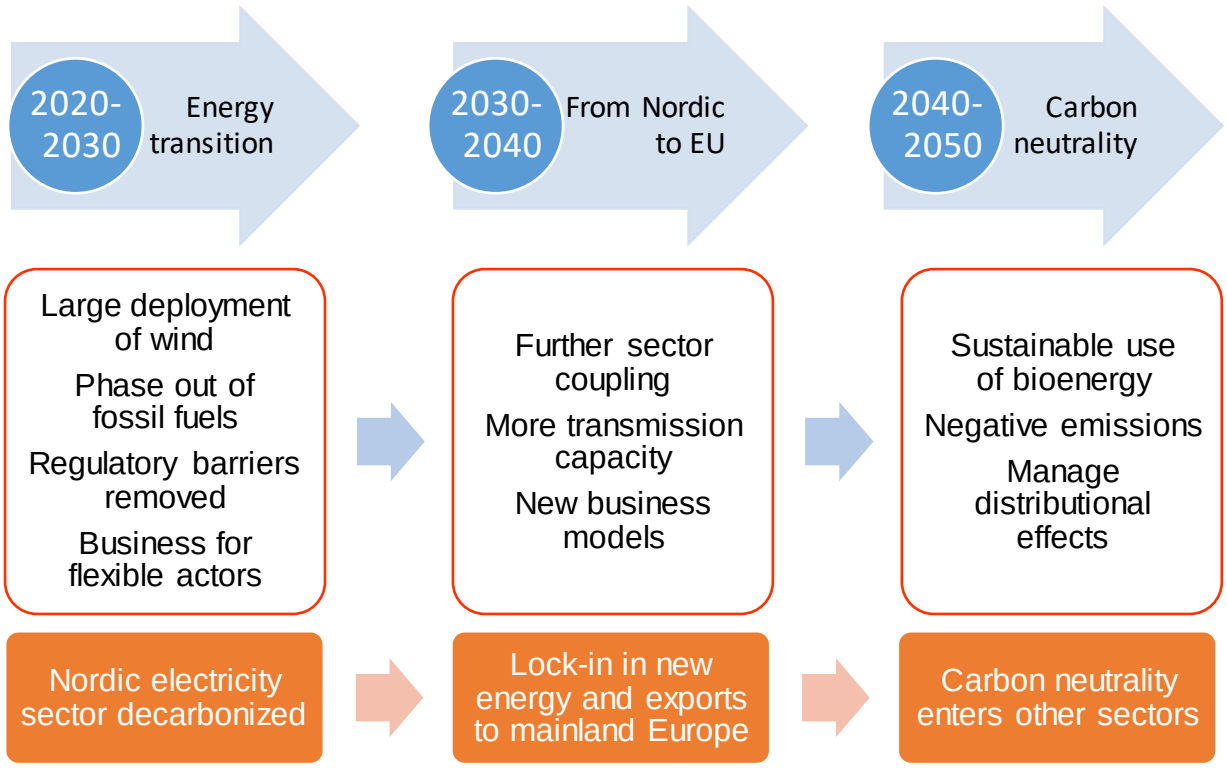

Figure 1. Stepwise roadmap toward carbon neutrality in the Nordics.

The second phase, referred to as "From Nordic to EU", takes place in the 2030s and is characterised by a distinctive lock-in into renewable energy and flexibility technologies in the energy sector. Further transmission capacity and continued smart sector coupling enable additional wind power deployment, as well as providing better business cases for flexible actors across sectors. This implies that the Nordic electricity and district heating sectors could be carbon-neutral as early as the 2030s, leading the way towards the decarbonisation of both the other sectors of the economy and the energy systems of other European countries, expected to be completed by 2050. **The Nordics can become net exporters of energy and green energy solutions.**

Due to the high intensity of investments in the installed capacity of technologies such as onshore wind power, important social acceptance and behavioural aspects could potentially hamper their deployment. Therefore, the socio-technical aspects would need special consideration, such as more careful siting of wind power and transmission lines, improved planning guidelines, and R&D efforts to further develop alternative technologies such as offshore wind power, which may be more acceptable. Similar social issues may arise with the deployment of new transmission lines or large solar photovoltaic farms.

Social acceptance of wind farms and transmission lines may hamper the development. Spatial planning, improved consumer involvement and R&D efforts in alternative technologies should be enforced.

Investments in R&D&D are another important socio-political variable, which might be of particular relevance for long-term heat storage in district heating. Our results suggest that this form of storage could be expanded significantly to serve as a balancing technology linked to P2H, in combination with short-term heat storage.

Finally, **in the Carbon-Neutral phase (2040-2050), the Nordics have an opportunity to go one step further and reach carbon negativity in the energy sector**, achieving overall carbon neutrality while other sectors still have positive emissions, and also acting as a lever for decarbonisation in other regions of Europe. This could require carbon capture in biomass-based energy generation, as well as the integration of natural carbon sinks (forests), among others.

Exports from the Nordics to the rest of the EU increase the revenues of Nordic electricity producers, but may also imply increased consumer prices. Likewise, carbon capture in the energy sector may imply additional costs in the energy sector and benefit other sectors of the economy. These distributional effects must be addressed by policy.

The energy sector could play a major role in a socio-economic optimal carbon neutrality pathway. The consequent distributional effects must be addressed by policy.

As indicated in the stepwise roadmap (Figure 1), we suggest that low hanging fruit in the Nordics, namely forms of smart sector coupling, should be picked before expanding the transmission capacity to other European regions. This will ensure business cases for P2X and accelerate the decarbonisation of the other energy sectors (heat, gas and transport), thus creating a solid foundation on which to develop Nordic export potentials.

Flexibility is important on both the demand and supply sides

Both the supply and demand sides of the power market can generate flexibility. With the right incentives to act flexibly, demand has a particularly relevant role to play by exploring the energy needs of other sectors through P2X. Similarly, on the spatial dimension, flexibility can be provided by local actors, as well as by other regions via transmission lines to surrounding countries. The key is to find the cheapest and most effective combination of flexibility options by exploring all the low-hanging fruit.

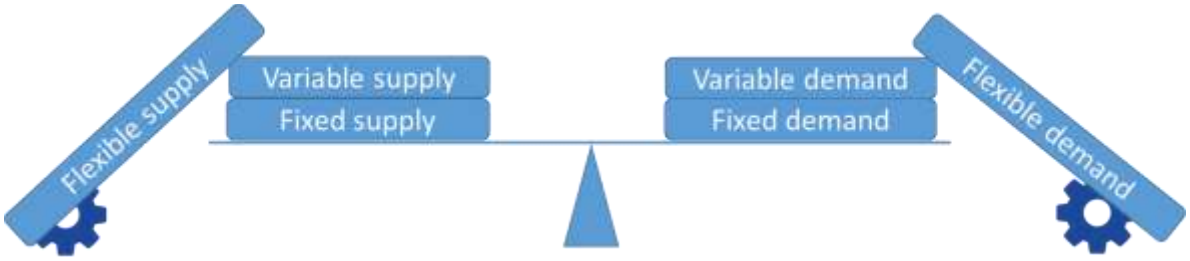

Figure 2. Flexible supply and demand balance the variability in generation and consumption.

With an increasing share of variable supply (mainly wind power), flexible demand becomes more important than today in order to have a system in balance. Power to heat (P2H) and power to gas (P2G) are flexible demand-side technologies in the electricity market that can make business cases for acting flexibly. It is therefore important that the regulatory and policy frameworks enable these business cases and that market signals reach these actors.

Sector coupling is effective only if it is done in a "smart way", where flexible demand and supply react to the need of flexibility. This requires efficient market signals and frameworks that facilitate flexible operation of and investment in P2X.

Selected Flex4RES publications

A summary and more details of the studies behind the above recommendations can be found in the Flex4RES report; ***Flexible Nordic Energy Systems: Summary Report***, which can be downloaded for free at https://www.Flex4RES.org

An additional 33 published journal articles and book chapters, 22 peer reviewed, published conference papers, 11 reports and 15 forthcoming journal articles under review are available at the Flex4RES webpage or on request to the authors.

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PodCasts

Energy Policycast, Flex4RES results disseminated in a straightforward (and geeky) way. With host D. M. Sneum. Available at: https://energypolicycast.podbean.com/ or https://www.nordicenergy.org/flagship/flex4res/flex4res-podcasts/

Available episodes:

F. Fausto, D.M. Sneum, ***Power Purchase Agreements: Good for the energy system – and for old ladies.***

P. Lund, D.M. Sneum, ***Policies for flexibility: A Flex4RES perspective. What have violins to do with flexibility and sector coupling?***

K. Skytte, D.M. Sneum, ***The future Nordic energy system. Water as storage and flexibility provider – flushing batteries away***.

Other dissemination channels

Homepage: www.Flex4RES.org

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