Market design options for procurement of flexibility

Nordic Energy Research

About this publication

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Nordic Energy Research

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Foreword

How to effectively incentivize DSO procurement of flexibility?

Distributed flexibility is very much at the center of current debates on electricity markets and how to integrate intermittent renewables. To contribute to this debate Nordic Energy Research and the Electricity Markets Group (a working group under the Nordic Council of Ministers) focus in this report on how Nordic distribution system operators (DSOs) can access flexibility sources for system operation needs through market-based solutions. Different flexibility markets and their design are presented and compared. The report concludes with recommendations for likely "no regret" steps that can be taken to allow flexibility markets to evolve and grow.

The DSOs need for flexibility for system operations plays a major role in encouraging the use of local flexibility. Now, the Nordic electricity actors once again can lead the way and demonstrate how effective market designs can be made that fulfill the EU Electricity Market Directive (2019/944).

We hope that this report can inspire DSOs to procure flexibility through market mechanisms. In addition, it is useful reading for all involved with the regulation of flexibility markets and flexibility market actors.

Klaus Skytte, CEO, Nordic Energy Research
Tatu Pahkala, Chair of the Electricity Markets Group

Photo: Johnér.se

1 Sammendrag / Summary

1.1 Sammendrag på norsk

AFRY har utført en studie for Nordisk Energiforskning (NER) som vurderer potensialet for nordiske nettselskaper til bruke eksplisitt fleksibilitet, og å evaluere forskjellige markedsdesign for fleksibilitetshandel. Kraftflyten i distribusjonsnettet er på vei til å bli mer ustabil etter hvert som fornybar kraft fases inn, og transport, oppvarming og andre sektorer vil bli elektrifisert for å nå klimamålene. Det er viktig å gi nettselskapene gode verktøy til å benytte distribuert fleksibilitet gjennom markedsløsninger, for å optimere behovet for nettinvesteringer og for å skape større muligheter for tilbydere av fleksibilitetstjenester. AFRY har gjennomført en litteraturstudie, en spørreundersøkelse blant store nordiske nettselskaper, og intervjuer med nettselskaper og andre relevante aktører som fleksibilitetsleverandører, markedsplasser for fleksibilitet, TSOer og bransjeforeninger. Synspunktene i rapporten er fra AFRYs prosjektgruppe med mindre annet er oppgitt.

Det følgende sammendraget er lagt opp etter problemstillingene NER har etterspurt en analyse av.

Anslått potensial for kortsiktig fleksibilitet i Norden
For nettselskaper er fleksibilitet på etterspørselssiden spesielt viktig. Basert på en gjennomgang av tilgjengelig litteratur, kan det nåværende kortvarige potensialet for forbruksfleksibilitet kanskje utgjøre rundt 10-40% av maksimalt forbruk per land. Det økonomiske potensialet er svært usikkert, men antageligvis betydelig mindre. Smart lading av elbiler og elektrisk oppvarming forventes å utgjøre det største vekstpotensialet i nær fremtid. I tillegg blir batterilagring sett på som en viktig teknologi siden det har mange forskjellige bruksområder, og industri, samt

produksjon på distribusjonsnettnivå, kan også øke potensialet. Imidlertid er nettselskapenes behov for fleksibilitet ofte svært lokale, og det tilgjengelige potensialet og den mulige varigheten for aktivering er avhengig av tidspunkt. Tilgjengelig fleksibilitet er også avhengig av prisen nettselskapene er villig til å betale. Emnene om potensial er beskrevet i rapportens kapittel 3.4.

Nettselskapenes behov for fleksibilitet på kort og lang sikt
I dag bruker nordiske nettselskaper fleksibilitet i begrenset grad, delvis på grunn av regulatoriske utfordringer og på grunn av kapasitetsøkninger ved reinvesteringer som uansett vil skje når nettene når sin levetid. I Finland ser det for eksempel ut til at både regulering og pågående investeringer er de viktigste hindringene for fleksibilitetsutnyttelse i stor skala. I Danmark nærmer også flere nett seg slutten på levetiden og vil bli reinvestert i.

Flere nordiske nettselskap er involvert pilotprosjekter for kjøp av fleksibilitet til ulike formål, som varierer fra land til land. I Finland gjennomføres for eksempel prosjekter som benytter batterilagring til å bedre forsyningssikkerheten under uvær, motivert av strenge regulatoriske krav til tilgjengelighet. I Norge og i Sverige fokuserer flere piloter på flaskehalshåndtering, som er et fremvoksende spørsmål på enkelte steder, spesielt i store svenske byer.

Mange av nettselskapene vi har konsultert antar at utnyttelse av fleksibilitet vil bli viktigere i fremtiden, særlig på grunn av vekst i kraftforbruk. De peker på at ny teknologi og digitalisering vil øke tilgangen til fleksible ressurser, men de fleste peker også på manglende økonomiske insentiver fra reguleringsmodellen som en barriere. Emnene er beskrevet i mer detalj i rapportens kapittel 3.4.

Løsninger som utvikles for nettselskapers bruk av fleksibilitet i Europa og andre steder
Flere lokale initiativer har dukket opp globalt de siste årene, som følge av endrede mønstre i kraftforbruk og -produksjon. De europeiske og nordiske initiativene som er sett på i denne rapporten varierer i form av ulik hensikt, produktdefinisjoner, eierskap til markedsplattformen, handelsmekanismer, koordineringsmekanismer og grad av integrasjon med andre markeder. I arbeidet med rapporten har vi spesielt studert fire plattformer/tilnærminger for lokal fleksibilitet: NODES, enera, GOPACS og Piclo. Alle disse gir nettselskaper tilgang til fleksibilitet fra ressurser med geografisk informasjon. De benytter imidlertid ulike produktdefinisjoner, som blant dem omfatter både langsiktige kontrakter for tilgjengelig fleksibilitet, kortsiktig prising av aktivert fleksibilitet, og kombinasjonsløsninger. De varierer også med hensyn til grad av aktiv koordinering med TSO, og i om løsningen er direkte knyttet til intradagmarkedet. De fire casene er beskrevet nærmere i rapportens kapittel 6.1.

Funksjonaliteter som bør være til stede i markeder for lokal fleksibilitet
Markeder for lokal fleksibilitet må ha produkter som er nyttige for nettselskapene. I mange tilfeller betyr dette at produktene må være tilstrekkelig pålitelige til å kunne utgjøre en midlertidig eller permanent erstatning for investeringer i kraftnettet. På den annen side kan kortsiktig handel føre til en mer effektiv bruk av fleksibilitetsressurser, ved å gi nettselskapene tilgang til det som er billigst til enhver tid. Tilnærmingene kan kombineres, og vekten på hvert element vil avhenge av formål, hvor lokalt problemet er, og av likviditet og andre markedsforhold. Markeder for lokal fleksibilitet vil også generelt ha nytte av transparens, gode prosedyrer for avregning, prekvalifisering og utveksling av geografisk informasjon, og (avhengig av utforming), koordineringsmekanismer mellom nettselskaper og TSO. Emnene er

beskrevet i rapportens kapittel 5.

Fordelene og ulempene med én eller flere markedsplasser for nettselskapers kjøp av fleksibilitet
Det er flere hundre nettselskaper i Norden, som vil si at i teorien kan det utvikles et stort antall ikke-overlappende, små markedsplasser. En veldig desentralisert tilnærming kan imidlertid være tungvint for leverandører av fleksibilitet (e.g. aggregatorer) med ressurser som elbiler og oppvarming fordelt over mange nettområder, i hvert fall hvis markedsplassene har ulke metoder for tilgang. Et annet ytterpunkt ville være én enkelt markedsplass eller noen få store, som ville bety stordriftsfordeler og bare ett inngangspunkt for alle kjøpere og selgere. Imidlertid kan det hende at størrelsen gjør det vanskelig for markedsplassen å innlemme de ulike behovene til alle nettselskaper, og insentivet til innovasjon kan også bli redusert på grunn av manglende konkurranse. Det kan være tilstede konkurranse også i en slik situasjon hvis det finnes flere store, geografisk overlappende markedsplasser, men det vil kreve avanserte metoder for interoperabilitet for å unngå delt likviditet og for mange inngangspunkter. Emnene er beskrevet i rapportens kapittel 5.2.4.

Markedsdesignets påvirkning på tilbydernes evne til å delta i andre markeder
Markeder for lokal fleksibilitet kan ha nytte av at lokale leverandører av fleksibilitet har tilgang til flere ulike inntektskilder, altså både fra nettselskapets lokale behov og fra kraftmarkedet og balansemarkedet. Dette vil forsterke incentivet til å investere i fleksibelt utstyr som også kan brukes til alle formål, inkludert lokale. Tilpasning til eksisterende markeder, for eksempel gjennom produktdesign, kan gjøre det enklere for aktører som allerede er aktive der til å selge mer lokal fleksibilitet. Enkelte plattformer beskrevet i rapporten har allerede utviklet løsninger som støtter en tett integrasjon med intradagmarkedet. Emnene er beskrevet i rapportens kapittel 5.

Nødvendig nivå for koordinering og for fleksibilitetshandel over landegrensene
Bedre koordineringsmekanismer mellom DSO og TSO kan være nødvendig for å unngå konflikter eller brudd på fysiske begrensninger. Koordinering krever i det minste gode systemer for informasjonsutveksling, og der det er nødvendig bør roller og ansvar avklares tydeligere. Noen løsninger vi har sett tar koordinering et skritt videre, gjennom en koordineringsplattform for nettselskaper og TSO. En slik plattform kan ha flere funksjoner, og kan fungere som et samlet inngangspunkt for nettselskaper og TSO til (potensielt flere) eksisterende markedsplasser, som intradagmarkedet. Avhengig av utforming kan dette medføre en svært sentralisert tilnærming. Emnet er beskrevet i mer detalj i kapittel 5.

Graden av sentralisering og standardisering kan være en avveining mellom effektivitet innenfor ett system og innovasjon som kan skape nye systemer. For øyeblikket virker det nyttig å legge stor vekt på innovasjon, ettersom utviklingen av markedsløsninger fortsatt er i en tidlig fase. Konkurranse, mangfold og utforsking av forskjellige alternativer vil gi verdifull praktisk erfaring i besvarelsen av fortsatt uløste spørsmål. For detaljert, «top-down» planlegging av en komplett framtidig markedsarkitektur kan føre til kostbare feil. Imidlertid kan visse aspekter som vil være gunstige i de aller fleste markedsdesign sannsynligvis utvikles i nærmeste fremtid, uten å hemme innovasjonen veldig mye. Dette er beskrevet nærmere i rapportens kapittel 7, som peker på at følgende skritt bør vurderes:

- Vurdering av reguleringsmodellene for de nordiske nettselskapene for å se i hvilken grad de forhindrer bruk av markedsløsninger for fleksibilitet;
- En mer detaljert vurdering av i hvilken grad eksisterende tilnærminger for

nettselskapenes bruk av fleksibilitet, som avbrytbare tariffer og betingede tilknytningsavtaler, vil påvirke utviklingen av et fleksibilitetsmarked;
- Tilrettelegge for bedre samarbeid og informasjonsutveksling mellom nettselskaper og TSO, og avklare ansvarsforhold der det er uklart;
- Samarbeid og læring mellom nettselskaper for å utvikle fellesnevnere for lokale fleksibilitetsprodukter, metoder for datautveksling, og prekvalifiseringsprosesser;
- Fortsette prosessen med å lære fra de nordiske og europeiske initiativene til markedsløsninger; og
- Informasjonsutveksling og læring mellom de nordiske landene.

1.2 Summary in English

AFRY was commissioned by Nordic Energy Research to assess the potential for Nordic distribution system operators (DSOs) to use flexibility for system operation and to evaluate different market designs and platforms that can facilitate market-based procurement of distributed flexibility. Power flows are becoming more volatile in distribution networks as electricity generation is increasingly reliant on intermittent renewable generation, and transport, heating and other sectors will be electrified in order to achieve climate targets. It is important to provide DSOs with novel tools such as market-based utilisation of distributed flexibility, which can help ensuring cost-efficient and reliable network services. Market-based flexibility procurement can reduce network investment needs and provide more value to the customers' smart assets. To assess the potential for distributed flexibility and explore market design options, AFRY has conducted a literature review, a survey among major Nordic DSOs, and interviews with DSOs and other key stakeholders such as flexibility providers, flexibility market operators, TSOs and industry associations. The views in the report are those of the AFRY project team unless otherwise noted.

What is the estimated amount of flexibility available to electricity markets in the Nordics?
For DSOs, demand-side flexibility is particularly important. A literature review suggests that the current potential for demand-side response could be around 10-40% of the maximum demand in each country, for very short intervals. The economic potential is highly uncertain, but probably substantially lower. Smart charging of electric vehicles and electric heating are expected to have the largest growth potential in the near future. In addition, battery storage is seen as an important technology as it has diverse capabilities, and generation and industry connected to the distribution network will also increase the potential. It should however be noted that the flexibility needs of DSOs are highly locational, and the available potential as well as the potential duration have temporal variations. Available flexibility is also dependent on the price that the DSO is willing to pay. Please see **chapter 3.4** for further discussion.

What is the estimated DSO need for flexibility in their system both short-term and long-term?
As of today, it appears that Nordic DSOs only use flexibility to a limited extent, in

part due to regulatory challenges and reinvestments that are already taking place as the networks are reaching the end of their lifetime. In Finland, both regulation and on-going investments appear to be the main barriers for wide-scale flexibility utilisation. In Denmark, several parts of the network are also near the end of their lifetime and will need reinvestment.

Many Nordic DSOs are piloting the use of flexibility for multiple different use cases, which vary between the countries. For example, there are projects in Finland that focus on improving security of supply during storms due to the tight regulatory requirements for network availability. In Norway and in Sweden there are pilots that focus more on the management of congestion, which is an emerging issue in certain locations, especially in large Swedish cities.

Many of the consulted DSOs see that utilisation of flexibility could become more important in the future, especially due to growth in electricity demand. They point to new technology and digitalisation as enabling factors for accessing flexible resources, but most also consider current regulatory incentives to be a barrier. Please see **chapters 3.3, 3.4, and 6.2** for further discussion.

What are the solutions being developed for procurement of flexibility for DSO needs in Europe and elsewhere? What are the key features of these solutions?
Multiple local flexibility market initiatives have emerged globally in recent years as a reaction to changes in electricity consumption and generation patterns. The developed solutions depend on local regulation as well as the physical opportunities and constraints that define the procurement mechanisms and product definitions. The European and Nordic flexibility market initiatives studied in this report differ in e.g. ownership of the market platform, trading mechanisms, use cases, and the product design. In addition, integration with other electricity market places and the level of coordination between different actors vary.

Four flexibility market operators were studied in detail for this report: NODES, enera, GOPACS and Piclo. All of these enable DSOs to procure flexibility from resources with locational information. A key difference between them is the product definition: some have tenders for long-term contracts for availability while other provide shorter-term activations, and combinations are also used. There are also differences in the degree to which there is active coordination with the TSO, and whether or not the solution is directly linked to the intraday market. Please see **chapter 6.1** for further discussion.

What should be key design features or technical solutions of the flexibility market design?
Local flexibility markets should have products that are useful to DSOs. In many cases this means an emphasis on sufficient reliability to act as substitutes for network investments. On the other hand, shorter-term trading can enhance economic efficiency by enabling DSOs to access cheaper flexibility resources. The approaches can be combined, and the weight on each will depend on the use case, how local the problem is, and on market circumstances such as liquidity. Markets for local flexibility will also benefit from transparency, streamlined procedures for settlement, prequalification, the exchange of locational information, and, depending on the design, DSO-TSO coordination mechanisms. Please see **chapter 5** for further discussion.

What are the advantages or disadvantages of one or several DSO flexibility market places?
Market design for local flexibility procurement includes several trade-offs. One question concerns the number of different marketplaces for local flexibility. There are several hundred DSOs in the Nordic countries, implying that in theory, a large number of non-overlapping, small marketplaces could be developed. A very decentralised approach could however be cumbersome for flexibility providers with small-scale, demand-size resources located across many DSO areas, at least if the marketplaces have very heterogeneous methods of access. The other extreme would be a single marketplace or maybe a few large ones, which would entail economies of scale and a single point of entry for everyone. However, it could also be too large to incorporate the various needs of all DSOs, and may mean a slower pace of innovation due to lacking competition. Incentives for competition can be present in a situation with multiple, geographically overlapping marketplaces, but this approach would require advanced interoperability standards in order to avoid split liquidity and too many entry points. Please see **chapter 5.2.4** for further discussion.

What is the potential impact, effect or restriction of the flexibility market design to flexibility providers' possibility to offer resources to other market places?
Markets for local flexibility can benefit from enabling local flexibility providers to access additional revenue streams, such as wholesale and balancing markets. This can also benefit DSOs, since it improves the business case for providers to invest in flexible equipment. Very strict requirements set in local flexibility service contracts could prohibit utilisation of flexibility in other markets, which reduces competition or entails higher costs of flexibility provision. Alignment with existing electricity markets, e.g. through product design, could lower the barrier to entry for market participants already active in existing markets. Some flexibility market operators have already developed solutions that support a close integration with the intraday market. Please see **chapter 5** for further discussion.

What level of coordination is required? What are the requirements needed for cross-border flexibility markets in the Nordic countries?
Better coordination mechanisms between DSOs and TSOs may be needed in order to avoid conflicts or violation of physical constraints. Coordination requires at least information exchange, and a clear allocation of roles and responsibilities between the stakeholders. Some flexibility market initiatives have opted for an expanded role for a DSO-TSO coordination platform, which can have more functionalities and provide DSOs and TSOs a single entry point to (potentially multiple) existing marketplaces. Depending on the functionalities of such a platform, this could entail a highly centralised approach. Please see **chapter 5** for further discussion.

In general, the degree of centralisation and standardisation may be a trade-off between efficiency within one system and innovation that can lead to new systems. At the moment, it seems useful to emphasise innovation, as flexibility market development is in an early phase. Competition, diversity, and exploration of different options will provide valuable practical experience pertaining to still unresolved questions. Too detailed, top-down planning of a market architecture could lead to costly mistakes. However, certain aspects can probably be developed in the near future without hurting competition very much. **Chapter 7** points out several low- or no-regret steps than could be taken:

- Assessment of the regulatory models for DSOs, reviewing their incentives for flexibility utilisation;
- A more detailed assessment of the extent to which existing DSO non-market approaches for flexibility utilisation, especially interruptible tariffs and conditional connection agreements, will influence the development of a competitive flexibility market;
- Close monitoring and continued learning from the Nordic and European flexibility market initiatives;
- DSO cooperation to develop common denominators for local flexibility products, methods for data exchange, and prequalification;
- Continuous development of information exchange between the key stakeholders; and
- Encourage TSO-DSO cooperation in active network management, and clarify the rules and responsibilities where necessary, on a national and Nordic level.

Photo: Mammut Media/norden.org

2 Background and context

The new Electricity Market Directive (2019/944)[1] aims to incentivise market-based use of flexibility as a key tool for DSOs. Today, Distribution System Operators (DSOs) in the Nordic countries rely mainly on network investments, and to an extent on bilateral agreements, interruptible end user contracts, and conditional connections to secure sufficient capacity for their customers. Regulators and DSOs have also started to promote distribution tariffs that are based on the peak load of the customer, aiming to limit consumption peaks. An introduction of more market-based procurement of flexibility, including through marketplaces, will constitute a change for most DSOs. It is therefore important for DSOs, as well as for TSOs, regulators, and flexibility providers, to explore in more detail what this may imply in the Nordic countries.

This report aims to research the potential and need for distributed explicit flexibility in the Nordic countries, and to assess different options for market-based flexibility procurement by DSOs. It is structured as follows:

- Chapter 3 is an overview of the situation today and discusses the prospects for using more distributed flexibility in the future, but without describing market-based options;
- Chapter 4 describes the current energy markets briefly;
- Chapter 5 discusses different options for flexibility product- and market design;
- Chapter 6 reviews real-world current examples of newly established flexibility

1. EU (2019): *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (text with EEA relevance)*. ELI: http://data.europa.eu/eli/dir/2019/944/oj

markets and pilot projects in the Nordic countries and in Europe; and
- Chapter 7 discusses possible next steps for regulators and system operators.

The report has been written by AFRY Consult AS. The views expressed in the report are those of the AFRY project team unless otherwise noted. Expressions like "we" and "our" refer to the AFRY project team. The client has however commented on drafts and made suggestions.

Photo: Arla.dk

3 Distributed flexibility in the Nordic countries: current state and outlook

This chapter describes the current state and outlook for the use of flexibility in the distribution network in the Nordic countries. First, it outlines the current role of the distribution system operator (DSO) and the future role envisaged for it in the European Union and affiliated countries,[2] with a particular focus on the vision of market-based procurement of flexibility. Second, it describes the concept of distributed flexibility, and purposes (use cases) for its use by DSOs. Next, it describes the current regulatory framework for the use of distributed flexibility in the Nordic countries, and the means by which it is currently used by DSOs. Finally, it describes the current and future potential and need for distributed flexibility. The chapter draws on AFRY industry experience, existing literature, interviews with DSOs and other stakeholders, and a survey distributed among major Nordic DSOs conducted for this report.

2. Among the Nordic countries, Denmark, Sweden, and Finland are EU members. Iceland and Norway are part of the European Economic Area (EEA).

3.1 Who and what are DSOs in the Nordic countries?

3.1.1 The European context

The concept of the Distribution System Operator (DSO) was introduced in the first electricity directive from the European Commission in 1996[3] and further defined in the directive of 2003.[4] The main content related to DSOs in the early directives (1996, 2003, and 2009[5] was on non-discriminatory access and tariffs for third parties. As the term DSO is already used interchangeably with e.g. "network company" or "grid company" in Europe, we will use the term DSO throughout this text, with reference to the company rather than the specific future role.

The Electricity Market Directive (2019/944),[6] hereafter "EMD19" is especially relevant for this report. It gives DSOs an extended role, introducing for instance access rights for consumers related to sale-back of flexibility and renewable surplus, directly or through aggregators or citizen energy communities. DSOs should take on a more active role both as buyers of distributed flexibility, and facilitate others' use of flexibility resources in their own network for system-wide benefits. As stated in EMD19's Article 32, DSOs

> "*shall procure . . .* [flexibility services] *in accordance with transparent, non-discriminatory and market-based procedures unless the regulatory authorities have established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or to higher congestion*." (L158/159),

and,

> "*shall cooperate with transmission system operators for the effective participation of market participants connected to their grid in retail, wholesale and balancing markets*" (L158/159).

Many of the details of how this should happen are not yet obvious. DSOs operate in different contexts in European countries, and few of them, if any at all, presently operate according to the intention in the relevant documents from the EU. European countries are currently exploring alternatives for the specifics of market-based procurement, as well as the DSO role more generally, on a national level. A pan-European DSO association was also recently established, of which the main tasks are to foster TSO/DSO cooperation and "*participation in elaboration of Network Codes relevant for DSO grids*".[7] (p.8)

3. EU (1996): *Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity*. ELI: http://data.europa.eu/eli/dir/1996/92/oj
4. EU (2003): *Directive 2003/54/EC of the European Parliament and of the Council of 26 June 2003 concerning common rules for the internal market in electricity and repealing Directive 96/92/EC - Statements made with regard to decommissioning and waste management activities.* ELI: http://data.europa.eu/eli/dir/2003/54/oj. See also Emissions-EUETS.com (2021): *Distribution System Operators* (DSOs) (web page): https://www.emissions-euets.com/internal-electricity-marketglossary/623-distribution-system-operators-dsos
5. EU (2009): *Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (Text with EEA relevance*). ELI: http://data.europa.eu/eli/dir/2009/72/oj
6. EU (2019): *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (text with EEA relevance*). ELI: http://data.europa.eu/eli/dir/2019/944/oj
7. *EU DSO Entity (2021): Webinar 21 January 2021.* https://www.eudsoentity.eu/media/yt0lh1ud/webinar-presentation_final.pdf

3.1.2 The Nordic reality

Currently, there is a large number of DSOs in the Nordic countries. Eurelectric figures from 2020 count 170 DSOs in Sweden, 119 in Norway, 77 in Finland and 40 in Denmark.[8] The size of the companies varies considerably, both with respect to the size of the networks, the number of customers connected and the power transmitted through from generators and to end users. As a result, although one might say that many tasks are universal and apply to all DSOs, the complexity of managing the power grids varies substantially.

The role of the DSO is under development in the Nordic countries. All of the countries have identified a need for more active DSOs, in line with the European discussions. It is however unclear which of the network companies that will take on the DSO role first in the near future.

3.2 What is distributed flexibility?

3.2.1 Definition

According to the EMD19, Article 32, "*distribution system operators should be able to procure such* [flexibility] *services from providers of distributed generation, demand response or energy storage*" (L 158/159). Distributed generation is defined as "*generating installations connected to the distribution system*" ((L 158/141), and demand response is defined as "*the change of electricity load by final customers from their normal or current consumption patterns in response to market signals . . . whether alone or through aggregation*" (L 158/140).

Based on this, we understand distributed flexibility as '*flexibility services provided by generating installations, demand response or energy storage connected to the distribution system'*. In this report, we may skip 'distributed' and refer only to flexibility, flexibility services, implicit/explicit flexibility and so on, unless otherwise stated.

3.2.2 Implicit and explicit flexibility

Two terms often referred to in discussions about flexibility are implicit and explicit flexibility. For example, EMD19 points at demand response both "*in response to time-variable electricity prices or incentive payments* [i.e. implicit flexibility], *or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organised market"* [i.e. explicit flexibility] (L158/140).

Price signals that stimulate implicit flexibility can have important long-term effects on the necessity of network expansion. In real-time management, however, it is uncertain how producers and consumers will respond to a price signal in a critical situation. The price per unit of power or energy is defined, but the resulting volume response is uncertain. There may also be limits to how DSOs can set these prices

8. Eurelectric (2020): *Distribution Grids in Europe. Facts and Figures 2020.*

through tariffs, for political reasons. This suggests a need for explicit flexibility, in which the activated volume can be explicitly controlled. The latter is the main focus in this report.

3.2.3 Flexibility as a product

The concept of flexibility markets suggests that flexibility is a product that can be bought and sold, and that it can be thought of as something else than a market for electricity. As several interpretations of flexibility markets exist, it is useful to be clear about what we mean by the concept of flexibility in this report.

Within electricity markets, we take "flexibility" to be a measure of indifference about the timing or fulfillment of electricity production or consumption, as well as the technical ability to make use of this indifference. Hence, flexibility has both a preferential and a technical dimension, although the technical dimension can be affected by preferences in the long term through the acquisition of flexible equipment.

Also, in this report, flexibility does not necessarily mean the ability to *abruptly* deviate from a previous plan. The plan itself may result from the optimisation of a flexible resource, and may be formulated well in advance of execution. Hence, some resources may be flexible in the planning phase but quite rigid in the operational phase. For example, electric car charging may have significant flexibility in the planning schedule for a whole night (e.g. 20:00 to 08:00), but may be quite inflexible at the margin as time approaches 08:00 A.M and the battery is still not at its target level.

In its perhaps simplest form, flexibility can be interpreted as demand or supply elasticity to price. In this regard, when electricity is the product, it may seem unnatural to say that flexibility is a product as well. However, the concept is made more difficult by some of the traits of electricity and what it is used for. Highly flexible resources will tend to mean those that can easily shift their consumption or production of electricity to a different time, or to replace it with energy use from a different energy carrier (e.g. fuels). Replacement with a different carrier (substitution) does not really complicate the concept of elasticity. However, the shifting of electricity consumption or production in time may do so, since the elasticity in a single hour becomes highly dependent on the possibility to "recover" consumption or production in a different hour.[9] Moreover, as we will return to in chapter 3.3.3, many resources in the power system are not subject to "accurate" price signals (and may never be).

For these reasons, an owner of a flexibility resource is likely to view flexibility in a somewhat different perspective. The starting point is typically that a resource owner is free to use it in any way he or she wants. The only real limitation is rated capacity (for a producer) or the size of the fuse (for a consumer), while the only monetary disincentive comes from market prices and tariffs. These disincentives are however usually "imperfect". Hence, a more practical business case for the resource owner may be to sell some amount of the right to use the resource freely, to a party that has an interest in using it in a different way (including simply limiting the consumer's

9. This is sometimes referred to as a rebound effect, although this means something different than the rebound effect for investment in energy efficiency (i.e. Jevon's Paradox).

right). A product in a flexibility market may then essentially be the option to control a flexible resource, within agreed limits.

Nevertheless, the activation of such an option implies shifts in energy consumption or generation by a certain volume. Hence, as long as flexibility is actually activated, it is interlinked with energy and will affect the general energy market, most visibly when it is activated on short notice and constitutes a shift away from a planned schedule. It is therefore useful to distinguish between the value of having flexibility available at the right moment (even if it is not used), and the value of activating flexibility of a certain volume. This distinction will be important in the discussion of long-term and short-term flexibility products, which we will return to in part 5.2.1.2.

3.2.4 DSO flexibility use cases

DSOs may use flexibility for several different purposes (use cases), as listed by e.g. the Universal Smart Energy Framework (USEF).[10] Key use cases include congestion management, voltage management, handling contingencies like faults, and reserves (redundancy, N-1 adherence). For most use cases, network reinforcement is a clear alternative, which means that flexibility often "competes" with this traditional option. A major motivation for facilitating the use of distributed flexibility is to enable DSOs to choose the most cost-effective alternative between network reinforcement and a flexibility-based solution.

For this study, we conducted a survey among major Nordic DSOs, receiving 14 answers with at least two per country (Sweden, Finland, Denmark, Norway).[11] Among the respondents, congestion management was the most frequently selected use case for current flexibility needs, as shown in the illustration below (DSOs could choose multiple options if they liked).

10. Universal Smart Energy Foundation (2015) *USEF: The framework explained.*
11. This is not a random or representative sample. However, given the large disparities in size among Nordic DSOs, the included DSOs cover a substantial amount of the network customers in each country.

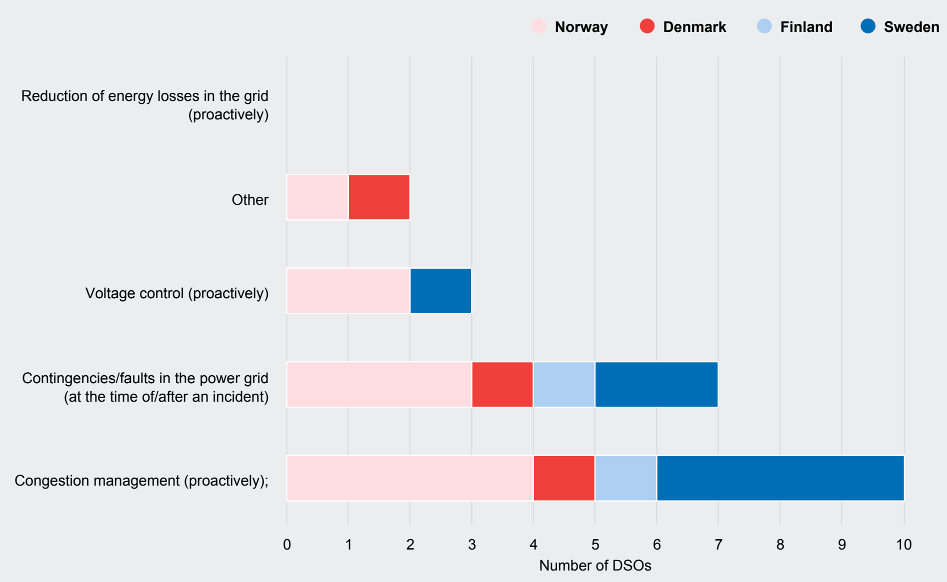

Figure 1. Survey answers to question 7:" The current need to procure distributed flexibility, as reported in the previous questions, is mainly related to:"

Compared to USEF's list of aggregator flexibility services,[12] grid capacity management was not included as an option, but it is likely that some of the DSOs considered this when answering congestion management. We also assume that both controlled islanding and redundancy (n-1) support, as described by USEF, are mainly related to proactive congestion management and services needed at the time of/after a contingency/fault in the power grid. Distribution-level power quality support (e.g. reduction of flicker, harmonics, etc.), as described by USEF, was not included as an option, but we do not think that this is a common use case for the procurement of distributed flexibility today.

To an extent, the need for congestion management arises from the fact that the wholesale energy markets do not take all network bottlenecks into account. This means that without active intervention by system operators, schedules of production and consumption that result from the wholesale market may be infeasible. As of today, the solution to this problem has mostly been re-dispatch after the market has cleared. While re-dispatch until now mostly has been the domain of TSOs, growing congestion at lower voltage levels suggest that it will also increasingly be needed there. Explicit flexibility solutions and markets that can mobilize flexibility resources at the distribution level can be seen as a part of these re-dispatch processes.

12. Universal Smart Energy Foundation (2015) USEF: *The framework explained* (p.18).

3.3 Regulatory framework and current DSO tools

DSOs are natural monopolies and therefore subject to substantial regulation by authorities. In this section, we discuss the regulatory framework for DSOs in the Nordic countries that is relevant for the development of flexibility markets, and which tools DSOs currently use to meet their customers' needs besides network reinforcement. In the following sections, we build on a Pöyry report from 2017[13] and include some of the main points which we find to be still relevant, supplemented by an updated discussion tailored to the purpose of this report.

3.3.1 Income regulation and incentives

The Nordic countries use regulatory models where DSOs are rewarded for keeping their costs low, i.e. being efficient.[14] The regulatory model can have a substantial impact on a DSO's case for flexibility procurement. In our survey, all but one of the respondents pointed to economic incentives from the regulatory model as a current barrier to procuring distributed flexibility. Here, an important detail is that respondents were informed that the term *procure explicit flexibility* also was "*...including e.g. through the use of interruptible tariffs.*" Interruptible tariffs are not very costly to DSOs when the discount in a customer's tariff can be recovered from other customers.

13. Pöyry Management Consulting for The Nordic Council of Ministers (2017): *Demand side flexibility in the Nordic electricity market from a distribution system operator perspective.*
14. Ibid.

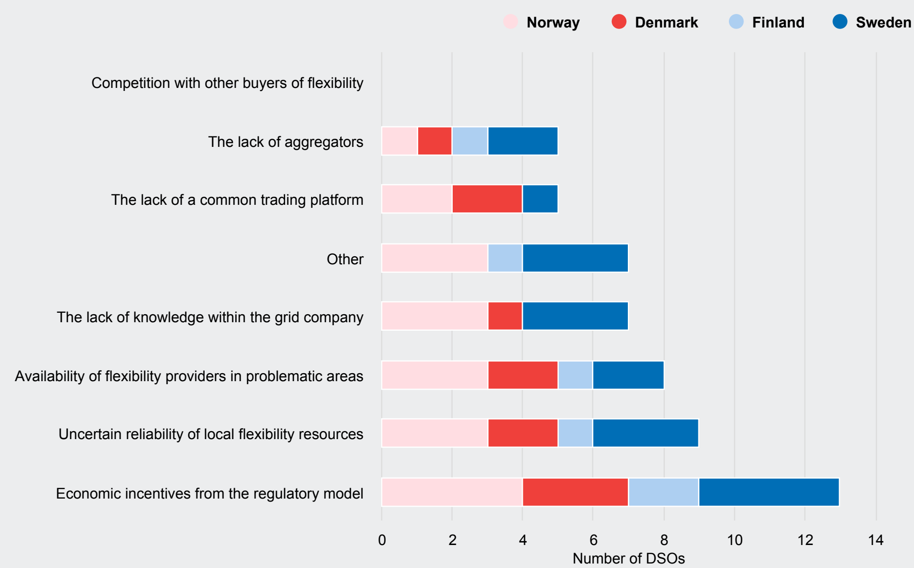

Figure 2. Survey responses to question 15: "From your side, what are the main current barriers when it comes to procuring distributed flexibility (when flexibility would be useful)"

Our survey did not ask respondents for exactly which features of the regulatory models that are considered problematic. Yet, from interviews, literature reviews, and previous work by AFRY, we are aware that the way operational costs (OPEX) are treated relative to investment-related costs (CAPEX) is one likely reason.

If a DSO purchases flexibility in a market or through a bilateral agreement, the payment would presumably count as an operating cost (OPEX). As long as a DSO can reduce its total costs through such a flexibility purchase, for example by reducing investment costs, it would not necessarily be a problem that the costs of such purchases are a part of the regulatory cost base in itself. For example, in systems with DEA benchmarking (like in Norway), a DSO can increase its efficiency score by achieving lower total costs than DSOs that are otherwise comparable, and thereby increase its profits. Hence, the problem is not necessarily that a flexibility purchase is classified as a cost, which can be recovered, but that it is classified as OPEX rather than CAPEX.

A somewhat different issue is however that if DSOs have access to very inexpensive or "free" flexibility (from their perspective) in the form of interruptible tariffs and/or conditional connections (see Section 3.3.4), the incentive to purchase flexibility in a market – which comes at a cost – will be reduced. We return to this in Section 3.3.4. However, it is worth noting again that the survey question explained that such solutions also were considered "flexibility procurement" in this context.

The need to change the regulatory model in order to incentivise smart use of the power grid was, amongst others, recognized by a group within the Danish energy sector, set down by the Government in order to give advice on how to reach the climate goals for 2030. With regards to explicit distributed flexibility, they advise that regulatory incentives between network reinforcements and "*smart flexibility solutions*" should be neutral.[15](p.126)

The Norwegian regulatory model has traits that favours investment, as described in a recent AFRY report to the Norwegian regulator.[16] As described there, such regulatory features can be a barrier for flexibility procurement, but it is not necessarily straightforward to change them in a way that also keeps other considerations of DSO regulations in mind. Achieving better neutrality between the two cost classes implies either reducing the profitability of investments, increasing the profitability of operational costs, or a combination. Reduced compensation for investments could, if that is the only change, be contested by DSOs, while increased compensation for operational expenses may be perceived to conflict with efficiency goals. A rebalancing of the compensation for each cost category can be a compromise, but can have significant distributional effects between DSOs. It may affect not only the profitability of new investments, but also that of existing capital and thus reduce the income cap of "capital intensive" DSOs in a high-investment cycle. Furthermore, DSO revenue cap models are approximations that do not reflect all DSO considerations. If investments give DSOs particular disadvantages outside of the model, one could argue that the model should in fact treat investments more favourably than other expenses. These issues are not dealt with in this report.

Our survey and other information sources indicate that regulatory model reform could be an important measure to realise flexibility markets that can serve DSO needs. However, we have not looked in detail at exactly which barriers these are in this report, as regulatory models are complex and would require a comprehensive treatment in themselves. In the future, an in-depth assessment of which regulatory barriers that prohibit DSOs from taking further steps towards more flexibility procurement could be useful.

As mentioned earlier, it is also important to keep in mind that Nordic DSOs may have access to a rather "inexpensive" form of flexibility procurement (from their perspective) today, in the form of interruptible tariffs. We will return to this, as well as other current non-market DSO tools, in Section 3.3.4.

3.3.2 Identification of opportunities to use flexibility

A prerequisite for DSO flexibility procurement is that DSOs consider flexibility as an alternative to traditional grid investments, at least in some cases. Hence, information about where and when flexibility can be used as an alternative is necessary. This exists to varying degrees today in the Nordic countries, and several initiatives are in development.

In long-term grid planning, DSOs need a network planning process that would easily

15. Regeringens klimapartnerskaber (2020): *I mål med den grønne omstilling 2030. Sektorkøreplan for energi- og forsyningssektorens bidrag til 70%-målsætningen.*
16. AFRY report to RME (2020): *Analyser av om og hvordan modell for fastsettelse av kostnadsnormer kan behandle investeringer og driftstiltak mer nøytralt gjennom endringer i kalibreringen.* The background for the report is that in 2019, the Norwegian regulator NVE-RME suggested a change in the regulatory model that would entail improved neutrality between capital- and operational expenditure. However, the proposed solution was unpopular with many DSOs, in large part due to its expected negative effect on the profitability of new and recent capital investments, and was not implemented.

compare the network investment cost against flexibility services. This is recognised in the EMD19, where the concept of network development plans is described as follows:

> "*The development of a distribution system shall be based on a transparent network development plan that the distribution system operator shall publish at least every two years and shall submit to the regulatory authority. The network development plan shall provide transparency on the medium and long-term flexibility services needed, and shall set out the planned investments for the next five-to-ten years, with particular emphasis on the main distribution infrastructure which is required in order to connect new generation capacity and new loads, including recharging points for electric vehicles. The network development plan shall also include the use of demand response, energy efficiency, energy storage facilities or other resources that the distribution system operator is to use as an alternative to system expansion.*" (L 158/160)

Besides long-term plans by DSOs, better exchange of information between system operators (DSOs and TSOs) can be beneficial in itself, with or without local flexibility markets. For the case of Norway, a report from 2019 argues that it is becoming increasingly important to foresee how actions in one network affects other networks.[17] Information systems that facilitate this can support coordination between system operators (DSOs and TSOs) that both want to draw on distributed flexibility, and may thereby also support the development of markets. In chapter 5, we will return to some of the key issues regarding DSO-TSO coordination.

3.3.3 Non-market DSO tools for implicit flexibility: price signals from network tariffs

The way network tariffs are structured is important when considering markets for explicit flexibility procurement, as they form an incentive for implicit flexibility. Since implicit flexibility, explicit flexibility, and network reinforcement can be seen as potentially complementary methods to achieve the same ultimate goal (low-cost, reliable, and sustainable energy services for final consumers), regulators and DSOs should look at them in combination when considering the current and future need for explicit flexibility procurement.

Implications for the need for explicit flexibility procurement

All else equal, economic efficiency should be improved when prices to a larger extent reflect the actual marginal cost of supplying each final customer at each point in time. Pricing in current electricity systems are often far from this state; as previously mentioned, energy markets are for example not granular enough to take all bottlenecks into account. Network tariffs can in theory be designed to somewhat compensate for this, but this approach is only used to a limited extent. The reasons for this are partly technological and practical, but may also in part be political; for example, a system that more closely mimicked the outcome of a more granular energy market could imply a tariff differentiation between customers that is

17. RME/Expert group (2020): *Fra brettet til det smarte nettet: Ansvar for driftskoordinering i kraftsystemet.*

incompatible with regulatory requirements for equal treatment of comparable customers. The Pöyry report from 2017 highlighted the limited possibility of DSOs in the Nordic countries to differentiate between customer groups.[18]

The way final consumers typically pay for electricity is thus, currently, not very conducive to the mobilisation of implicit demand-side flexibility. However, new technology and the use of smart meters will open up new possibilities. Aside from local congestion issues, the value of more price-responsive consumers on a system level will also become more important as more and more intermittent generation comes online. Hence, it seems likely that many forms of demand in the Nordic countries will be more price-responsive going forward, with or without explicit flexibility procurement by DSOs. Yet, there are practical limits to how far this can be taken, and there is reason to believe that flexibility procurement in the form of explicit flexibility will have to do a part of the job. Furthermore, depending on tariff design, there may be situations where implicit demand response increases, rather than reduces, the need for explicit flexibility at a certain location in the network. For example, wholesale spot prices dropping to zero or negative levels could trigger a surge of electric vehicle (EV) fast charging that causes a local congestion problem.

Implications for the functioning of flexibility markets

The possibility of improved demand-side scheduling based on price signals (implicit flexibility) may make it easier for a flexibility provider to name a price for his or her offers in explicit flexibility markets. In our interviews in this project, we were informed that both sellers and buyers in local flexibility platforms currently seem to have some difficulty in naming their prices, which could entail inefficiencies. While some of this may turn out to be temporary, it appears in any case that cost-reflective price signals can constitute useful benchmarks, which can allow more accurate pricing in markets for explicit flexibility.

Furthermore, cost-reflective price signals can, at least in theory, mitigate some of the potential problems of exploitative "gaming" in explicit flexibility trading. For example, when flexibility providers are paid to reduce their consumption from a baseline, there exists an underlying incentive for them to shift the baseline upwards in order to trigger an activation. They could do this deliberately, but it could also be an automatic response from machine learning systems that look for patterns to exploit. However, a well-designed tariff is likely to make it costly to increase consumption at critical times, e.g. on cold winter days, and would reduce the incentive to attempt this.

Although there may be trade-offs between implicit and explicit flexibility, the reasons mentioned above suggest that price signals can be useful complements to explicit flexibility as long as they are well designed and cost reflective. Price signals that are not, however, could have the opposite effect. Hence, for several reasons, attention should still be given to develop cost-reflective price signals further, alongside markets for explicit flexibility, and to consider combined effects. This pertains to network tariffs as well as access to retail contracts with time-varying prices based on the wholesale market.

18. Pöyry Management Consulting for The Nordic Council of Ministers (2017): *Demand side flexibility in the Nordic electricity market from a distribution system operator perspective.*

3.3.4 Non-market DSO tools for explicit flexibility: interruptible tariffs and conditional connection agreements

Besides price signals from tariffs, Nordic DSOs also rely on explicit flexibility in various forms. In our survey, the most common approach appears to be interruptible tariffs, as shown in the figure below.[19] Interruptible tariffs grant a network customer a reduced tariff in return for the DSO obtaining the option to interrupt or reduce their power outtake if needed.

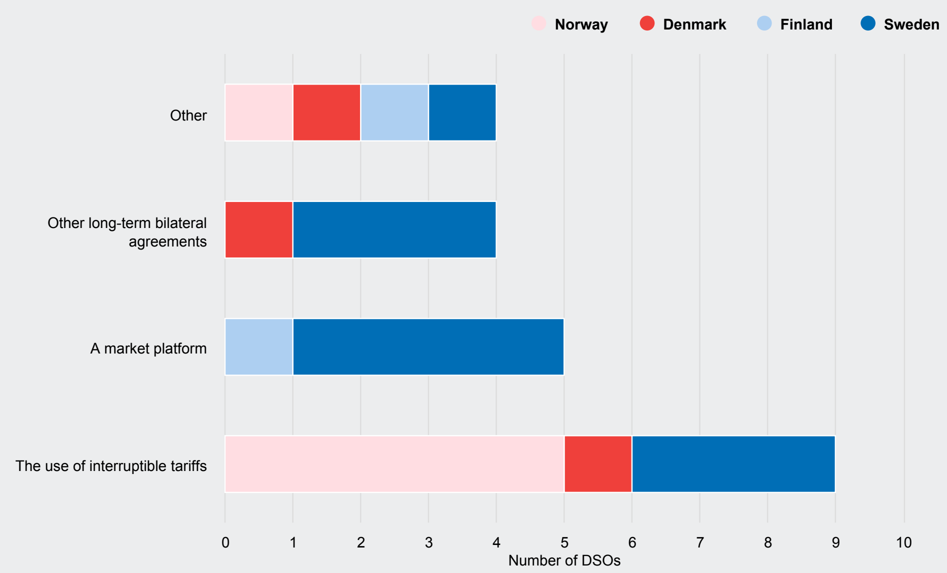

Figure 3. Survey answers to question 4: "Distributed flexibility is currently procured in my grid company through.."

19. There may be some debate about the term "procurement" in the case of interruptible tariffs and conditional connections. However, in the survey, we informed respondents that these solutions also would be covered by this term.

Interruptible tariffs can have a tangible impact on network capacity planning today. For example, the largest Norwegian DSO Elvia only considers "prioritised" expected power demand, meaning demand from customers not on an interruptible tariff, as dimensioning for the network's capacity.[20]

Another scheme, somewhat related to but separate from that of interruptible tariffs, is conditional connections for new network customers. When a new customer wishes to connect to the network or increase his access, he or she may be required by the DSO to pay an investment contribution or connection fee.[21] A conditional connection means that the DSO allows a reduced investment contribution or connection fee, in return for a right to disconnect or reduce the power outtake of the customer if needed.

Conditional connections can reduce total costs when the connecting customer's flexibility is a cheaper alternative than the cost of network reinforcement. However, it does not necessarily mean that the cheapest possible solution is used. Depending on the situation, other, already connected customers could have been able to provide flexibility to solve the same problem at an even lower cost.

Conditional connections schemes are predicated on the requirement to pay an investment contribution or connection fee, and thereby touch the more general debate about how fair and accurate these requirements are. The policy on this issue, and on conditional connections as an alternative, can have implications for the development of flexibility markets. Specifically, the flexibility sourced from customers with conditional connections could compete with the flexibility DSOs would like to purchase in market. The former may be more attractive because the cost is carried by the customer and the DSO may be able to disconnect or down-regulate the customer freely (depending on the exact design). Interruptible tariffs that do not impact the DSOs' operational costs will have a similar effect. Hence, insofar as conditional connections and interruptible tariffs provide DSOs with "free" or very inexpensive flexibility (from the DSO's perspective), the incentive to instead purchase flexibility in a market will be lower.

In chapter 4, we will return to interruptible tariffs and conditional connections, and discuss market-based alternatives. First, however, we will look at the current and future need and potential for distributed flexibility in the Nordic countries.

3.4 Need and potential for distributed flexibility

In this section we explore the current and future potential for distributed flexibility in the Nordic countries, as well as the need for flexibility as seen from the perspective of Nordic DSOs. Conclusions are based both on a literature review and on answers to our own survey from some of the largest Nordic DSOs. The main focus is here on demand-side flexibility.

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20. Elvia (2020): *Kraftsystemutredning 2020-2040*, Oslo, Akershus og Østfold.
21. The variation in the use of connection fees and investment contributions in the Nordic countries was described in the report Pöyry Management Consulting for The Nordic Council of Ministers (2017): *Demand side flexibility in the Nordic electricity market from a distribution system operator perspective.*

3.4.1 Current flexibility potential and need

Several studies have attempted to estimate the flexibility potential in the different Nordic countries. We summarise some selected estimates below. It is difficult to give precise estimates of both the technical and the economic potential, as both are subject to significant uncertainty and because definitions of technical and economic potential depend on the study. It is clear that the economic potential is highly dependent on the assumptions related to e.g. price signals, as well as costs at the end user level.

Another important aspect is the duration of the flexibility activation, especially when it comes to down-regulation of power consumption. Many resources might be able to turn consumption down or off for a very short time, but as the duration persists the cost increases and less flexibility will be available. As described earlier, prolonged limitations on consumption may also lead to a rebound problem in which the consumption will cause a peak when reverted. For example, electrical heating may be fully switched on after hours of cooling down in winter.

In a report from 2016,[22] the Swedish Energy Markets Inspectorate (EI) reported a technical potential for demand side flexibility in **Sweden** of around 8 GW during the winter, of which 5.5 GW stems from households and 2 GW from the industrial sector (p.10). The flexibility potential from households is mainly related to electrical heating systems and varies largely throughout the year, down to 1.5 GW in the summer.[23] According to a report by IVA,[24] flexibility from small-building heating is however only available for a duration of up to "*a few hours without affecting comfort*" (p.22, own translation). Furthermore, as the EI study's number of 5.5 GW was for single-family houses,[25] the number for all buildings is higher; in a report for the Nordic Council of Ministers in 2017,[26] Vista Analyse suggested that if the same methods were used for all buildings, the number could increase to 7 GW (p.50).[27]

In 2018, the Norwegian TSO Statnett estimated the theoretical potential for demand side flexibility in **Norway** to be roughly 10 GW (read from graph) in a peak hour with a total of 25 GW consumption (p.20).[28] Here, roughly 3.3 GW of the potential is related to space heating (of which 1.5 GW in commercial buildings and 1.8 GW in households), and 1.5 GW is related to water heating (of which 0.5 GW in commercial buildings and 1 GW in households). In sum, the potential from households is almost 3 GW, somewhat higher than the "realistic" potential estimated by the Norwegian regulator NVE in 2016 of 2.5 GW.[29] It is however underlined that the latter estimate is a very rough one.

A 2018 study, based on a broad literature survey, summarized the available demand side flexibility per Nordic country.[30] The focus of the study was on "*the possibility to*

22. Energimarknadsinspektionen (2016): *Atgarder for okad efterfrageflexibilitet i det svenska elsystemet*, See also the underlying sources: Nyholm, E; Puranik, S; Mata, E; Odenberger, M & Johnson, F (2016): *Demand response potential of electrical space heating in Swedish single-family dwellings.* Buildings and Environment, February, vol.96, pp 270-286. & NEPP (2016): *Reglering av kraftsystemet med ett stort inslag av variabel produktion.* The report by Energimarknadsinspektionen denotes the technical potential as the potential "*which should be possible to activate with the right incentives and technology*" (p.28, own translation from Swedish).
23. Ibid.
24. Kungl. Ingenjörsvetenskapsakademien (IVA) (2015): *Scenarier för den framtida elanvändningen.*
25. Originally from Nyholm et al. (2016)
26. Vista Analyse for the Nordic Council of Ministers (2017): *Flexible demand for electricity and power, barriers and opportunities.*
27. However, as they point out (p.50), the same method applied for the other Nordic countries leads to a very high estimate for Norway.
28. Statnett (2018): *Fleksibilitet i det nordiske kraftmarkedet 2018–2040.*
29. NVE (2017): *Fremtidens elkunder. Potensial for fleksibilitet på forbrukssiden.*
30. Söder, L; Lund, P; Koduvere, H; Bolkesjø, T; Rossebø, G; Rosenlund-Soysal, E; Skytte, K; Katz, & Blumberga, D

reduce the peak in situations with high demand and lower amounts of solar and wind power" (p.655).

	Sweden	Norway	Finland	Denmark
Peak demand (GW) in study	27	24	15.1	6.1
Flexibility potential from household heating (GW)	2-5.5	1-2.7	1.2-1.5	0.1-0.2
Flexibility potential from industry (GW)	1.9-2.3	0.3-1.5	1.4	0-0.2
Other flexibility potential (GW)	0.2	0.8-1.7	1.9	0.6-1.0
Sum (GW)	4.1-8	2-6	4.4-4.7	0.7-1.4

Table 1: Technical demand side flexibility potential. Source: Söder et.al. 2018[31] (rounded numbers and sum based on individual categories)

The authors note that "*The comparison shows a large variation in the obtained estimates both within and between countries. This is the result of differences in estimation method*" (p.662). The Swedish estimate is in line with the estimate from the Swedish Energy Markets Inspectorate, but even the highest estimate for Norway is much lower than Statnett's estimate from 2018.

In the report from 2018, Statnett estimates the **Nordic** technical potential for demand side flexibility in 2020 to be between 17 and 39 GW, which is the assumed maximum load reduction for a short time interval.[32] The largest potential, between 5 and 25 GW, stems from heating systems in households and commercial buildings. Furthermore, Statnett estimates the economic potential in 2020, given an electricity price of €200/MWh. The economic potential depends on the duration, and varies from 8 GW with a very short duration down to about 1.5 GW with a duration of up to six hours. In other words, Statnett estimates that the economic potential is less than half of the lowest estimated technical potential, even when only used for a very short time.

In sum, the technical potential for demand side flexibility is uncertain, but probably substantial. The potential reported in Table 2 corresponds to roughly 40% of peak demand in Norway and around 10-30% of peak demand in the other countries.[33] Some flexibility available from large industry may however be connected to the transmission grid and thus not available to DSOs.

(2018). *A review of demand side flexibility potential in Northern Europe.* Renewable and Sustainable Energy Reviews 91 (2018) pp. 654-664.

31. Ibid.
32. Statnett (2018): *Fleksibilitet i det nordiske kraftmarkedet 2018–2040,* p.21
33. Based on peak demand in Table 1.

	Sweden	Norway	Finland	Denmark
Demand side flexibility potential (GW)	8-9.5	10	4.4-4.7	0.7-1.4
Source	Swedish Energy Markets Inspectorate	Statnett	Literature survey by L. Söder et.al.	Literature survey by L. Söder et.al.

Table 2

Estimates of current demand side flexibility potential from selected sources for Sweden[34], Norway[35], Finland and Denmark[36]

Besides demand side flexibility, there might be quite substantial flexibility available from production units in the distribution grid. In fact, as if 2017, around 40% of installed generation capacity in Norway was connected to the distribution grid.[37] In Denmark as of 2019, nearly 80 % of all renewable power was connected to the distribution grid.[38] It varies to what extent these production units are available for flexibility procurement by DSOs. Production units can be regulated down or fully switched off, which might be beneficial e.g. if voltage rises too much, but the opportunities to regulate production up vary significantly between different technologies and across time. Especially, solar PV and wind power will tend to produce at maximum capacity when they can, unless given an incentive to withhold some capacity in order to respond to sudden needs for up-regulation. Moreover, solar PV and wind can only be flexible when they have the ability to produce at all, which means that their actual flexibility often is zero depending on the weather or the time in the day. Hence, for long-term capacity planning when net demand is the dimensioning factor, solar, wind and similar intermittent generation is unreliable. When production is the dimensioning factor, however, the situation is obviously different.

DSO survey results: current use of flexibility

In our DSO survey, we asked several questions regarding the current need to procure distributed flexibility. The answers are summarized in the following figures:

34. Energimarknadsinspektionen (2016): *Åtgärder för ökad efterfrågeflexibilitet i det svenska elsystemet* og Vista Analyse for the Nordic Council of Ministers (2017): *Flexible demand for electricity and power, barriers and opportunities.*
35. Statnett (2018): *Fleksibilitet i det nordiske kraftmarkedet 2018–2040*
36. Söder, L; Lund, P; Koduvere, H; Bolkesjø, T; Rossebo, G; Rosenlund-Soysal, E; Skytte, K; Katz, & Blumberga, D (2018). *A review of demand side flexibility potential in Northern Europe.* Renewable and Sustainable EnergyReviews 91 (2018) pp. 654-664.
37. According to Statnett; see Energi Norge (2018): *Drift og utvikling av kraftnettet – utforming av DSO-rollen.*
38. Regeringens klimapartnerskaber, (2020): *I mål med den grønne omstilling 2030* (p.62).

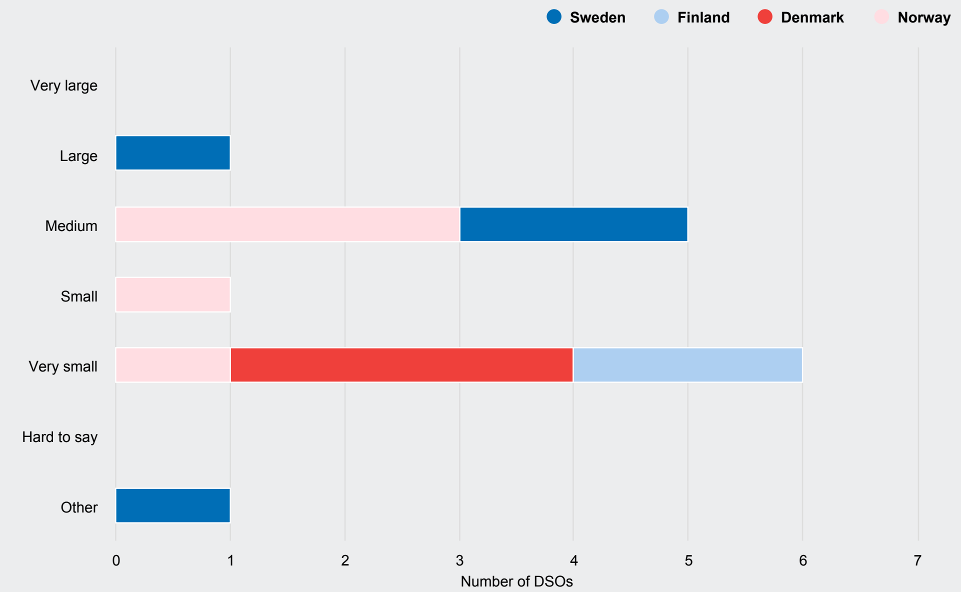

Figure 4. Survey answers to question 3: "The current need to procure distributed flexibility in my company's grid is.." (One of the answers from a Danish company was reclassified from "very, very small" to the category "very small").

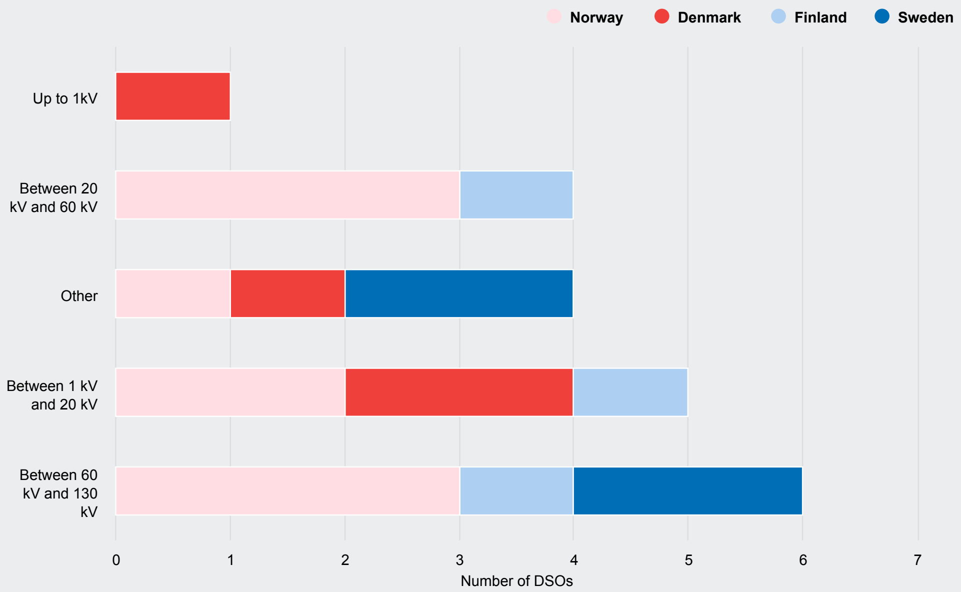

Figure 5. Survey answers to question 5: "The current need to procure distributed flexibility is mainly related to operational issues (examples in question 7) occurring at voltage level (choose the best suiting alternative(s)).

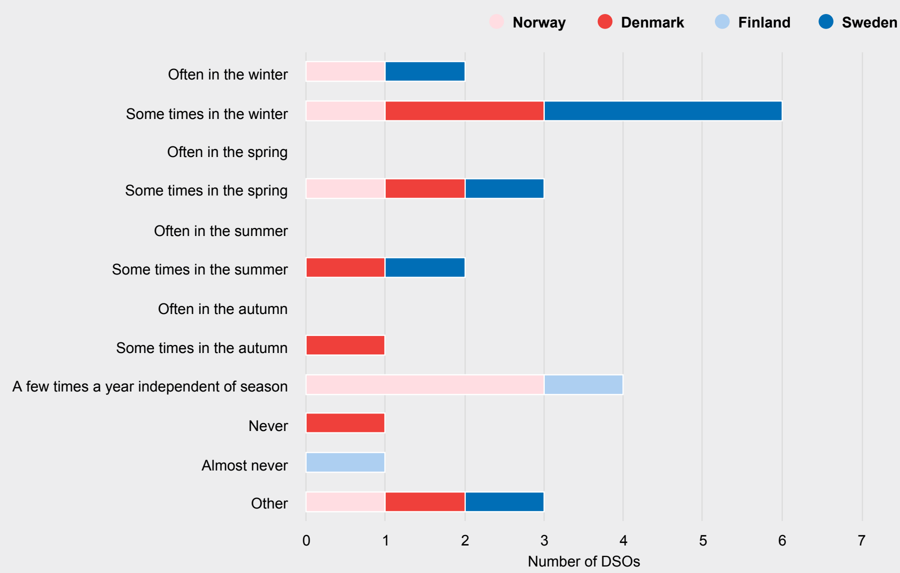

Figure 6. Survey responses to question 6: "The current need to procure distributed flexibility, as reported in the previous questions, appears:"

These results mostly align with what we have heard in interviews with DSOs and other organisations involved in flexibility solutions: the current need for flexibility is rather small, the need arises once in a while, most frequently in the winter, and explicit flexibility is very rarely used at the lowest voltage levels (<1 kV).

3.4.2 Future flexibility potential and need

When looking into the future, the flexibility potential becomes even more uncertain. However, if the potential is already large today, it will certainly become larger in the future. Developments driving the future need for flexibility also represent some of the most important new sources of flexibility. Thus, one might say that future supply and demand for flexibility – at least to some degree – go hand in hand.

The most obvious example of this is electric vehicles (EVs), which are entering the Nordic countries with ambitious targets going ahead. As EVs are charged at relatively high power in homes or service buildings, they may put strain on the low voltage distribution grids and potentially increase the need for grid investment – unless the charging can be done at times of the day when there is available capacity in the grid.

In **Norway,** there are already nearly 350 000 electric cars and around 140 000 chargeable hybrids, with respective market shares of 54% and 20% in 2020.[39] The Government's goal is that all new cars sold from 2025 will be zero-emission vehicles, which are likely to mostly be EVs. The Norwegian regulator NVE estimates a

39. Elbil.no (n.d.): *Elbilstatistikk* (web page): https://elbil.no/elbilstatistikk/

Norwegian flexibility potential in 2030 of 2 GW from electric vehicles. In addition comes just above 4 GW from households,[40] up from the current 2.5-3 GW (see section 3.4.1).

In **Finland**, only 0.35 % of the car park is currently electric, plus 1.7 % plug-in hybrids.[41] According to a recent *Roadmap for Fossil-free Transport*, prepared by a working group under the Ministry of Transport and Communications, Finland should target 700 000 electric passenger cars by 2030.[42] According to an AFRY assessment on the impacts of electrification to the Finnish power system, that EV target would mean approximately 2.5 TWh of electricity consumption, of which 25-33% could be expected to be charged smartly. In terms of capacity, this would imply 0.7-1.0 GW of flexibility. Further, electric heating in households, including direct electric heating and heat pumps, is assumed to provide approximately 1.6 GW of flexibility in 2030. In addition to the flexibility from household customers, commercial and smaller industrial customers can provide flexibility to DSOs through for example large-scale heat pumps.[43]

Denmark aims to have 1 million "green" cars in 2030.[44] Plans aiming to reach the Government's goal of 70 % reduction in CO_2-emissions by 2030 point to an ambitious program of electrification, from 35 TWh in 2019 to 71 TWh in 2030.[45] About 25 % of this increase, 9 TWh, would be due to the introduction of heat pumps, of which 3 TWh in private households and 3 TWh in district heating centrals.[46]

The interest organization Dansk Energi seems to also expect some peak shaving possibilities from heat pumps.[47] In total, the long-term flexibility potential from buildings (both private households, public buildings and the service sector) is estimated to be around 0.5 GW.[48] Vista Analyse deduces from this and other studies that "*the medium-long term potential in Denmark is 500 MW and maybe as high as 1400 MW under favourable regulatory conditions, high stock of heat pumps and electric boilers, and high penetration of electric vehicles*" (p.23).[49]

In **Sweden**, the Government has a target to reduce climate gas emissions in the transport sector (domestic air transport excluded) by minimum 70 % from 2010 by 2030 at the latest.[50] According to a forecast by the interest organization Power Circle, there may be as many as 2.5 million EVs and hybrid plug-in vehicles in 2030.[51]

The Swedish Energy Markets Inspectorate expects that in 2030, the potential for demand side flexibility from households and the industrial sector will be similar to today (i.e. ca. 5.5 GW from households and 0.5 GW from industry, as reported in section 3.4.1).[52] This is because an increase in electricity used for heating through

40. NVE (2017): *Fremtidens elkunder. Potensial for fleksibilitet på forbrukssiden.*
41. Finnish Information Centre of Automobile Sector (2021): *Passenger car fleet by fuel type* (web page): https://www.aut.fi/en/statistics/vehicle_fleet/vehicle_fleet_by_fuel_type/passenger_cars
42. Finnish Ministry of Transport and Communications (2020): *Fossiilittoman liikenteen tiekartta -työryhmän loppuraportti*. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162508/LVM_2020_17.pdf
43. AFRY (2021): *Hiilineutraalisuustavoitteen vaikutukset sähköjärjestelmään.* https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/162705/VNTEAS_2021_4.pdf
44. Aftale mellem regeringen, Radikale Venstre, Socialistisk Folkeparti og Enhedslisten (2020): *Grøn omstilling av vejtransporten.*
45. Regeringens klimapartnerskaber (2020): *I mål med den grønne omstilling 2030* (p. 51).
46. Ibid.
47. Ibid (pp. 66-67).
48. Intelligent Energi (n.d.): *Sådan bliver bygninger aktive medspillere i det intelligente energisystem.*
49. Vista Analyse for the Nordic Council of Ministers (2017): *Flexible demand for electricity and power, barriers and opportunities.*
50. Energimyndigheten (2020): *Sveriges energi- og klimatmål* (web page): https://www.energimyndigheten.se/klimat--miljo/sveriges-energi--och-klimatmal
51. Power Circle (n.d): *Elbilsläget* 2018
52. Energimarknadsinspektionen (2016): *Åtgärder för ökad efterfrågeflexibilitet i det svenska elsystemet*

heat pumps is outweighed by a warmer climate and energy efficiency measures.

In the report from 2018, Statnett[53] refers to estimates of the **Nordic** demand side flexibility potential of 12 GW in 2040, of which 6 GW comes from heating systems in households (p.20). This may however be somewhat low compared with the sum of the numbers by country, as listed above.

DSO survey results: future flexibility use

In our survey, we asked the respondents how they expect the need to procure distributed flexibility would evolve towards 2030 and beyond. The formulation of these questions can be difficult, as the use of flexibility depends strongly on what is assumed about conditions like regulations, network tariffs, and other factors. This could entail significant confounding effects in the answers. We therefore framed several of the questions around a hypothetically optimal future, meaning that DSOs could assume that regulation and conditions would give unbiased incentives between network investment, the use of price-based signals (e.g. network tariffs) and explicit flexibility procurement. The answers to the key questions are listed below.

For some context, respondents were asked (question 9) to assess their own knowledge about the future need to procure flexibility on a scale from 1 to 5 (1=very poorly developed and 5=very well developed). The average rating was 2.43.

In question 7, respondents were asked about the main drivers for future flexibility needs:

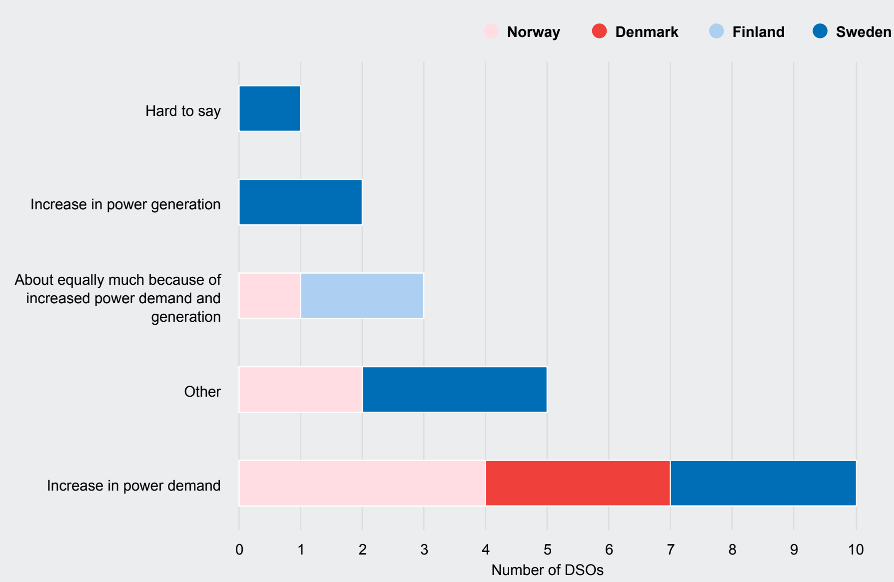

Figure 7. Survey answers to question 8: "The future (2030 and beyond) need for grid capacity upgrades and/or flexibility (both implicit and explicit) will mainly be driven by.."

53. Statnett (2018): *Fleksibilitet i det nordiske kraftmarkedet 2018–2040.*

The key expected driver is increase in power demand, but several respondents also note that generation could be an issue. For example, one respondent pointed out that it may apply in rural areas while demand is the main problem in an urban area.

Questions 10 and 11 tried to elicit whether it would be optimal to use more flexibility in the future than today, and if so, how often and when this flexibility would be used.

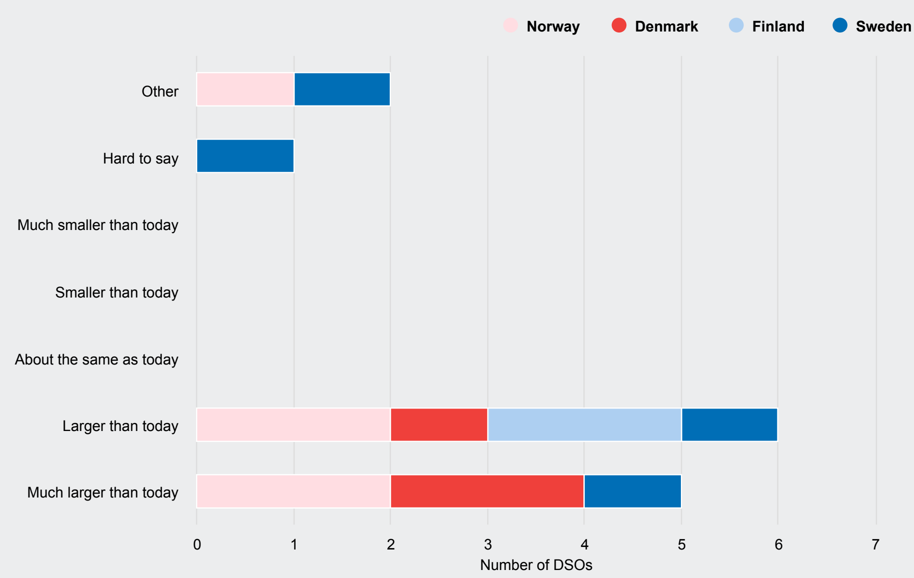

Figure 8. Survey answers to question 10: "Given an optimal split (in a societal perspective) between grid investments, implicit flexibility (stimulated by tariffs and other price signals) and explicit flexibility procurement, the FUTURE (2030 and beyond) use of flexibility procurement is likely to be:"

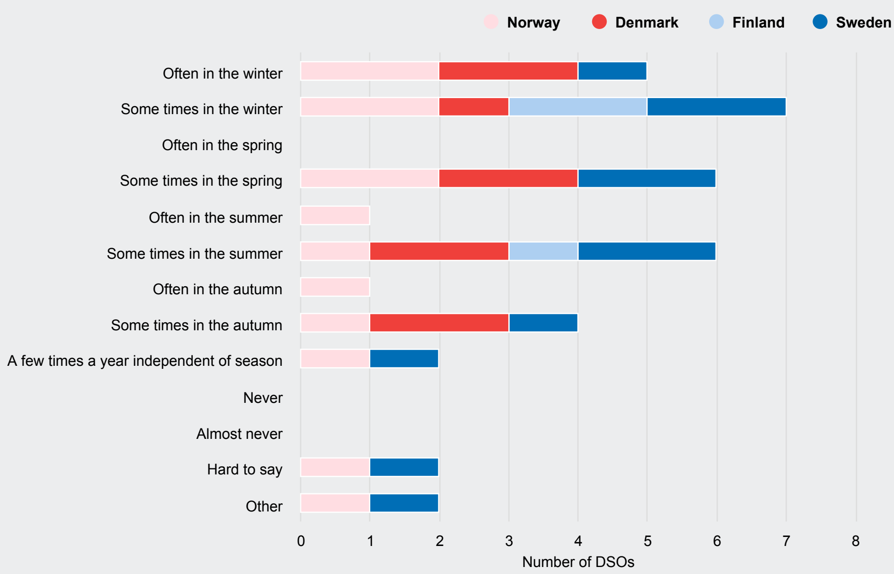

Figure 9. Survey answers to question 11: "The need to procure flexibility as reported in the previous question would appear:"

In these questions, it appears that DSOs expect it to be optimal to use more flexibility procurement in 2030 than today, and that the use of flexibility in this future will be used more often than only on rare occasions. The answers to question 11 are worth comparing with answers to question 6, which asked about when and how often flexibility is used today. The table below shows this contrast.

Comparison: the need to procure distributed flexibility arises:	6. Today (number of DSOs):	11. Expectation in "optimal" future (number of DSOs):
Often in the winter	2	5
Sometimes in the winter	6	7
Often in the spring	-	-
Sometimes in the spring	3	6
Often in the summer	-	1
Sometimes in the summer	2	6
Often in the autumn	-	1
Sometimes in the autumn	1	4
A few times a year, independent of season	4	2
Never	1	-
Almost never	1	-
Hard to say	NA	2
Other (free text allowed)	3	2

Table 3. Comparison of answers to survey questions 6 and 11. Here, categories are summed per country.

There is a clear increase. However, it is almost only in the winter season that flexibility is expected to be a frequently recurring need ("often") and it is worth noting that this is still only expected by 5 out of 14 respondents. This implies that most of these DSOs do not expect very frequent activation of flexibility (and hence, in the context of a market, not very frequent short-term trading) even in the far future and even when an optimal amount of flexibility is used. Responses to question 14, which addresses the value of flexibility use, can also be seen as a confirmation of this view (we will return to question 14 shortly).

After respondents were asked to envisage an "optimal" future in question 10 and 11, we then asked how much flexibility procurement they actually expected would be used, compared with that future:

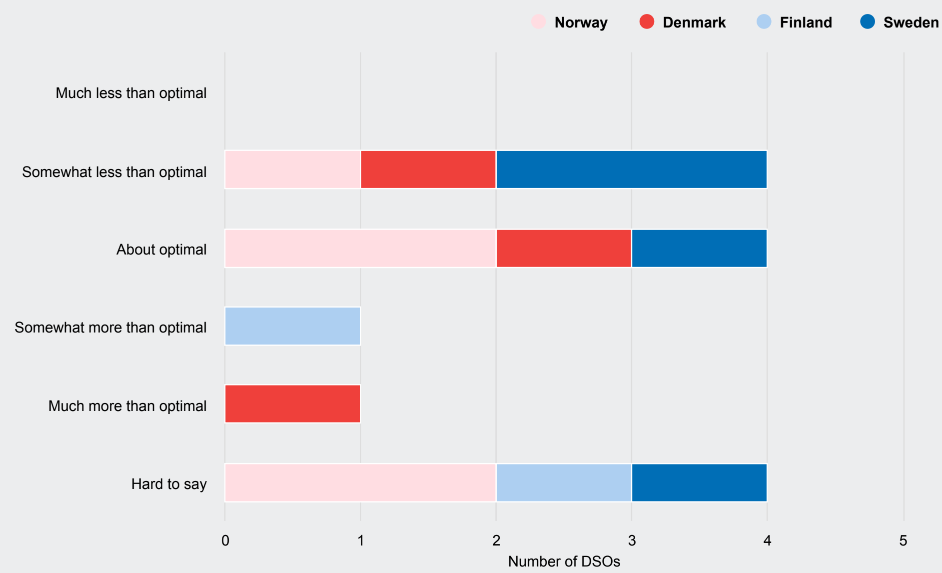

Figure 10. Answers to survey question 12: "Given your expectations about the future (including regulatory policy), how do you think actual flexibility procurement will be, compared to the optimal level for society around 2030 (as reported in question 10)?"

In question 13, respondents were invited to explain their answers to question 12 in free text if they answered it with something else than "about optimal". Here, a few responding "somewhat less" or "much less" pointed to regulatory issues, and one emphasised that "*the national/international approach to markets/products is hard to achieve. I believe there is no one-size-fits all for these new products, and that a more local approach should be taken*".

Some of the other answers we received were also interesting, but seemed to address somewhat different issues.

Question 14 dealt with how DSOs assessed flexibility procurement as an alternative to network reinforcement. As we expected that respondents could consider the current regulatory model in their answer, we attempted to control for this in the wording of the question:

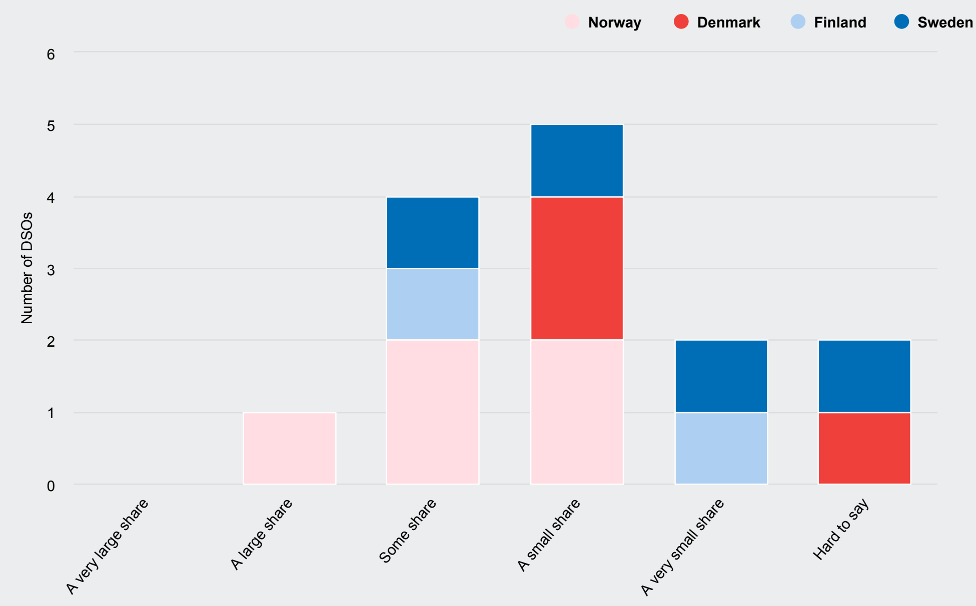

Figure 11. Survey answers to question 14: "Over the next 10-20 years, approximately how much network capacity expansion would you say could be meaningfully reduced or postponed by procuring flexibility, if government regulatory policy provided neutral (socioeconomically optimal) incentives between capacity expansion and all alternatives to it?"

The answer categories are subjective, and do not inform us about any absolute level or cost saving potential. The more interesting issue is whether is there is any pattern in the way DSOs from different countries answer. The sample size is of course too small to draw inferences to other DSOs by country, but at least between the (large) DSOs that answered the survey, it is visible that the Norwegian DSOs seem to have a somewhat more optimistic view than e.g. the Danish DSOs.

A likely explanation for why most DSOs answer "small" or "very small" could be that capacity expansions are planned in combination with reinvestments. As components may be nearing the end of their lifetime, DSOs may consider that it makes little sense to not at the same time increase capacity (additional capacity adds little to total investment costs). However, while a reinvestment may ultimately be unavoidable, quick growth in demand or generation could cause the DSO to implement it earlier in order to also increase capacity. Hence, we should expect to see some impact from the fact that we included "postponed" in the question wording: while flexibility may not be able to ultimately replace a capacity increase, it may affect the timing.

Another likely and related explanation may be that DSOs do not consider flexibility procurement to be sufficiently reliable in comparison with network reinforcement, as the results in Figure 2 indicate.

3.5 Possible implications for market design

While Chapter 3 is mostly descriptive of the current state and future outlook for distributed flexibility in the Nordic countries, certain insights have emerged that could have implications for policy and strategic decisions regarding market design:

- Based on our survey of major DSOs, it appears that there may be a need to look more closely into the incentives for flexibility procurement in the regulatory models. At the same time, experience from attempts to reform the Norwegian model show that better incentives may come at the expense of other considerations, so adjustments need to take a holistic view.
- It may also be worth looking more closely at how interruptible tariffs and conditional connections affect the development of a flexibility market. The main causal effects are probably known, but the magnitude of the impact will require a more quantitative approach.
- The survey and interviews indicate that DSOs have a strong preference for long-term reliability when considering flexibility as a substitute for investment.

Photo: Johnér.se

4 Existing electricity markets: overview and stakeholders

Many of the alternatives for flexibility markets that are useful for DSOs include integration with existing energy markets. In this regard, it is worthwhile to first briefly describe the Nordic and European power system in which new flexibility markets will be embedded, and to summarise the key stakeholders. This will provide a background reference when reading chapters 5-7.

4.1 Overview of markets

At present, the current European electricity markets may be divided into four distinct "phases", sorted by their distance to the operating hour:

- **The long-term hedging market:** A purely financial market, going several years into the future. Producers and consumers use this to hedge price risks. It has no impact on the physical flows of power.
- **The day-ahead market:** The daily auction whereby producers and consumers provide individual supply- and demand curves. These are aggregated into market-wide curves that are used to calculate a universal clearing price for each hour in each price zone. The demand side has historically been highly inelastic, but is becoming more responsive as consumers are increasingly faced with time-varying prices and employ the technology to respond to them.
- **The intraday market:** The intraday market is a pay-as-bid based market running continuously 24/7. Products for next day are opened for cross-border trading after the day-ahead auction is completed and are tradable up until an hour (or

closer) before physical delivery. The market allows producers and consumers to continuously adjust their portfolios to adapt to new information and more accurate forecasts as time gets closer to physical delivery. The market is becoming increasingly important as new intermittent renewables, which are more difficult to forecast, becomes a larger proportion of the generation mix.

- **Balancing markets:** These are reserve markets run by the TSOs, whereby the TSO in each country procures reserves for balancing (maintaining frequency). Nordic TSOs also use these reserves for congestion management. A process is currently underway to develop a shared Nordic market for balancing (the Nordic Balancing Model or NBM), which in turn will be integrated with European balancing platforms.

4.2 Key stakeholders

The markets are populated by a wide range of stakeholders, and the introduction of markets for distributed flexibility will spawn even more. Below, we give a brief overview of the key roles and responsibilities that will be involved in a market for flexibility.

Stakeholder	Role in today's electricity market	Additional role in future flexibility market
Market participants with flexibility	Their flexibility is reflected in the bids and offers on the Day-ahead, Intraday and/or the balancing market.	Can sell their flexibility to DSOs, and perhaps also to TSOs outside of the current balancing market timeframe. This will increase the value of their flexible assets.
Balance Responsible Parties (BRP)	A market participant that is responsible for imbalances, or another party acting on its behalf. Wants to reduce imbalance costs.	It is yet unclear how flexibility trading and its impact on balancing and BRPs will be regulated.
Independent Aggregators (IA) or small and unconventional market participants without BRP role	Aggregate (usually small-scale) flexible resources	Their role and coexistence with traditional BRPs and retailers is not yet defined. Their actions, whether they are made by themselves or through an aggregator will influence the overall system balance.
Market Operators	This includes power exchanges like Nord Pool and EPEX Spot. Highly regulated. Must be Nominated Electricity Market Operator (NEMO) to operate in the Nordic market.	Can range from conventional power exchanges such as Nord Pool and EPEX Spot to local market platforms such as ETPA (see chapter 6.1.4) and specialised market platforms for flexibility such as NODES.

TSO	Manage transmission of electrical power in the national grids and ensure system balance between production and consumption in real time. Manage congestion through balancing markets, mainly using bids from generators for this task.	Extending the use of distributed flexibility to improve operational security in a cost-effective way. Coordinate actions with DSOs to the necessary extent.
DSO	Operate local and regional low, medium and high voltage networks.	Procuring distributed flexibility resources for congestion management, voltage management, and redundancy at lower voltage levels in a cost-effective way. Coordinate actions with the TSO and other DSOs to the necessary extent.
National Regulatory Authorities (NRA)	Lay the groundwork for a level playing field and foster efficient functioning of the market. Financial and wholesale power markets are regulated by EMIR and REMIT respectively.	Must lay the groundwork for a level playing field for flexibility providers. It is not yet clear what regulatory regime markets for local flexibility falls under. Additional regulation is likely needed.
Market Surveillance	Monitor and report any suspicious activity to the relevant agency covering the market, to help preventing market manipulation and insider trading.	As complexity increases, their role will become increasingly important.

Photo: Energifyn.dk

5 Flexibility market design: objectives and choices

This chapter summarises characteristics and design choices in future flexibility markets. In Section 5.1, we highlight some of the general characteristics of flexibility markets that are likely to be beneficial in all or most market designs. The questions of how to achieve these characteristics lead to a discussion of concrete market design choices and trade-offs, which is the topic of Section 5.2. In combination with chapters 6 and 7, the structure of the remainder of the report is illustrated in the figure below:

Traits of well-functioning flexibility markets and supporting frameworks (5.1)	- High liquidity and low barriers to entry - Competition and innovation - Low regulatory risk, aligned regulation - Market transparency - Information exchange between system operators
Design choices and dilemmas (5.2)	- Flexibility products - Prequalification - Coordination between DSOs and TSOs - Market architecture and platforms - Balancing responsibility - Cross-border trading of flexibility - Settlement and validation
Existing initiatives and pilots (Chapter 6)	- NODES - PICLO - Enera - GOPACS and ETPA - Pilots in the Nordic countries
Practical implementation: Actions and first steps (Chapter 7)	- Review of DSO regulatory models and incentives for using flexibility - Improve methods for DSO-TSO transparency and information exchange - Industry cooperation on defining (some) key products and methods for DSOs - Continuing the process of learning from pilots and regulatory sandboxes - Nordic cooperation in the broader European debate

Several of the specific choices for flexibility market design are complex and need to take many different considerations into account. There is a large number of variables, and at this stage there are probably too many uncertainties for it to be advisable to suggest a complete, top-down architecture for a future market. Rather, the development of markets for distributed flexibility is currently in an exploratory stage, where different pilot solutions are being tested in Europe and elsewhere (some of which are described in Chapter 6). This process should continue. Hence, the aim of Chapter 5 is mainly to point out some of the key dilemmas in market design, and to describe important trade-offs. Nevertheless, there are certain no-regret or low-regret steps that can be taken in order to advance the process. These are pointed to throughout, and some of the key sets of such actions are summarised in Chapter 7.

5.1 Traits of well-functioning flexibility markets and supporting frameworks

In this section, we summarise operational characteristics of functional flexibility markets, which include:

- High liquidity and low barriers to entry
- Competition and innovation
- Low regulatory risk, aligned regulation
- Market transparency
- Information exchange between system operators

5.1.1 High liquidity and low barriers to entry

To maximise market efficiency and utilize all the potential resources within it, strong incentives are not enough. Unlocking the full potential requires a framework that does not exclude entities from participating in the market without good reason. For flexibility relevant to DSOs, a key challenge is that much of the potential flexibility available to address local problems consists of small-scale demand side resources that often need aggregation and automated solutions to enter a market. This is a new development compared with the existing model that has traditionally relied on generators as the main sources of flexibility. The EMD19 states that "*Consumers should be able to consume, to store and to sell self-generated electricity to the market and to participate in all electricity markets by providing flexibility to the system*" (L 158/130) but points out, at the same time, that several barriers currently stand in the way. Regulatory barriers or rules set by marketplaces are often implemented for good reasons, but their rationale may be challenged as technology changes. Some key barriers, their likely implications, and possible mitigation actions are described below.

- **Minimum bidding size:** One potential barrier is minimum requirements for bid sizes, which is a challenge for incorporation of small-scale, demand-side resources, a potential that is currently largely untapped. Technological change is likely to mitigate this problem over time. For example, the default minimum bidding size for the Norwegian TSO Statnett's mFRR product is currently 10 MW, but recent tests suggest that a granularity of 1 MW can be feasible.[54] Successful implementation of flexibility markets requires that both technology, regulations, and requirements from system operators allow a high degree of granularity, and the reduction of minimum bidding sizes can enable a more liquid market. It is thus important that rules keep up with technology.
- **Clear regulation of independent aggregators:** The mobilisation of small demand-side resources will largely occur through aggregators, which means that the regulation concerning independent aggregators should be in focus going forward. In particular, this pertains to balancing responsibility, and the EMD19 requirement that independent aggregators should be financially responsible for imbalances.[55] The Nordic wholesale electricity market requires

54. Statnett (2021): *Distributed balancing of the power grid. Results from the eFleks pilot in the mFRR-market 2019/2020.*
55. According to the Directive's Article 17, regulation in EU Member States should ensure "*an obligation on market participants engaged in aggregation to be financially responsible for the imbalances that they cause in the*

everyone injecting into or withdrawing from the grid to either be a balance responsible party (BRP) or act via one, so that every kWh is accounted for. Activations of flexibility that deviate from the plans of BRPs will trigger imbalances, which raises the question of whether and how an entity without balancing responsibility for that resource compensates its BRP. The Nordic Energy Regulators (NordReg) have recently taken a stance against a "no compensation" model, although the details remain to be considered.[56] For this, they recommend a "*quantitative socio-economic analysis on models of compensation*" (p.29) which "*should be the basis for any decision on compensation mechanisms*" (p.29). As such an analysis is not yet available and is beyond the scope of this study, this report does not take a stance on this issue here but simply notes, like NordReg, that there is a trade-off between the degree of compensation to BRPs from independent aggregators and the attractiveness of the independent aggregator business model. Strict requirements for compensation is likely to form an entry barrier.

- **Technical implementation and operational cost:** Joining a new market usually means a minimum of investment to integrate into the different technical components. For smaller players this can be costly compared to the small margins they can gain from trading. For larger players often participating in multiple markets simultaneously, the integration can be complex and costly and therefore discourage joining. That applies to the daily operations as well. This suggests that a well-designed market should aim to simplify integration, create standards, limit the number of interfaces, and support the digitalisation and the drive towards end-to-end automation.

5.1.2 Innovation and competition

Like other markets, flexibility markets should aim to minimise transaction costs and reward continual development of products and services, with the goal of lowering the cost for end consumers. A well-functioning market should therefore facilitate competition on all levels where possible.

This principle also extends to competition between different market solutions or platforms, which can drive innovation. This suggests risks associated with locking into particular centralised services too early, even if the market ultimately may move toward consolidation over time. At the current stage, where several solutions are being tested in new flexibility markets, pilots, and regulatory sandboxes, there is value in not committing very strongly to a particular track.

5.1.3 Low regulatory risk, aligned regulation

To ensure willingness to invest in the market, regulatory risks should be minimised. This also includes the process for amending existing arrangements. Changes in regulation can have a large impact on investors, including those who invest in flexible

electricity system; to that extent they shall be balance responsible parties or shall delegate their balancing responsibility" (L158/153)

56. NordReg (2020): *Nordic Regulatory Framework for Independent Aggregation.*

equipment. In the long run, frequent regulatory changes will drive the willingness to invest down and can lead to a less efficient market where fewer participate. Hence, regulation should ideally be rather stable over time. This does not, however, have to stand in the way of local regulatory sandboxes and pilot projects. Rather, it suggests that regulatory changes should be well-thought out, and tests can be a part of the assessment process.

Similarly, stability of regulation across space (e.g. similarity between jurisdictions) also carries several important benefits. In particular, aligned rules over large geographic areas and markets simplify participation in the markets for companies operating in multiple areas and regions. Compliance can be costly, and alignment can therefore help driving the transaction costs down. It will also drive the willingness of new parties to enter new markets, therefore helping to achieve more liquidity.

Yet, it is worth noting that the regulatory framework for DSOs is still quite different in several respects in the Nordic countries, partly explained by differences in geography, demographics, key industries, natural resources, electrification, transportation policy, etc. In particular, differences in resource endowments and past investments in very long-lived infrastructure entail that these differences do not subside easily, even as the energy system undergoes major changes in other respects. While regulatory alignment is useful in several areas, there are also areas in which what is best for one country is not necessarily the best for all.

5.1.4 Market transparency

In an efficient market, all market participants optimise their orders based on all relevant information available to them at the time of planning and execution. It is therefore essential that all significant information should be made publicly available at the same time to all participants, to ensure fair competition. The information also needs to be understood to make use of it in decision making. Pricing mechanisms and processes therefore need to be transparent.

The EMD19 expresses this clearly in article 3.4:

> "*Member States shall ensure a level playing field where electricity undertakings are subject to transparent, proportionate and non-discriminatory rules, fees and treatment, in particular with respect to balancing responsibility, access to wholesale markets, access to data, switching processes and billing regimes and, where applicable, licensing*" (L 158 /143).

While the Nordic power market has been regarded as transparent, more complexity in the form of new market places (such as markets for distributed flexibility, with potentially unprecedented numbers of connected devices), changes to congestion management and balancing markets, and new types of products may challenge the status quo.

5.1.5 Information exchange between system operators

To enhance the efficiency of markets where DSOs and TSOs are key buyers of small-scale, local, or aggregated flexibility, it becomes increasingly important to exchange information between different networks and system operators. This has been pointed out as beneficial in itself, with or without local flexibility markets. A Norwegian report from 2020 argues that it is becoming increasingly important to foresee how actions in one network affect conditions in another.[57] The report also points out:

- the need for DSOs to have access to production plans in their own network (p.61);
- that is not technically feasible to use a network model that covers all voltage levels in Norway and can resolve both balancing and congestion avoidance quickly enough (p.57). Hence, to the extent balancing and congestion management is done as an integrated process, this process cannot extend downward to all voltage levels; and
- that DSOs should be informed about activation of bids to the TSO reserve markets in their own network, and should in given circumstances be able to block bids that would cause local congestion (p.59).

The implication for flexibility markets is that DSO-TSO coordination and transparency is both important in itself and an enabling factor for market-based procurement. Hence, development towards better information exchange, e.g. between network models, is likely to be beneficial in any case.

How DSO-TSO coordination or information exchange should be connected to the market itself is a more complicated question, which also requires other considerations. We will return to this issue in Sections 5.2.3 and 5.2.4.

5.2 Design choices and key dilemmas

The principles from the previous chapter are likely to broadly apply to all or most versions of flexibility markets. In this section, we will look at more specific design considerations and highlight some of the key trade-offs. This pertains to the product design process, prequalification, coordination requirements between system operators, market architecture and platforms, treatment of balancing responsibility when flexibility is activated, and the settlement and validation process.

57. RME/Expert group (2020): *Fra brettet til det smarte nettet: Ansvar for driftskoordinering i kraftsystemet.*

5.2.1 Flexibility products

The EMD19 requires that

> "*Distribution system operators, subject to approval by the regulatory authority, or the regulatory authority itself, shall, in a transparent and participatory process that includes all relevant system users and transmission system operators, establish the specifications for the flexibility services procured and, where appropriate, standardised market products for such services at least at national level*." (L 158 / 160).

The range of future flexibility products for DSOs may have to be quite heterogeneous and customised to local needs. Hence, we do not find it sensible to attempt definitions for a range of detailed products in this report. Many of the details and nuances are likely to be best worked out as a part of pilot studies, existing markets, and through the ongoing interplay between new flexibility providers and their prospective customers. At the same time, given the large number of DSOs in each of the Nordic countries, it will probably be inefficient that every single one works out their own catalogue of product specifications from scratch. Also, as shown above, the EMD19 requires, at least "*where appropriate*", a degree of standardisation. While product design should enable customization and local considerations, it is likely that there are certain products, or at least product parameters, that will tend to be the same, and useful, for most or all DSOs. Cooperation among DSOs and other stakeholders in the design of products, for example through national industry associations, may thus save costs. Important principles to keep in mind in such a process would be:

- Technological neutrality;
- Avoiding excessive individual customisation by each DSO, as this may hinder the business case for flexibility providers and thereby reduce the supply of flexibility for all DSOs in the long term; and
- It may also be beneficial to first prioritize the development of broadly applicable products that are likely to provide a good business case for flexibility providers.

This can get providers started with a virtuous cycle of experience, growth, and lower costs.

In this section we will only discuss products broadly, focusing on their most consequential characteristics. We will give particular attention to solutions that may enhance short-term efficiency but still take DSOs' concerns for long-term reliability into account.

As a starting point, we find it useful to highlight the advantages of market-based ways to procure flexibility. As described in Chapter 3, DSOs in the Nordic countries already use explicit flexibility, but only to a limited extent through market platforms.

5.2.1.1 Benefits of market-based solutions

One of the main purposes of a market is to enable efficient resource allocation. In the context of flexibility market, this means allowing the least expensive flexibility resources available to be used first. This merit order is constantly changing, especially when resources consist of demand-response. Hence, a welfare-maximising market should ideally set prices continually and activate different flexibility resources at different times. This constitutes a difference from interruptible tariffs, conditional connection agreements, and other long-term agreements where the DSO can freely activate a particular provider's flexibility at little or no cost to itself. When energy consumption is reduced by an activation through this kind of agreement, it may not be the least valuable consumption there and then.[58]

It is however worth noting that the characteristics of interruptible tariffs and conditional connections partly reflect DSOs' concerns for long-term reliability and predictability. This can be difficult to obtain in small, illiquid markets that are based on short-term pricing. The DSO may not be willing to trust that a counterparty will be there to bid into a local short-term flexibility market in the future. This creates a demand for long-term guarantees for availability, which is likely to be especially pronounced at low voltage levels where there are few and mainly demand-side providers. Potential suppliers of flexibility may also want long-term predictability, to secure their revenue. This is especially the case when investing in flexible equipment. Hence, given that both DSOs and providers sometimes want long-term contracts, a natural question is then how this concern best can be made more market-based and combined with shorter-term trading.

In the following, we will discuss this issue and others in a framework of three main dimensions when considering product specifics: the temporal, the spatial, and the volumetric.

5.2.1.2 Temporal dimensions

When specifying the exact product, there may be multiple temporal dimensions, the main being the following:

- Delivery time: At what time does the flexibility need to be activated?
- Notice period: How long in advance will the buyer (e.g. DSO) need to notify the flexibility provider about the activation of the flexibility bid?
- Duration of activation: For how long will the flexibility be activated?

However, not all of these may be required in all use cases. The most important temporal parameters are the delivery time and duration, and these parameters are also used in the intraday markets. We will return to the notice time later.

In short-term energy markets like the day-ahead and the intraday market, trading occurs from almost two days prior to delivery until the starting time of delivery, while in the TSO reserve markets, the reserves are procured at multiple time frames (seasonally, weekly, etc.). In markets trading in local flexibility, several alternatives are available. DSOs can draw on flexibility from their customers (existing and prospective) at multiple times:

- In the investment / connection phase, as new customers seek to connect to the network or potentially to install self-generation or storage;
- In a long-term flexibility procurement phase, where DSOs can procure availability from already connected providers; and
- In the short-term procurement phase / activation phase, where available flexibility may be offered and purchased shortly before activation, according to emerging needs (e.g. day to day).

58. As mentioned in chapter 3, an existing issue with interruptible tariffs is that as tariff reductions that can be recovered by charging other network customers more, they may not send an appropriate cost signal to DSOs. This is however a somewhat different issue than the design of the contract.

Availability and activation

Two broad, separable types of value streams are often considered in flexibility markets:[59]

- **Availability**: the assurance that a flexible resource is ready to provide a service at the right time and place, if needed. Much like insurance, payments for availability can be considered worthwhile even if the flexibility is never activated.
- **Activation:** the activation of the flexibility service.

These values can be combined in various ways. One conceivable solution would be that the DSO pays providers of flexibility for availability, but not for activation. In other words, the provider is paid the same whether the resource is activated or not, which is essentially how some non-market solutions like interruptible tariffs work today. The approach of not having a separate activation price has some beneficial properties. For example, there is no incentive to "game" the system by creating a congestion problem in order to trigger activation. Yet, there are also drawbacks, as indicated initially in this section. The absence of an activation price means that the value of flexibility at the time of potential activation is not captured accurately, which can entail suboptimal use of it. An activation payment contributes to a more accurate match between the necessary volume and the compensation for it, and captures the time-varying value of flexibility.

Activation prices may be implemented in several different ways. One approach is that the buyer and seller agree on an activation price when the long-term availability contract is agreed. This may be simple, e.g. a fixed sum per activation, or depend on parameters like volume, duration, notice time, etc. Compensation by volume and duration can mean that the activation becomes much like an energy-based transaction, similar to what is traded in intraday markets.

The NODES platform (see Section 6.1.1) has a "Longflex" market that can be seen as a way to bridge the gap between long-term reliability and short-term activation. A Longflex contract enables the possibility of a payment for availability for defined periods (determined in a tender)[60] and a maximum activation price. For the flexibility provider, availability is treated as a placement of short-term offers in the market at the agreed period. These will compete with offers from other flexibility providers that are available at the time. The provider holding the LongFlex can also edit the short term offers associated with the LongFlex contract, in response to offers from other providers. The provider holding the LongFlex contract can do so as long as the edited offer price is at or below the maximum price and the edited offer volume is at or above the volume set out by the Longflex contract.[61]

This setup addresses multiple objectives:

- The DSO pays for an assurance that flexibility will be available at the critical time;
- The provider is paid for holding flexible resources ready, whether or not they are used;
- A maximum price can insure the buyer against extreme prices; and
- Competition during the activation phase implies a better chance that the activated flexibility actually will be the cheapest at the time.

59. See e.g. NODES (n.d.): *A fully integrated marketplace for flexibility*. White paper., and Harbo, S.; Hansen, L.H. & Heussen, K. (2013): *FLECH—Market Specification Analysis*.
60. NODES is also able to incorporate long-term contracts that originate outside NODES.
61. From communication with NODES

In long-term contracts that include both an availability component and an activation component, the relative weight on each will probably depend on the situation and reflect the parties' respective tolerances for risk. For the most local problems, i.e. at low voltage levels where liquidity will be difficult to come by, it seems likely that the results will weigh toward availability payments. In other cases, e.g. in a mature market and at a higher voltage level, the DSO may be willing to procure larger volumes only in the short term.

In some cases, it may be sensible to procure availability in different installments and time frames, and sometimes not too long before the (potential) time of activation. For contracts that last very long (e.g. years), it can be hard to know in advance exactly when availability will be needed. This applies especially if the purpose is to use energy storage as backup for certain types of use cases, as for example in the pilot project the DSO Elenia is currently running to improve security of supply during storms in Finland (see Section 6.2.3). The contract could of course require the provider to be available at all times (which would be similar to current nonmarket solutions like interruptible tariffs). However, it may be more efficient to only call for availability when needed; especially for energy storage, a requirement of year-round, constant availability would be costly. Energy storage is of course an excellent source of short-term flexibility, but needs some notice time to store the energy in advance in order to be available for discharge. In these cases, a contract including separate payments for long-term availability (e.g. an annual payment) and shorter-term procurement of availability (e.g. payment for some days or weeks when flexibility is alerted) combines the concern for long-term security for the DSO and for the seller (who may need to invest in energy storage) with the possibility to use the storage for other purposes when the DSO considers the risk of outages to be low.

Whether or not availability contracts function as commitments to give offers to a short-term market, it will, given that availability payments are considered necessary, probably enhance efficiency if buyers have the chance to procure availability frequently and closer to the operating hour. The shorter the time between the procurement of availability and activation, the more the outcome will begin to resemble a market without availability payments.

Secondary markets

Long-term contracts can be combined with a so-called secondary market to increase freedom of choice for the flexibility providers without compromising the certainty for the DSO. This solution is for example considered by the PICLO platform (see chapter 6.1.2).[62] and its importance was emphasized by a long-term flexibility provider we interviewed in Finland. In a secondary market, the obligation to be available at the time and location which the DSO defined can be transferred to another party who can fulfil the DSO need.

There is a secondary market for reserve capacity in the UK, and opening of a secondary market has been planned for TSO reserve capacity markets in Nordics but the details are not clear, for example, whether there would be a centralised platform to facilitate secondary trading.

62. See also PICLO (2021): *Five things you should know about secondary markets*. Piclo Blog, https://blog.piclo.energy/post/641931263886966784/five-things-you-should-know-about-secondary

Notice period

The necessary notice periods for a flexibility resource may arguably be divided into 1) the time it takes to become available for activation, and 2) when available, the time between the activation signal and the activation itself.

The notice period for becoming available may be important for flexibility that is needed to support redundancy or reduce outage durations. One example would be the mentioned Finnish battery pilots (see section 6.2.3) with the aim to reduce outage duration for customers – a battery needs a certain notice period to be fully charged for the upcoming storm. In the pilot, the DSO informs the service provider in D-1, i.e. the notice time is approximately one day. Some technologies may need longer-term planning. For example, some technologies may be able to switch quickly between electricity and fuels, but may need to schedule flexible periods where they have sufficient fuels in stock.

For products that are very rarely activated, there might be a need for an estimate of the number of activations within a certain time period. For example in the use case of securing network reliability during storms, a DSO might estimate that a back-up power supply would be needed three times a year, approximately. In this case a notice period may be used.

5.2.1.3 Spatial dimensions

As the DSOs' needs for flexibility are local in nature, locational information is required on both buy and sell sides. Initially, aggregators and other flexibility providers know the locations of their own contracted assets, but not necessarily the locations of congestion problems. DSOs know where the congestion problems are, but not necessarily where the potential assets are. Hence, an exchange of locational information is often necessary.

There are several ways to do this, and the preferred approach may depend on whether the DSO sets an auction for long-term availability contract for future needs, purchases availability in an intermediate time frame, or is procuring flexibility in real time (see "temporal dimensions"). It also depends on the minimum bidding size and the degree to which aggregation of small-scale resources is required. The locations of the flexibility assets need to be connected to the grid topology, although the topology itself may not have to be disclosed to the public.

In long-term availability tenders, it is most convenient that the DSO defines a congestion area based on some public information, and signals the locations where potential flexibility can be drawn from. This makes it straightforward for flexibility providers to participate; they can use their existing assets in the announced locations, or, depending on the rules of the tender, commit to contract new ones in that area before the delivery period. When the providers are aware of the congestion area long in advance, they can focus on obtaining flexible resources there.

In short-term trading with a small minimum bidding size, flexibility providers could conceivably place very granular offers into the market continually and at the same time signal the location of each. They could do this without necessarily knowing where the congested areas are. Another mechanism, e.g. in the market platform, would stack all small-scale offers (from all providers) to match bids from flexibility buyers, which may be spatially defined. However, if flexibility providers want or need to aggregate their resources to a larger volume before they formulate an offer to the market, they will want information about the congestion zones in advance to "compose" each offer.

On their part, DSOs may have several reasons for wanting to know where in their network flexible assets are located. For example, it enables the DSO to identify and anticipate possible activations by a TSO, based on combinations of assets, that could trigger local congestion. Furthermore, for short-term trading, it can give the DSO an idea of how much flexibility will be available in the near future rather than it being revealed only shortly before the need arises. For example, a DSO may be able to anticipate the likely volume of flexibility that can be mobilized at critical locations during the winter season, well in advance. This information could reduce the need for long-term availability procurement. However, it should be considered that end-user flexibility is not a fixed resource; the supply can increase substantially if a higher willingness to pay is signaled.

Methods for information exchange about asset locations and congestion areas seem valuable in most market designs. This suggests that it would be beneficial for DSOs to cooperate with each other in developing standardised methods to express the locational information, both for the flexibility assets or bids, and for publishing of the congestion area.

5.2.1.4 Volumetric dimensions

Volumetric dimensions define the amount of flexibility that the buyer requires. The main options for volumetric definition are capacity and energy. A capacity volume combined with a duration results in energy that will be settled if providers are paid by volume. Ordering MWs is more intuitive than energy also because the capacity of network components are expressed in MWs. Using capacity as the main parameter for the ordered volume is in line with the TSO balancing energy markets: the TSO orders X MW of balancing energy for Y minutes at a certain price, and it results in an energy payment in EUR/MWh.

A low minimum bidding size ensures easy participation in the markets and allows cheaper combinations of small-scale resources to be used. For integration with intraday markets, the minimum bidding size should not be higher than the minimum bidding size there (currently 0.1 MW). Regardless, aggregation of resources within the same "flexibility area" should be allowed to maximise participation opportunities. The granularity of the offer could be aligned with the minimum bidding size, i.e. if the minimum bidding size would be 0.01MW, the size could be incremented by steps of 0.01MW.

A need for a maximum bidding size might not be as important if the offer is divisible into blocks that are reasonable for the DSO. If a market participant places a very large offer, it should be ensured that the DSO does not need to pay for the extra capacity that was not required.

5.2.1.5 Other dimensions

There might be other dimensions in the product design, depending on the specific need of a DSO use case or based on demands from the flexibility service providers. The need for such dimensions should be carefully evaluated case by case, because all additional requirements in general market rules make the solution more complicated.

It should be possible for the flexibility provider to define maximum durations of an activation, possibly with a resting and/or recovery time. The need for these kinds of parameters can however be handled through trading mechanisms (placing offers only for the maximum period) or by aggregating different offers into a whole that can fulfil the need.

The algorithm selecting the suitable offers might consider the factors resulting in the optimal combination. Such factors may be related to TSO/DSO coordination, or the actual impact on the critical network component which might differ from one location to another in distribution grids where network losses may impact the optimal selection. These factors are not strictly part of product design, but data for such considerations should be available for decision making.

Although local needs for flexibility vary significantly, it will probably be beneficial for platforms for local flexibility to have products available that are aligned with wholesale and balancing market products whenever possible. Aligning the key parameters with the existing market products can help flexibility providers to participate in DSO flexibility markets without making large changes to the existing trading strategies. The varying needs could be possible to accommodate by mimicking the different wholesale market products such as block-bids, parent-child-grandchild bids[63] etc. which were developed to facilitate efficient participation of different technologies in wholesale markets.

5.2.2 Prequalification

All electricity markets have some kind of entry criteria that need to be met before accessing the market. This is true also for local flexibility markets due to multiple reasons. First, the DSO might be interested in the credibility of the flexibility provider in managing the flexibility assets. Second, the capabilities of flexibility assets need to be evaluated against the network needs. Third, assets need to be connected to the DSO grid and their location must be specified when flexibility trading takes place. The eligibility checking process is often called prequalification (or only qualification).

The DSO prequalification process would most likely resemble the existing TSO prequalification process in which the TSO checks that the assets are capable of providing reserve capacity. If the asset or assets meet the technical requirements of the reserve product, the TSO signs a contract with the service provider, registers the flexibility in national reserve IT systems, and provides access to the reserve market platform. Each Nordic TSO has its own criteria and register for the assets although the markets are Nordic. For example, locational information and aggregation rules may differ between the countries. The Nordic TSOs have however standardised the minimum data that needs to be available in the Nordic reserve markets.

The four flexibility market solutions reviewed in Chapter 6 (NODES, Piclo, Enera, and GOPACS) use prequalification methods that in most cases are carried out by the system operator to whose network the flexible resource belongs.[64]

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63. The acceptance of the subsequent bids depend on the activation of the first bid. The linking might be due toe.g. high start-up costs after which the marginal production cost can be lower. In that case, the parent order will have a higher price while the child orders are cheaper, but the child cannot be accepted without the parent being accepted as well.
64. Schittekatte, T & Meeus, L (2020): *Flexibility markets: Q&A with project pioneers*. Utilities Policy, 63 (2020).

5.2.3 Coordination between DSOs and TSOs

TSOs and DSOs have similar tasks in different parts of the grid, including management of congestion in grid stations and transmission lines. Furthermore, TSOs are responsible for maintaining balance (frequency) at the system-wide level. The tasks of DSOs and TSOs are not independent of each other, as actions taken at one level of the grid may influence management in the other. Therefore, the activities of DSOs and TSOs must be coordinated.[65] Such coordination is conceptually challenging, and there is a large body of literature on how to do it.[66] It is a concept also addressed by many of the existing flexibility markets and pilots across Europe, as well as R&D projects such as INTERRFACE.[67]

As pointed out earlier, coordination between system operators is valuable whether or not advanced flexibility markets are developed. Better information exchange alone is likely to improve system operation in a future with more distributed generation and load-intensive consumption. However, it can also be an important supporting pillar for a flexibility market (see Section 5.1.5). Some of its key functions would be to facilitate:

- exchange of information between DSOs and the TSO about problems to solve, on multiple time horizons
- allocation of responsibilities: if there is doubt, who is responsible for solving a congestion issue and potential knock-on effects

There is some debate about how extensive coordination needs to be, for example whether it should go beyond information exchange and allocation of responsibilities where they are unclear.

One of the currently debated questions on DSO-TSO coordination concerns the DSO's possibilities to block bids from the balancing markets that could worsen local congestion. The recent report on DSO-TSO coordination in Norway raises the question about whether the network owner should compensate local flexibility providers in such cases.[68] This brings up the questions about who it is that should pay the price for scarcity of network capacity, for which views may differ between countries.[69]

It is worth noting that whoever bears the cost, the presence of a market for local flexibility can trigger the use of local flexibility proactively to make room for the activation of balancing bids, if profitable:

- If a compensation is required, the DSO has an incentive to purchase local flexibility to avoid having to block the bid, if that is cheaper. Alternatively, the DSO may expand network capacity.
- If there is no compensation, flexibility providers whose balancing bids are blocked have an incentive, if profitable, to alleviate enough local congestion to ensure that the bid is not blocked and thereby give its own resources access to the TSO market.

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65. See ENTSO-E (2017): *Distributed flexibility and the value of TSO/DSO coordination.* Policy paper.
66. See for example: CEDEC, E.DSO, ENTSO-E, eurelectric, & GEODE (2016): TSO-DSO Data management report., and CEDEC, E.DSO, ENTSO-E, eurelectric, & GEODE (2019): TSO-DSO Report: An integrated approach to active system management.
67. INTERRFACE (2019): *INTERRFACE (TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system* (web page): http://www.interrface.eu/The-project
68. RME/Expert group (2020): *Fra brettet til det smarte nettet: Ansvar for driftskoordinering i kraftsystemet.*
69. See also Chapter 3, on the related issue of investment contributions and connection fees.

The use of local flexibility for this purpose requires that the value of participation in the balancing market exceeds the cost of creating room for participation. It is unclear how often this will be the case. In any case, however, the scarcity of local network capacity to accommodate participation in system-wide markets is a cost that is carried by someone. Making this cost as transparent as possible is likely to enhance efficiency.

Under today's regulation, the DSO must normally accommodate the consumption patterns of its connected customers: either by expanding the network, or by using alternatives like flexibility procurement. For example, if wholesale spot prices should drop to zero and trigger a surge in local EV charging that would lead to congestion in the DSO's grid, the DSO cannot simply block their consumption without compensation.[70] The cost falls on the DSO (and by extension, its customers). A natural question is therefore if the same EV charging surge should be treated differently if it instead is triggered, for example, by the TSO's activation of a flexibility bid for balancing (if the DSO can block balancing bids at no costs to itself, there is a difference in treatment). Hence, some of the key questions regarding TSO-DSO coordination touch the questions of who it is that ultimately should pay for network capacity or its alternatives.

As we show in chapter 6, different levels of DSO/TSO coordination are being piloted. This is a good step forward, and it is important to continue the work towards a solution that would be generally accepted and adheres to good market design principles. That requires a broader approach than what is limited to one local congestion problem. While this is a national decision, finding common denominators could benefit all and profit from economies of scale.

5.2.4 Market place integration and architectures

One of the questions often discussed in the design of future flexibility markets is whether "many" or "few" platforms will be better, and the relationships between different markets, marketplaces, functions, and platforms. As there are hundreds of DSOs in the Nordic countries and each is mainly concerned with their own network area, one could imagine many different local marketplaces. On the other hand, one marketplace could naturally also serve multiple DSOs, as e.g. Piclo does in the United Kingdom (see section 6.1.2). Hence, the theoretical range of options spans from one platform per DSO to one platform that covers all. Furthermore, another (although not mutually exclusive) option is the concept of a functionality, possibly as a part of a DSO-TSO coordination platform, that forms a single entry point for DSOs and TSOs to access one or multiple marketplaces. All cases involve potentially difficult trade-offs.

It should also be noted that the number of marketplaces becomes less important if mechanisms to link them together exist. To simplify the problem somewhat we may say that as a starting point, most actors in the market will be interested in simplicity and easy access to liquidity. As long as this is ensured, it may not matter very much

70. The exception would of course be if the customer(s) e.g. have a conditional connection agreement, are on an interruptible tariff, or have a market-based availability contract without an activation price. In these cases, however, the customers have already been compensated in advance.

to the market participant whether this means one big marketplace or several interlinked marketplaces.

Buyers of flexibility and flexibility providers may approach this from two different angles:

- **Buyers of flexibility** would be interested in a single or a limited number of entry points that would give access to the maximum number of flexibility providers - although for DSOs, the focus will be on providers within their network area. The flexible resources within the DSO's network area will likely be controlled by multiple flexibility providers, and the DSO would like to have access to offers from all of these.
- **Flexibility providers** may have flexible resources spread across many DSO areas, and would then most likely want to avoid having to connect to many different local DSO platforms if each has its own rules and specifications. Rather, they would probably prefer to connect to a selected platform or entry point that suits their needs, and which allows them easy access to sell flexibility to multiple DSOs[71] as well as other buyers or markets.

A platform built around only one of the two sets of concerns above could however imply certain challenges:

- If DSOs build or configure individual platforms just or mostly for themselves, the result will be many, smaller platforms. As mentioned, this may not be attractive for flexibility service providers that have resources in multiple areas. Hence, each DSO's platform could struggle to attract enough flexibility in their area.
- If each flexibility service provider connects to one of several large, geographically overlapping platforms that reach multiple DSOs but are not interoperable, it could mean a split of liquidity and a situation where DSOs have access to only some providers per platform or entry point. In this case, to make use of all the flexibility in their area, the DSO would have to connect to multiple platforms, which could be inconvenient and costly.

In sum, it is likely that both the DSOs and the flexibility providers would prefer to not connect to the market(s) through too many different entry points. A stylized illustration of this is shown in Figure 12 below. By itself, this can be an argument in favor of larger marketplaces that give flexibility providers access to multiple buyers, and vice versa. However, a marketplace that is too large and not subject to competition can mean a slower pace of innovation, and could also have trouble meeting the potentially diverse and customized product specifications of DSOs. The need to integrate with other markets and to participate in large platforms may also differ somewhat between DSOs. Some DSOs may have a larger need for highly customized contracts, which can be burdensome to accommodate in a standardized platform. For example, one DSO respondent to our survey pointed out that a "*national/international*" approach to products could be difficult, and emphasized the importance of local solutions.

71. To be clear, the flexibility provider cannot normally offer the same resources to multiple DSOs, but will still find it convenient to not operate in too many different marketplaces at the same time.

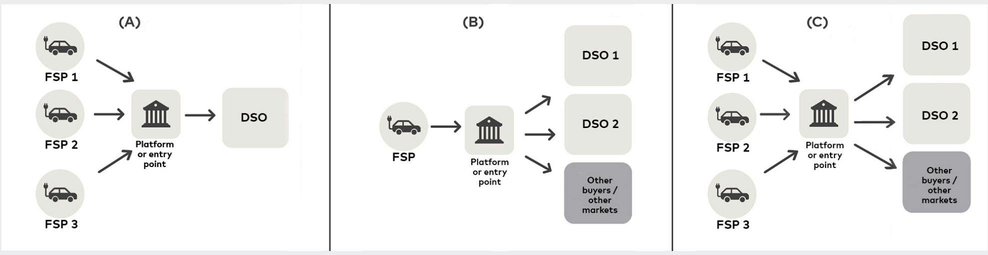

Figure 12. From left to right: A) the main concerns of a DSO, B) the main concerns of a flexibility provider, C) a solution encompassing both, which would entail a marketplace of a certain size (connecting multiple flexibility providers to multiple DSOs).

It is thus a difficult question "how large" marketplaces need to be and "how many" of them is optimal. For example, it is not yet clear exactly how heterogeneous DSO needs are and how cumbersome it is (or needs to be) for providers to connect to multiple marketplaces. At least in an early stage, the best way to resolve this question (and others) could therefore be a more practical and experimental approach rather than a theoretical one. At the moment several flexibility markets, pilots and research programs, such as those described in chapter 6, are in development, and more may appear. This provides an opportunity for learning, innovation, and a bottom-up approach to the development of future solutions. Hence, at least at this stage, it may be premature to plan a future system in every detail and from the top down.

In general, there may two broad (although not mutually exclusive) ways a competitive and innovative environment can be fostered also in a case of larger, centralized marketplaces. One possibility could be a situation with different regional (geographically non-overlapping) marketplaces, where each DSO would be connected to only one platform at a time. Another would be a layer of geographically overlapping but interoperable marketplaces in competition with each other. Each of these approaches also has some drawbacks, however; the first may entail too many different entry points for non-DSOs, while the second will require interoperability functions that can be challenging to implement.

DSO-TSO coordination platforms as an entry point to markets

An alternative approach, represented by e.g. the GOPACS / ETPA solution (see Section 6.1.4), would be that DSOs do not connect directly to a local market platform, but rather to a DSO-TSO platform that functions as an entry point into the relevant markets. GOPACS is a platform used by several Dutch DSOs and the TSO (TenneT), which gives them access to buy flexibility from the Dutch intraday market ETPA. In order for these orders to be useful for congestion management, they are supplemented with locational information. The GOPACS platform also handles DSO -TSO coordination and links each trade with a countertrade in the intraday market to ensure that activations are neutral with respect to balance (see section 6.1.4).

This setup enables both DSOs, the TSO, and flexibility providers to connect to a single entry point (GOPACS for the DSOs and TSO, the intraday market for the providers), which simplifies the operations for both.

A limitation of the solution may be that it only connects to the ETPA intraday market. Yet, as described in more detail in Section 6.1.4, GOPACS also considers connecting to other markets. Similarly, the idea of a DSO-TSO platform as an entry point for DSOs and TSO ancillary service markets to multiple marketplaces is a part of the INTERRFACE project (see Section 6.2.3).

A coordination platform or a similar function that acts as a single entry point could allow several marketplaces offering the same type of products to operate in the same DSO area, without splitting the liquidity of the local resources. Given the model of a single entry point for system operators, there are certain advantages to allow it to connect to different marketplaces. However, there are also some challenges.

One advantage would be that given that the solution entails a connection to existing wholesale markets (like GOPACS connects to ETPA), it would be compatible with a situation where several power exchanges are active in the same area. This is now possible in the Nordic wholesale market, through the Multi NEMO (Nominated Electricity Market Operators) arrangements that were implemented for Single Intraday Coupling (SIDC) and Single Day Ahead Coupling (SDAC) in Europe in recent years. Where power exchanges had a (close to) monopolistic position in the countries they operated in, the new arrangement opens for competition without splitting the liquidity. In practice this means that producers and consumers in for example the Nordic wholesale power market no longer are limited to Nord Pool, but have the flexibility to trade on EPEX Spot instead. This would also include independent aggregators, retailers, and others who mobilise local flexibility that is relevant for DSOs.

Another advantage would be that competition between marketplaces of a similar kind can lead to innovation and lower transaction costs, and flexibility providers will have more choice in where to trade. It would be in line with the European target market model on the wholesale side, where power exchanges already compete.

However, there are also some challenges associated with a solution where multiple marketplaces connect to a single entry point or a DSO-TSO coordination platform. One would be that a coordination platform or a similar centralized function covers too many of the functionalities that ideally should be managed by marketplaces. It might also be costly and could end up locking in on solutions that are not supporting innovation for market places connected to it.

Dependence on the evolution of European markets

The future architecture of markets for local flexibility is of course dependent on the structure for European flexibility markets in general. When considering different designs, it makes a difference whether one assumes that something entirely new should be built from the ground up, or whether new flexibility markets should be adapted to what currently exists. For example, it may be argued that the most efficient market for flexibility, including for local needs, would be one where BRPs, TSOs and DSOs all compete for the same flexibility on equal terms. This would however require a new, comprehensive set of regulations.

At the moment the TSOs have their own markets for their particular needs. This has certain implications for the development of markets for local flexibility; for example, the GOPACS platform is built on the premise that the TSO (and DSOs) can access bids from the intraday market. For Nordic TSOs, there is an ongoing development toward the Nordic Balancing Model (NBM), and eventually an integration with European balancing platforms MARI and PICASSO. This also has implications. To take one example, the Norwegian TSO Statnett currently uses mFRR bids for both balancing and operative congestion management, and does the latter also in the regional distribution networks (which are owned by DSOs). Statnett has argued that if regional DSOs should handle operational congestion management, the methods should be compatible with NBM.[72]

Legacy effects and ongoing developments may limit the range of practically feasible options, at least in the shorter term. Furthermore, as mentioned previously, the development of markets for local flexibility is in many respects still in an exploratory stage. Hence, it may be too early to point to an idealised future design in all details. For example, this pertains to the choice of the three main options for the integration of DSO congestion management, TSO congestion management, and balancing outlined in the recent TSO-DSO report by CEDEC, E.DSO, ENTSO-E, eurelectric, and GEODE.[73] The three outlined options in the report, "*separate TSO & DSO congestion management*", "*combine TSO & DSO congestion management*", and "*combine balancing bids and congestion management*" (p.32) all have their pros and cons, and the authors note that "*there are remaining open questions on how to move forward with these models and which one to choose*" (p.36).

The complexity of the flexibility market implementation project depends on the scope and sophistication the market design aims for. Early initiatives typically aim at proving a minimum viable solution. The complexity of the market solution should therefore be balanced with the costs, and against the available timeline in which the market needs to be established.

Perfect real-time coordination of the complex whole of all distribution and transmission network components, all flexibility resources and all market places would require a very high level of integration and large computing capacity. Increased sophistication entails higher development costs. On the other hand, uncoordinated actions increase costs for DSOs or for flexibility providers, and the costs should be evaluated from both sell and buy sides.

However, the market design should aim, in the long term at least, at lower transaction costs for both buyers and sellers, and avoid causing negative externalities such as violation of physical limits of the network. Technical sophistication depends on the market design – for example, the auction platform for contracting long-term flexibility agreements could be simpler than short-term trading.

As mentioned initially, creating a detailed market design might be too early as the DSOs have just recently started to adopt a more active role and there is no clear need in many countries or in the case of many DSOs. The DSO flexibility market would likely be based on decentralised calculations and decision-making with well-functioning interfaces. It is important to start with the minimum viable solution, and increase the complexity with time and experience. With a decentralised solution, the

72. Statnett (2020) *Statnetts høringsinnspill på ekspertgruppens anbefalinger og RMEs spørsmål* (p.3).
73. CEDEC, E.DSO, ENTSO-E, eurelectric, and GEODE (2019): *TSO-DSO Report: An integrated approach to active system management.*

most advanced DSOs with sufficient resources could start collaboration and development of joint solutions.

Scaling up and expanding of the solution across the nation – or even across the Nordics – would be a project comparable with the development of integrated wholesale markets, or with the implementation of national data hubs, from which parallels and experiences could be drawn. The potential socio-economic benefits of Nordic and European intraday and balancing markets were expected to be substantial, but we have seen that building them has taken more time than initially planned. Before deciding to harmonise and integrate flexibility markets in Nordics, it should be assessed whether the benefits outweigh the costs.

5.2.5 Balancing responsibilities

After the day-ahead auctions, BRPs are committed to a plan for their net position for the coming 24-hour period. Adjustments after the day-ahead market, for example because of better information, can be conducted through the intraday market. Deviations from the trades on the wholesale markets will mean an imbalance, on which the TSOs apply an imbalance charge. It is natural to consider this in relation to flexibility trading, since an activated flexibility can impact the BRP's balance towards the TSO.

If this is to be addressed, a mechanism needs to be in place that minimises the risk for the BRP as well as the DSO and TSO. We have discovered two main conceptual approaches to handling this problem: the traded volumes either need to be reported as a trade between the DSO and the BRP to the TSO in the same way as in the wholesale market, or managed separately by the BRP, either in the BRP's own portfolio or in the intraday market. While the exact roles outlined here may be somewhat different and depend on regulation, the general concept can be elicited.

Concept 1: Trade is reported by market platform as in the wholesale intraday market

One option is that a flexibility trade is treated in the same way as a wholesale intraday trade between two BRPs. This means that both the DSO and the BRP trade legs are reported (nominated) to the TSO. Therefore, the BRP’s new position is reported to the TSO and therefore is given the correct net position at the TSO grid level without further process.

However, the DSO, which is the other counterparty of the trade, will also hold a position. This is a risk that a DSO likely wants to mitigate. To neutralise this, the platform needs to allow for a counter trade for the DSO in the opposite direction. A counter trade could be done in one of the ways described in the following.

The example below illustrates how the process could work in practice:

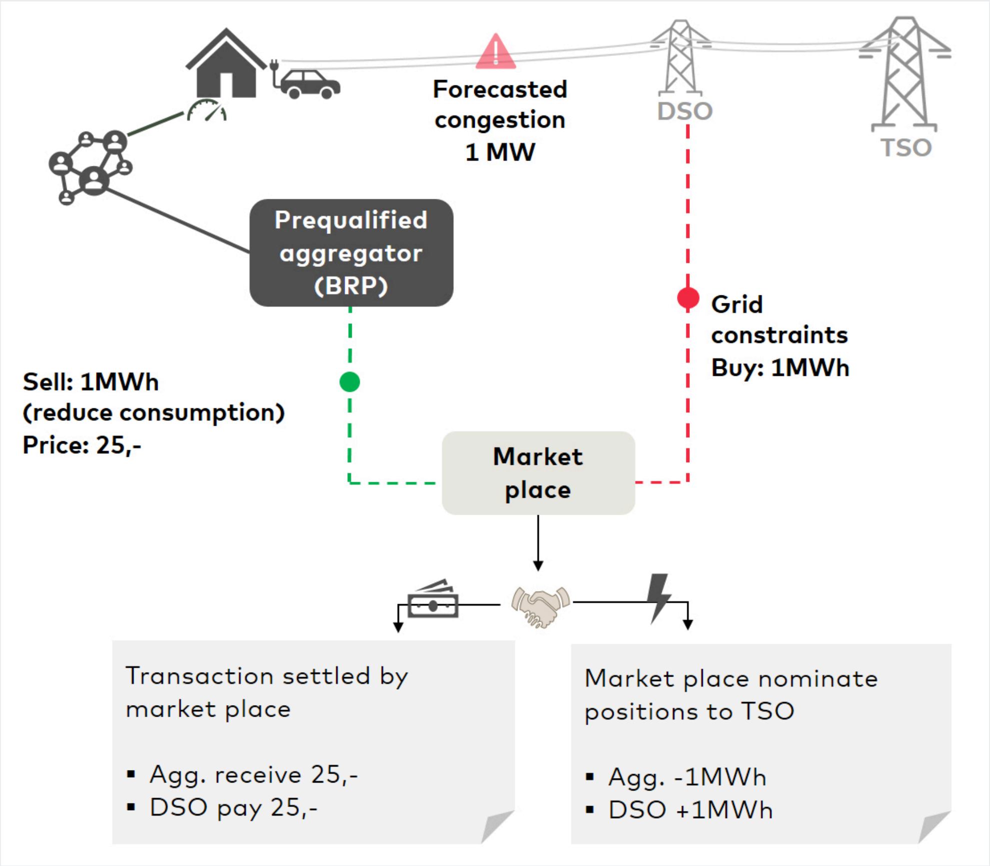

Figure 13. Illustration of case where both the BRP and the DSO trade legs are nominated (1)

In Figure 13, a DSO forecasts a need to reduce net consumption by 1 MW in a specific hour. For this they procure flexibility from a prequalified aggregator in their network. In this example it is an aggregator selling, i.e. reducing consumption by 1 MWh. The transaction is matched and settled by the marketplace, and the aggregator is paid 25,- by the DSO. The transaction is also reported to the TSO as a change in their net position. For the aggregator, it means that the 1 MWh reduction in consumption is deducted from what was previously planned and reported. For example, if they had reported a net position of +10MWh on their portfolio, it would now be +9MWh. Their net position is now in level with what they will consume. For the DSO, they have just bought 1MWh, giving them a net position of +1MWh (assuming they didn't hold any position from before). This is shown in Figure 14 as a 1MWh imbalance on the TSO grid.

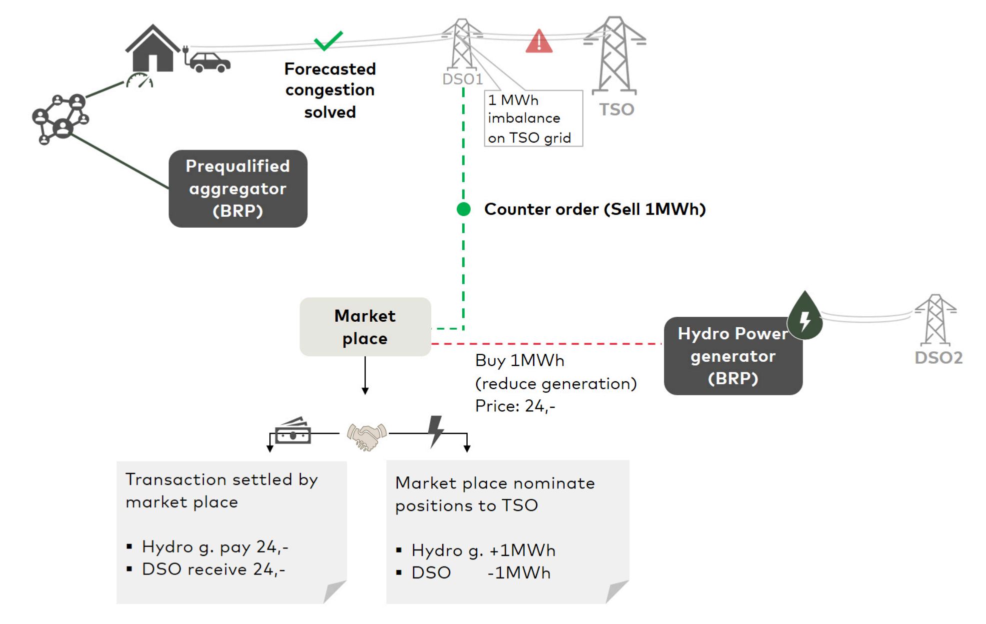

Figure 14. Illustration of case where both the BRP and the DSO trade legs are nominated (2)

To neutralise this position, a countertrade is conducted in the intraday market, as illustrated in Figure 14. For simplicity we assume that the flexibility is traded in the same marketplace as the wholesale intraday market. A counter trade could conceivably be conducted in one of the following ways:

- counter trade is managed by DSO manually in the intraday platform (which leads to questions about whether a DSO should be allowed to do so)
- counter trade is managed by a TSO/DSO coordination platform
- counter trade is managed in market place on behalf of DSO

In the example, the DSO sells the excess 1MWh on the intraday market to a Hydropower generator that is willing to buy it and therefore reduce its planned generation by 1MWh. The trade is reported to the TSO, and the DSOs net position is therefore changed from +1MWh to 0MWh and they no longer have an imbalance.

Concept 2: Trade is *not* reported and BRP is responsible for solving the balancing

The other alternative is to give the full responsibility for balancing the procured flexibility to the BRP. The flexibility trade is not reported to the TSO and therefore the DSO holds no net position. BRP is free to conduct their balancing as they want, to allow them to optimise the value. They can do this either by trading the imbalance in the wholesale intraday market or by handling it in their own portfolio.

In that way, the BRP neutralises its position. In this example it means that the DSO, which bought 1MWh, does not have any position and therefore holds no imbalance risk. However, the aggregator, who is a balancing responsible party, has now sold 1MWh and is therefore supposed to reduce its consumption. The change in planned consumption is not reflected in the balance towards the TSO. If their net consumption was +10MWh, it now remains +10MWh when it should have been +9MWh. To reflect their new plans, they have two options. Either, balance the position within their own portfolio by increasing consumption somewhere else, or trade the 1MWh in the intraday market.

Financially, the main difference is that the aggregator is paid twice: Once for the flexibility of reducing consumption and once from trading the power in the intraday market to balance the position.

Key takeaway:

One of the advantages of the first concept is that it treats a flexibility trade in the same way as a trade in the wholesale intraday market. This allows for better interoperability with existing wholesale markets and it reduces the number of transactions needed to be conducted by the BRP. It is transparent and the price signals would reflect prices in the intraday market. The BRP order would incorporate the price of the flexibility into the wholesale price, meaning the value of the flexibility is added into the price. Since the trade is nominated as a wholesale electricity trade, it can be offered on intraday markets thus allowing other BRPs to trade it as well. The weakness of this alternative is that it relies on a liquid intraday market to execute a counter trade.

The second alternative allows the BRP to first sell the flexibility and then sell the power on the intraday market (or other ways) to maximise its profit. The price signals of the flexibility order would reflect the value of the flexibility alone. The electricity would be traded in the market separately. It gives BRP more freedom, but it may go into an unregulated territory where the BRP has no real responsibility since the trade is not reported as traded electricity. It also reduces the interoperability with the intraday market compared to the first alternative. That said, it may leave more room for DSOs to define more tailored products to meet their needs.

5.2.6 Cross-border trading of flexibility

As discussed earlier, DSO markets are local in nature, and there are no direct benefits of connecting DSOs' flexibility tools with each other across borders. However, well integrated wholesale- and balancing markets can benefit DSOs, since it improves the business case of flexibility providers in general. For example, when flexibility providers acting in a local market become exposed to a potential imbalance (as discussed in 5.2.5), it is advantageous that they have the possibility to restore their balance by trading in a wider market, including cross-border trading.

TSOs are always required between the DSOs or the local flexibilities present in neighbouring countries because they manage cross-border capacity and flows on the interconnectors. The TSOs have highly advanced capacity and flow management in the existing markets. First, capacity is reserved through a European transfer capacity management tool simultaneously when matching the buy and sell orders in the intraday markets. Similarly, the TSOs manage the cross-border capacity in the balancing markets, either by reserving it beforehand or actively monitoring in real-time whether the left-over capacity from the intraday market can be utilised for Nordic/European balancing markets. If the local flexibility market activations would be coupled with intraday markets, the cross-border aspect would naturally be included.

5.2.7 Settlement and validation process

Settlement for a long term availability contract can be uncomplicated: a contract is signed, and the financial compensation will be paid according to the terms and conditions. Settlement and validation for the activation of the flexible resource, is however more difficult.

The key problem is that it is not straightforward to check exactly how much flexibility that was activated as a result of the flexibility trade itself, rather than for some other reason. There is thus a "baseline problem" which refers to how it is hard to know what would have happened in the absence of activation. Yet, flexibility trading that goes by volume, where market actors bid for regulation up or down, depends on such a baseline. As previously mentioned, flexibility providers could also be incentivised to manipulate their baselines. Even if they do not, buyers may suspect it of them. This could cause a need for extensive procedures and oversight that could increase transaction costs.

When the flexibility product is up- or downregulation and a baseline is required, there may be no perfect or even good solution to the baseline problem. This report does not deal with the baseline definition problem in detail, but note, like NordREG,[74] that in principle it would be beneficial for flexibility markets across the Nordic countries to eventually use a standard methodology. This would make it easier for flexibility providers to operate in different markets, and they would not be treated more favourably in some jurisdictions than in others.[75] However, this is also an area where more deliberation and probably also practical experience from pilots would be valuable before a direction is chosen. It can be very difficult to set a meaningful baseline to begin with, and the heterogeneity of different flexible assets adds to the challenge. Hence, if standardised methodologies should be implemented on a wide scale, they should be thoroughly tested and analysed first.

74. NordREG (2020): *Nordic Regulatory Framework for Independent Aggregation.*
75. Ibid.

Photo: Unsplash.com

6 Review of European flexibility market initiatives

Multiple initiatives for local flexibility markets have taken place globally in recent years as a reaction to changes in electricity consumption and generation patterns. The size and level of maturity in these initiatives varies greatly. Some are in the early project stage while others are more established and commercially active. In the first section of this chapter we will take a closer look at some of the existing active flexibility markets in Europe and make a comparison of these. In the following sections we will give an overview of other key flexibility projects such as bilateral pilots and concept development initiatives that are taking place in Nordics to give a broader image of different market design options.

6.1 Active flexibility markets in Europe

Various flexibility markets and platforms have been developed with differing functionalities, depending on the local regulation as well as the physical opportunities and constraints. To provide a review that is relevant for the Nordic countries, we have selected platforms that have been in operation for some years, are located in Europe and have conducted trades successfully. The selected markets are NODES, Piclo, enera and GOPACS/ETPA. The same four markets were reviewed in a 2020 article in Utilities Policy,[76] however, with a somewhat different focus in some respects. Some of the market solutions have also been updated since then.

76. Schittekatte, T & Meeus, L (2020): *Flexibility markets: Q&A with project pioneers*. Utilities Policy, 63 (2020).

The table below summarises the key features of the four markets. The background, trading processes and products are described in more detail in the following chapters. The information used comes partly from interviews, and partly from other available information. Where information is based on an interview, those interviewed have reviewed, approved, and for some passages revised the text concerning them in this chapter to ensure correct information.

	NODES	PICLO	enera	GOPACS / ETPA
Countries of operation	Today: Norway, UK, Germany, Sweden and EU funded research projects	UK, Ireland, plans for expansion	Germany	The Netherlands
Use cases for DSOs	Active congestion management and long-term capacity management	Network congestion management (postponing or replacing traditional investments)	Active congestion management	Active congestion management
Product type	Short-term activation only and long-term with products activation and availability payment; both are flexible with multiple parameters available	Long-term contract (MW), flexible parameters defined by a DSO	Flexible, parameters consisting of 0.1MW/15-min blocks on both supply and demand side	Intraday product with locational information
Trading mechanism	Long-term contracts allocated using the methodology defined in conjunction with the DSO and continuous trading for short-term trading/activation	Auction	Continuous trading	Continuous trading
Price-setting	Pay-as-bid in the ShortFlex market	Pay-as-bid	Pay-as-bid	Pay-as-bid
TSO-DSO coordination	Various approaches under discussion	No (TSO not participating)	Coordination process	Yes, through GOPACS platform
Link to other electricity markets	Link to TSO mFRR market, where NODES passes unmatched ShortFlex orders to the TSO for participation. TSO could also procure volumes directly on NODES.	Yes – Piclo is developing a secondary market for TSO capacity	System based on EPEX intraday platform	Yes, through ETPA which is a local intraday market
Financial settlement	Settlement via NODES	Settled bilaterally	Settled bilaterally	Settled via market platform
Verification of physical delivery	NODES currently conducts the verification	Currently completed by DSOs, with plans to bring onto the platform during 2021		System operator's responsibility

Table 4: Summary of key characteristics of four flexibility market platforms

6.1.1 NODES

NODES[77] is a joint venture owned by the Nordic and Baltic TSOs and the electricity utility Agder Energi. NODES started as a flexibility market project in Norway, but has since then extended its presence and is active in numerous locations in Europe. NODES caters Mitnetz in Germany, NorFlex demonstration in Norway, IntraFlex project in Great Britain, sthlmflex initiative in Sweden, EU funded FLEXGRID and EUniversal[78] and other pilot projects.

NODES positions itself in the middle of the different market actors and acts as an independent market operator between them. Initially, NODES aimed at offering a single interface for flexibility service providers to access DSO flexibility markets, TSO balancing services markets and wholesale markets. However, due to varius complexities, NODES focuses now on providing a route for distributed flexibilities to the DSOs' and TSOs' ancillary service markets, including congestion and capacity management, and balancing of the power system.

Today, NODES offers two types of flexibility markets for the DSOs: ShortFlex and LongFlex.

ShortFlex is a flexibility market with continuous trading in which flexibility procurement takes place close to real-time. The ShortFlex market is an activation price only market. Transacted volumes are considered activated. The NODES platform enables stacking of bids from different flexibility providers that are available in the right location and at the right time in order to fulfil the flexibility need of the DSO at the lowest cost. NODES operates a marketplace where offers placed by DSOs and flexibility service providers are matched.

LongFlex is a market for longer term availability contracts. NODES runs tenders for these contracts and also has the capability of registering contracts on its platform that have been entered into outside of NODES. Long-term contracts are availability contracts that ensure that flexibility is available when the DSO needs it. The long-term contract consists of compensation for both availability and activation. They are activated via the ShortFlex market.

NODES facilitates the right locational identification of the asset through its platform in which the DSO defines congestion areas. The flexibility service providers can register their flexibility resources and the DSO links them to each congestion area.

In short, trading with ShortFlex is conducted as follows:

1. DSOs register congestion areas in NODES platform
2. Flexibility providers register their assets in NODES platform, and the asset is connected to a congestion area by the DSO
3. The DSO and the flex provider place bids/offers where they define volume and price they are willing to buy/sell at. Both the DSO or the FSP can be the first to do so.
4. Bids and orders are matched continuously, in order of price.

77. See NODES (2018): *A fully integrated marketplace for flexibility.* White paper., as well as NODES (2021): European marketplace for decentralised flexibility (web page): https://nodesmarket.com/
78. NODES (n.d.): *Use Cases* (web page): https://nodesmarket.com/case/

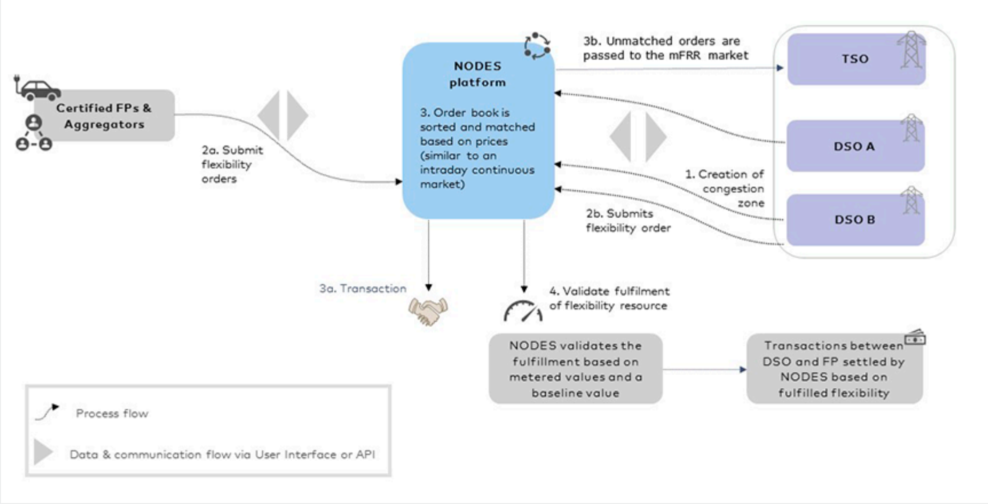

Figure 15. Overview of NODES' Shortflex market. By AFRY, based on text

The LongFlex process differs given that contracts are longer term and consist of an availability payment and an activation payment.

1. DSO defines key information of a tender.
2. DSO can publish the request for LongFlex via NODES platform, including volume sought, for what periods, and maximum activation/availability price it is willing to pay.
3. Flexibility providers respond to these requests
4. The DSO accepts the requests it wishes to accept according to the allocation methodology that the DSO has defined.
5. LongFlex contracts are formed on the platform.

Alternatively the tender can be run outside of the platform – in which case the DSO request is available not only to flexibility service providers that are already active on NODES. As noted, NODES also has the capability of registering contracts entered into outside of NODES on the NODES platform.

In both of these cases, the activation element of the LongFlex contract competes with offers in the ShortFlex market. (This ensures that if there is a lower priced offer available, the DSO can activate that offer rather than the LongFlex contract.) NODES creates automatically ShortFlex bids from the awarded LongFlex at a given price and volume or the flexibility service provider can itself place offers in the ShortFlex market up to the price and for the volume and relevant delivery periods defined in the contract.

NODES also operates a service where it passes unmatched ShortFLex orders to the relevant TSO's mFRR market.

The settlement is similar for ShortFlex and LongFlex, i.e. NODES facilitates cash flows between the contracting parties.

NODES validates the delivery of the flexibility based on metered values and a baseline. Meter values are provided by the flexibility service providers via a metering value hub, with different hubs and formats used across different projects and markets. Typically, NODES will provide a default baseline on the platform calculated using a methodology decided in conjunction with the DSO. The flexibility service provider can choose to override this with a baseline it has calculated on its own, up until trading. NODES considers that there may be value in the collection of metering values by a regulated settlement entity such as a DSO or a TSO, by using a datahub. In NODES's view a centralised, or at least standardised methodology and data format should be used by all DSOs because unaligned processes are a significant barrier to market participation for flexibility service providers.

6.1.2 Piclo

Piclo[79] provides a digital service for DSO flexibility procurement via Piclo Flex which is an independent flexibility marketplace platform, which serves as a single place for DSOs to source flexibility from flexibility providers. Piclo (previously known as Open Utility) was established in 2013 as a peer-to-peer trading platform. Piclo Flex was launched in 2018 within a UK Government-backed innovation project, which was trialled by all six UK DSOs. The results of the first DSO auction were announced in July 2019 and Piclo Flex now operates as the largest independent marketplace for DSO flexibility. Currently, four UK DSOs use Piclo Flex. According to an interview, Piclo is going to expand its geographical presence in near future.

Piclo sees itself as a facilitator for DSOs for ensuring compliance with regulatory requirements, such as the Clean Energy Package, regarding the procurement of flexibility. The DSOs use Piclo to procure flexibility services as part of their grid planning process which requires comparison of flexibility services with traditional network components. The DSOs use the platform to hold auctions for long bilateral agreements with local flexibility providers to defer or replace traditional grid investments well ahead of actual delivery time. In some circumstances, delivery will start after one year, which allows for new flexibility investments.

The procurement process consists of several steps.

1. A DSO publishes a flexibility need for a specified area in the platform. The DSO is free to specify the estimated activation times and characteristics according to its locational and temporal needs. For example, the DSO might need activation during winter mornings for two hours, or according to a more dynamic pattern.
2. Flexibility providers can apply for qualification to become eligible participant in the forthcoming auction.
3. The flexibility provider answers a set of questions to comply as a company, and fills out the characteristics of the asset that would provide the flexibility service.
4. The DSO checks whether the flexibility provider and the asset appear suitable and approves the qualification.
5. The DSO opens bidding for the qualified parties, and the qualified parties can enter their bids.

79. See Piclo (n.d.): *Piclo Flex. The independent marketplace for trading energy flexibility online* (web page): https://picloflex.com/

6. The DSO analyses the bids and makes the procurement decision after the bidding deadline.
7. The winners signs a contract with the DSO.

Currently, the whole auction process may take several months, starting from DSO planning processes to signing of the contracts. The main reason for such long lead-times is that nearly all of the process steps are conducted manually by the DSOs. Piclo is developing solutions to facilitate automation of the procurement, but DSOs need to develop solutions on their side as well. With more automated processes, long-term procurement may evolve to more dynamic flexibility trading facilitated by Piclo. Currently there is no real-time trading on the Piclo platform, but more shorter term trading is being planned.

The British TSO is not purchasing flexibility on the Piclo flex platform, but Piclo will provide a route to TSO markets in the UK by offering a secondary market for long-term reserve capacity contracts. The capacity providers can transfer the availability obligation to another party ahead of delivery if there is mutual benefit. The DSOs are not involved in this process, but according to Piclo, the regulator Ofgem has signposted the need for DSO secondary markets during the next DSO price control.

Piclo is developing Application Programming Interfaces (APIs) to allow easy system integrations to Piclo Flex. This will enable the automation of asset data, bidding and qualification of thousands of flexible assets without much manual work. In addition, Piclo has web-based user interfaces for less-automated processes. For example, Piclo offers a graphic user interface of auction areas and data uploads through excel spreadsheets for the users that are not using APIs.

At least so far there is no coordination with the DSOs and the TSO in the auction phase. According to Piclo, it is establishing services to support better coordination, starting with contracts and procurement visibility between TSOs and DSOs. In Piclo's view, the coordination question does not only consider TSO and DSOs, but there is a need for coordination with other participants such as flexibility providers and Balancing Responsible Parties. Hence, the coordination might as well take place between the DSO and the customer, meaning there may not be a need for a centralised coordination platform, which for example INTERRFACE project is based on (see chapter 6.2.3). Piclo's view is that in practice coordination will start to emerge organically when different parties start sharing relevant information with each other, through for example procurement platforms like Piclo.

Piclo sees that increased market transparency and utilisation of machine learning may be potent tools to fight market manipulation, and these solutions are already used in financial markets. Participants with suspicious behaviour can be suspended from participating in trading.

6.1.3 Enera

The enera project[80] is one of five showcase projects within a funding program called "Smart Energy Showcases – Digital Agenda for the Energy Transition" (SINTEG). SINTEG is a programme in Germany seeking to use digital technology to drive forward the energy transition. The different SINTEG showcases cover different regions in Germany. The enera showcase is set up in the north-west of Lower Saxony.[81]

One of the key pillars for the project is to provide a market-based congestion management service allowing DSOs to procure flexibility. The project for delivering the market place was initiated by the German utility EWE and the Central European power exchange EPEX SPOT in 2017. The platform was initially designed to avoid costly curtailment of renewable energy production in the networks of two German DSOs (Avacon Netz and EWE NETZ) and of one TSO (TenneT).

Early 2019 they launched the market platform pilot, offering trading of flexible assets between Certified Flexibility Providers and System Operators on what EPEX calls the Local Flexibility Market (LFM). First trade was successfully executed 4 February 2019.

The key characteristics are:

- 24/7 Continuous trading
- Pay-as-bid model
- Offer hourly and quarterly products
- Products are listed 15:00 CET the day before delivery and can be traded up to 5 minutes before the delivery time of the product
- Market is split up in more granular market areas than in the wholesale electricity market. Market areas are defined by system operators and correspond to a specific portion of the grid. The definition of market areas over time can change, and new market areas can be added. Each market area has a separate order book. The enera project started with 11 market areas, that were increased to 23 over the project timeline
- For each area, two unique products are created, one renewable and one non-renewable product.
- In the same way as for wholesale electricity markets, a MWh traded means the market participant is committed to produce or consume that MWh in the applicable time period (1 hour or 15 minutes, depending on the product) it was traded. However, the trade is not reported to the TSO. BRP is responsible for balancing the position in its portfolio or in the intraday market.

Example of how it works in practice:

1. System operator forecasts congestion and submits a flexibility buy or sell order to the LFM platform for the applicable delivery hour (or quarter) and location, containing the volume needed to alleviate the congestion and the price they are

80. See:
    - Sinteg (2021): The SINTEG Funding Programme (web page): https://www.sinteg.de/en/programme
    - EPEX SPOT (2019): Local Flexibility Markets: Beyond the Status-quo. GSM Symposium, 7th of July 2019
    - EPEX SPOT (2020): Local flexibility markets: beyond the status quo 20.4.2020
    - EPEX SPOT (2019): Using enera's experience to complement the upcoming redispatch regime with flexibility from load & other non-regulated assets.
81. Sinteg (2021): *enera – Digitalisation of energy supply* (web page): https://www.sinteg.de/en/showcases/enera

willing to pay for it.

2. A Certified Flexibility Provider with a flexible asset that fulfils the DSO's requirements can voluntarily, if the price is right, submit a matching flexibility order in the direction needed (either sell or buy).
3. LFM Order Book (OBK) matching algorithm matches the orders and the transaction is executed
4. The Certified Flexibility Provider is now obliged to deliver the flexibility in accordance with the trade and the pre-specified characteristics of the traded product. Depending on the nature of the flexibility asset, that could mean to consume more or less power or to produce more or less power. In contrast to the wholesale intraday market, this would need to happen in the exact location given in the contract they traded
5. Transaction is settled bilaterally between the flexibility provider and the DSO/TSO

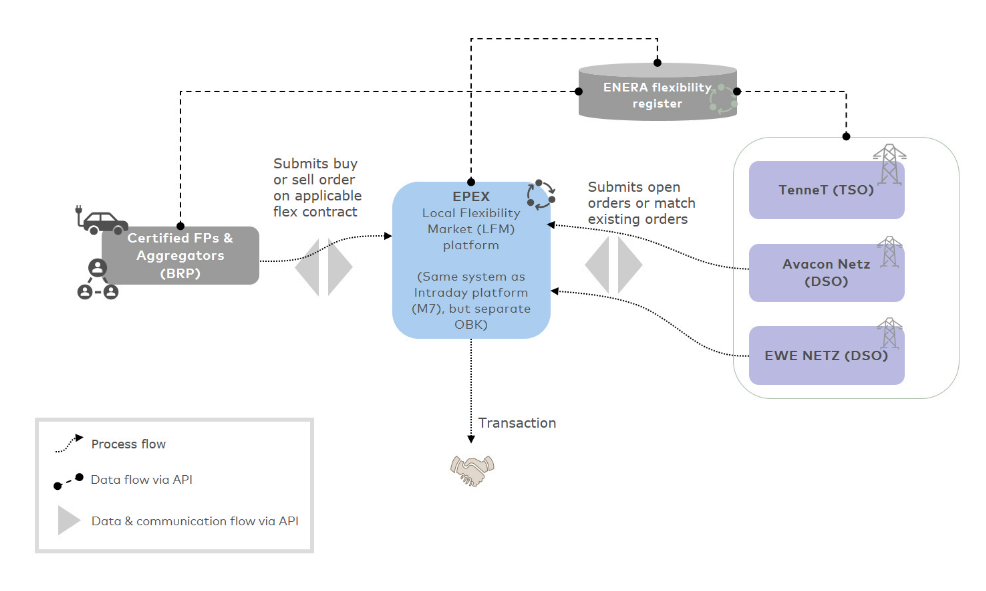

Figure 16. Illustration of ENERA market model. By AFRY, based on text.

The LFM platform is based on the same trading system as EPEX's intraday market, so the same API and user interface can be used. This allows for a single-entry point for participants already active in the wholesale intraday market, thus lowering the barriers of entry and reduces IT integration effort for flexibility providers wanting to participate in both markets.

Flexibility products are also set up in the same way as wholesale intraday products, with only a few exceptions such as product name and minimum price (-50.0 EUR/MWh instead of -9999.9 EUR/MWh), which further harmonises the two markets.[82]

Between early 2019 and mid-2020, enera has succeeded to certify 360MW of flexibility from nine market participants, reaching more than 4000 orders and 130

82. EPEX SPOT (2019): *Local Flexibility Markets: Beyond the Status-quo.* GSM Symposium, 7th of July 2019.

successful transactions.[83] While these numbers are still insignificant compared with the wholesale intraday market, it does demonstrate an integrated market design for trading flexibility that is complementary to the intraday and balancing markets.

The enera showcase is not limited to delivering a trading platform. It also covers a full end-to-end environment for operating a market. That includes a registry for flexibility assets, a verification platform and a TSO-DSO coordination scheme as well as the necessary market procedures and contractual- and governance framework.[84]

6.1.4 GOPACS and ETPA

GOPACS[85] is a joint TSO-DSO coordination platform for congestion management that is owned by the TSO TenneT and four Dutch DSOs. The acronym GOPACS stands for Grid Operators Platform for Congestion Solutions. The decision to develop the concept was taken in 2016, and the first version of the GOPACS platform was launched and in operation in 2019.

The GOPACS platform is connected to the local intraday market ETPA that operates currently only in the Netherlands. ETPA acts as an entry point for market participants, allowing them to trade wholesale electricity between themselves and flexibility with DSOs and TSO on the same platform.[86]

Key characteristics:

- 24/7 Continuous trading within the intraday timeframe
- Pay-as-bid model
- Offer products with hourly and quarterly resolution
- Products correspond to wholesale intraday products but with a locational tag. Market participants in the intraday market can opt whether they insert the locational parameter or not, but the locational parameter is an opportunity for additional revenue.
- The System Operator buys a product called an "Intraday Congestion Spread" (IDCONS) which is a buy and sell combination of orders, and only pays for the spread between these. The purpose is that the flexibility activation has a neutral effect on the system balance. See also Section 5.2.5, which discusses balancing responsibility and counter-trading.
- The coordination platform acts to avoid orders that could cause problems elsewhere in the network.
- In the spring of 2021, GOPACS has also extended their solution with a portal where large consumers can place bids when requested to do so by GOPACS.[87]

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83. EPEX SPOT (2020): *Local flexibility markets: beyond the status quo* 20.4.2020,
84. EPEX SPOT (2019): *Using enera's experience to complement the upcoming redispatch regime with flexibility from load & other non-regulated assets.*
85. See GOPACS (2021): *GOPACS – the platform to solve congestion in the electricity grid* (web page): https://en.gopacs.eu/, GOPACS (2019): *Joint TSO-DSO platform for Market-Based Congestion Management*, CEEM Conference Local Flexibility Platforms, 29.5.2019., and Reunald, A. (2019): *The participation of greenhouses in the redispatch market for congestion management on the electricity grid.* Master Thesis, TU Delft, Netherlands.
86. GOPACS (2019): *Joint TSO-DSO platform for Market-Based Congestion Management.*
87. GOPACS (2021): New GOPACS portal for congestion management (website): https://www.gopacs.eu/nieuw-portaal-gopacs-voor-congestiemanagement/

For market participants trading on ETPA, this is how it works in practice:

1. System operators predict potential congestion in the grid for the next day and within the same day.
2. System operators can publish a request for flexibility from market participants.
3. To alleviate the congestion, they can purchase locational flexibility through the GOPACS platform from ETPA orders.
4. Market participants can make their intraday orders available to the system operators by flagging them as "GOPACS available." It will also include the location of the asset in the form of a unique identification code called EAN.
5. Once an order is submitted on the ETPA market it is available not only to system operators but also to other market participants.
6. When a suitable combination of balanced orders is found, GOPACS sends a request to the intraday market to activate the combination. The combination entails that the effect of orders within the congested area is made neutral by opposite-direction orders outside it.
7. A trade confirmation is sent to all parties.
8. Trade is settled through the market platform.

GOPACS reports having conversations with other market operators to connect to GOPACS.[88] By allowing multiple market operators connecting to the joint TSO/DSO platform, flexibility providers would have more options to choose from.

6.1.5 Summary of the existing flexibility markets in Europe

As seen in the previous chapters, the approaches for flexibility trading differ slightly between the flexibility market operators.

Long-term and short-term markets

NODES offers both a long-term and a short-term market that are linked to one another. This provides DSOs with the benefit of ensuring liquidity in the short-term market, meaning that a flexibility provider that has sold a flexibility "obligation" for a long time period offers this resource in the short-term. For the flexibility providers, a benefit of this concept is that they get paid at least for being available, regardless of the flexibility being activated or not.

Piclo offers a long-term market, but in contrast to NODES, they have no market platform for the short-term activation of the distributed flexibility resource. Instead, the DSO and the flexibility provider enter into a bilateral agreement where DSO can activate the flexibility when needed, in accordance with the bilateral contract.

Enera and GOPACS have been developed with a focus on the short-term trading of flexibility.

Simple access

ETPA and Enera use the same or similar interface (both UI and API) as their intraday

88. GOPACS (2021): *About GOPACS* (web page): https://en.gopacs.eu/about-gopacs

markets, therefore EPEX's and ETPA's existing customers are given an easy entry into the flexibility market. Because they offer API solutions, their market participants who have already automated their solution in the intraday market will be able to utilise their existing solution in the flexibility market as well. In both Germany and the Netherlands, most trading on the intraday market is conducted via an API, meaning it is likely that most of their customers use an API solution today. Utilising existing interfaces (APIs and UIs) do not only reduce the implementation cost but also simplifies the day-to-day operation for market participants.

All the platforms described in this chapter are built on the same idea that a flexibility market design should be customer centric in order to attract liquidity. A complex market design will drive away the willingness to participate in a flexibility market.

TSO/DSO coordination

The GOPACS platform is developed for both DSOs and the TSO, and acts to avoid activations of flexibility that could lead to problems elsewhere in the network.

Piclo acknowledges the need for a coordination between different parties. However, they see that the coordination can take place in many forms, not necessarily being (only) TSO/DSO coordination but perhaps between a DSO and a market participant.

6.2 Overview of Nordic flexibility pilots and initiatives

In the Nordic countries, pilots have emerged in Norway and lately also in Sweden where grid congestions have become more pronounced in large cities. Initiatives from Finland and Denmark also show that challenges may arise in the near future and that DSOs are willing to consider more innovative solutions in delivering distribution services and managing the grid. We have researched these various initiatives through interviews and a literature review. Where information comes from an interview, interview subjects have been able to verify and correct it.

6.2.1 Pilots in Norway

In Norway, there are several pilot projects related to distributed flexibility. For example, in 2019, Enova, an organization for public funding under the Department for Climate and Environment, distributed more than 200 million NOK to eight large scale demonstration projects for the future energy system, all of which concern local flexibility and smart grid solutions.[89] The pilots, which all involve Norwegian DSOs to a larger or lesser extent, might be placed in the following categories:

- **Local demand and supply management:** Six of the pilot project are testing local power management with various degrees of production, battery storage and smart charging solutions. One of the pilots, Elnett 21, is connecting an airport, an industrial area and a port in the Stavanger area. The aim is to reduce the peak power needed to charge airplanes as well as electric vehicles and marine

89. Enova (2019): *210 millioner til framtidens energisystem* (web page): https://presse.enova.no/pressreleases/210-millioner-til-framtidens-energisystem-2829629?_ga=2.2395440.182488962.1614168343-433344679.1605458784

transportation.[90] Other pilots are located in urban areas with small domestic consumers, or in more rural areas with large industrial power demand.

- **Flexible and digital distribution grids:** Under the umbrella of the Norwegian Smartgrid Centre, seven DSOs are developing a "toolbox" for smart grid solutions that can reduce the need for conventional grid investment.[91]
- **Flexibility trading, including TSO/DSO coordination:** NorFlex is a concept development and demonstration project, aiming to demonstrate the benefits of utilizing flexibility, both for three regional DSOs and for the TSO Statnett.[92] The trading is conducted on the NODES platform.[93] The project aims to test how flexibility use can be provided by multiple actors and applied in multiple network areas and on different voltage levels.[94]

In addition to these pilot projects, there are at least three joint TSO/DSO pilots, focusing on issues related to congestion management, operational support and voltage control in the regional distribution grid. The overall objective is to "*demonstrate the need and opportunities for better coordination and information exchange, better planning tools and data exchange between the DSOs and the TSO.*"(p.13)[95] As mentioned earlier, Norwegian DSOs own regional distribution grids, but Statnett handles congestion in the operating hour also at this voltage level.

6.2.2 Pilots in Sweden

We have looked at two flexibility market initiatives for DSOs in Sweden: stlhmflex and CoordiNet. Sthlmflex is a collaboration between the TSO, Svenska Kraftnät, and the two DSOs in the Stockholm area, Vattenfall and Ellevio. The aim is to create a market place for flexibility where DSOs can procure flexibility and resources can participate on voluntary basis, in order to avoid capacity constraints. There are limited possibilities to increase connection to the transmission grid and the regional distribution grid. There is also a need for flexibility when planned and unplanned outages occur. The market place is in a pilot stage and is testing with up regulation, both from demand and supply side, during the winter 2020-21.[96] By having two DSOs participating in the market, there is a possibility to trade capacity between the different grid areas,[97] a feature that is seen as a benefit with stlhlmflex.

CoordiNet is an EU funded research project that aims to develop market places for network ancillary services. In Sweden there are four pilots within the grid areas of Vattenfall and E.ON.[98] The market place in Skåne, operated by E.ON, is called Switch.[99] In Skåne and Uppsala the flexibility needs are coming from requests for more capacity from industries and society, while Gotland and Västernorrland are

90. Elnett21 (n.d.): *About Elnett21* (web page): https://www.elnett21.no/about-elnett21
91. Smartgridsenteret (2019): *Enova gir støtte til fremtidens fleksible og digitale distribusjonsnett* (web page): https://smartgrids.no/smartgridsenteret-vinner-storskala-demo-konkurranse-mottar-25-millioner-kroner/
92. Enova (n.d.)*: NORFLEX* (web page): https://www.enova.no/om-enova/om-organisasjonen/teknologiportefoljen/norflex/
93. NODES (2019): *NORFLEX receives Enova funding - NODES is a proud partner* (web page): https://nodesmarket.com/norflex-receives-enova-funding-nodes-is-a-proud-partner/
94. Enova (n.d.): *NORFLEX* (web page): https://www.enova.no/om-enova/om-organisasjonen/teknologiportefoljen/norflex/
95. Fingrid, Energinet, Statnett, Svenska kraftnät (2020): *Local flexibility projects in the Nordics.*
96. See SvK (2021): *sthlmflx* (web page): https://www.svk.se/sthlmflex
97. Trading capacity means e.g. load shedding in one DSO area to allow for the other to increase outtake from the transmission grid, given that they have the same transmission connection point.
98. CoordiNet (n.d.): *Sweden* (web page): https://coordinet-project.eu/pilots/sweden.
99. E.On (n.d.): *Flexibilitet krävs för smartare elnät.* White Paper / Switch.

experiencing problems with connecting new wind power capacity.[100]

The pilots have been using a limited number of simplified products, all of them traded as capacity. The trading horizon has been both day-ahead and intraday. Also mFFR, as a complement to the TSO product, has been traded at DSO level. Participants have been industrial scale heat pumps and electric boilers, both with significant flexible capacity and required steering mechanisms. In areas where large scale heat pumps are not available, aggregators are expected to play an important role. Sthlmflex is using NODES as a platform.

6.2.3 Pilots in Finland

The Finnish DSO flexibility initiatives are mainly focused on ensuring security of supply as the regulatory limits to maximum outage durations are tight. Improving the security of supply has been mostly pursued by replacing overhead lines by underground cables although other techniques could be utilised as well.

Two large DSOs in Finland, namely Caruna and Elenia, have started piloting of batteries in providing power during network outages caused by storms. The battery will feed a couple of buildings should the electricity supply through the overhead lines disrupt because of a fallen tree, for example. The battery contracts have been negotiated bilaterally with the DSOs and the battery service provider, and no market place has been established. Elenia pays an annual service fee which is comparable to the cost of disruption. If the service fee would be 15 EUR/kWh/a, it would be profitable for Elenia to purchase battery service in 68 locations. If the service fee would be 30 EUR/kWh/a, only four locations would be profitable for the DSO.[101]

Elenia plans to expand the utilisation of batteries in the future, and the aim is to have 20-40 batteries installed during 2022-2024. The batteries will be installed in the medium voltage network. Over the longer term, Elenia believes that flexibility might be needed in the low voltage grid as well because higher penetration of electric vehicles and distributed energy resources may cause local problems. Flexibility markets might be a solution to those problems as well. Elenia has participated in European market design projects to prepare the data exchange models especially towards the TSO. In the near future, more emphasis is put on developing the internal processes, capabilities and preparedness which are required to adopt the new DSO role.

In addition to flexibility service pilots run bilaterally between DSOs and battery owners, there are two flexibility market initiatives in Finland that aim to build a flexibility platform.

The first, INTERRFACE, is an EU funded project which aims to build and demonstrate an interoperable flexibility market framework that links European wholesale and balancing markets, Nordic (Baltic) reserve markets and local congestion management markets together. The framework extends to regulated and competitive domains. The regulated domains are run by the regulated entities such as TSOs and DSOs, or regulated centralised settlement units. The non-regulated domain is free for all service providers to offer and develop services, and

100. CoordiNet (n.d.): *Sweden* (web page): https://coordinet-project.eu/pilots/sweden.
101. Kainulainen, M. (2019): *The utilization potential of rural network supporting battery storage in Elenia's network.* Master Thesis, Tampere University.

they are all equally allowed to connect to the regulated platforms.

In the framework designed in the INTERRFACE project, all qualified competitive flexibility market operators and flexibility providers would send their bids to a joint TSO/DSO platform, which would direct the bids into different ancillary services markets in which the bids could be eligibly used. The TSO/DSO platform would take care of coordination of the needs and constraints of the different networks according to common rules and data provided by the networks. The aim of the open TSO/DSO interface is to ensure impartiality and competition among the flexibility market operators and other non-regulated actors. In Fingrid's view, centralised databases are crucial in order to verify and settle the flexibility trades across all the markets. This was highlighted also by other interviewed parties. INTERRFACE will be continued in another EU funded project, OneNet.[102] Competitive market operators Nord Pool and Piclo will participate in the OneNet project as well.[103]

The other Finnish flexibility market initiative, Flexens, is a start-up operating in Åland island with the aim to establish a local market place for flexibility. The local market would be linked to reserve markets in Finland and Sweden.

6.2.4 Pilots in Denmark

The Danish TSO Energinet and the DSO Cerius have cooperated in a project on the island of Lolland, which often has a surplus of renewable energy.[104] The concept is to use local flexibility from renewable producers for down-regulation in a market-based way, when there is insufficient capacity in the transmission grid. Simply put, the local producers bid into the TSOs reserve market, but with a geographical tag, that enables the activation of resources in the right location. The solution requires coordination between the TSO and the DSO, in order to avoid disturbances in the local network.

Another project by Dansk Energi and Energinet is to enable easier market access for aggregators by testing the possibility of using the existing meters in flexible equipment. This can reduce costs, and allow consumers to sign deals with several different aggregators.[105] Energinet, Dansk Energi and DSOs also have at least two other ongoing projects. The first, which aims at further developing TSO-DSO cooperation, was initiated in 2018, while another specifically deals with a coordinated tariff model between the TSO and the DSOs.[106]

6.2.5 Insights from flexibility pilots in the Nordic countries

The flexibility pilots are varied, but certain traits are recurring. The insights gained so far are also likely to be transferable between countries and somewhat different use cases.

102. OneNet (n.d): *Five things to know about OneNet Project* (web page): https://onenet-project.eu/five-things-to-know-about-onenet-project/
103. European Commission (2021): *One Network for Europe* (web page): https://cordis.europa.eu/project/id/957739
104. Dansk Energi and Energinet (2019): *Handel med lokal fleksibilitet – notat.*
105. Fingrid, Energinet, Statnett, Svenska kraftnät (2020): *Local flexibility projects in the Nordics.*
106. Ibid.

DSO-TSO coordination

Several of the pilots involve the testing of solutions and procedures to allow coordination between DSOs and the TSO. The case from Lolland in Denmark is an example, where the need for flexibility comes from a bottleneck in the transmission grid but the TSO's actions to resolve it could cause trouble with the local DSO's network.[107]

Congestion in the transmission grid, which is generally more common than in low voltage levels, could trigger significant flexibility response from distributed resources. To ensure coordination, DSOs can have an impact on this market even if they are not themselves procuring flexibility, for example if they block mFRR bids from the TSO due to local congestion. In Norway, another issue is that the TSO handles congestion in the regional distribution grid as well as at the transmission level. This suggests a need for coordination, as is tested e.g. in the Norwegian project between Statnett and Mørenett (a DSO), where Mørenett uses mFRR for congestion management.[108] In pilots in Sweden DSOs use flexibility to mitigate transmission-level congestion, but through an adaptation to the system by which DSOs subscribe to a given capacity level per transmission connection point.

Reliability and long-term contracts

The need for reliability is emphasised by several DSOs, if the flexibility solutions are meant to defer or reduce the need for network reinforcements. In agreements with network customers during the connection phase or the long-term procurement phase, this need can also be mutual. According to one provider of battery services, long-term contracts are considered essential both from DSO's and the service provider's point of view: the DSOs need to be sure of the availability, and the service providers need certainty about future revenues in order to make the investment decision. The same actor also highlighted that a secondary market for long-term contracts would be beneficial, so that the obligation to be available could be transferred to another party.

System development and integration

Some of the interviewees commented that market design and development of IT tools must start well before market opening and that standards regarding exchange of information are developed, and that security legislation, GDPR and market regulation must be considered early in design and information sharing processes. It is however also notable that we see some of the already developed solutions being applied in new situations (e.g. NODES). Easy transferability and universality may turn out to be important for local flexibility markets, as the need for local flexibility may be temporary and disappear during the next network capacity upgrade.

107. Dansk Energi and Energinet (2019): *Handel med lokal fleksibilitet* – notat.
108. Fingrid, Energinet, Statnett, Svenska kraftnat (2020): *Local flexibility projects in the Nordics.*

Photo: Unsplash.com

7 Practical implementation: actions and first steps

The report has explored multiple alternatives for market designs, and described the characteristics of several new flexibility markets and initiatives. A natural question is "what next?" What are the next logical steps for regulators, system operators, and other stakeholders?

As of today, creating a detailed, large-scale market design in a top-down fashion might be too early. The Nordic DSOs have just recently started to adopt a more active role, and several questions about what an ideal future system should look like are still unresolved. Learning and innovation is still going on through multiple pilot studies, regulatory sandboxes, and in some cases, functioning markets (although yet with a limited scope). It could be premature to commit strongly to one market design just yet. Electricity market design initiatives tend to take many years to develop, and they typically culminate into a large IT project involving multiple stakeholders. Hence, the costs of going in the wrong direction due to inadequate knowledge and experience could be high.

There are however certain first steps that appear to be low- or no-regret actions. Some of these are potentially large, but mainly, there is a large number of small ones. For this chapter, we group them in a few broad categories:

- Regulatory framework: reviewing regulatory models, analyse the impact of current non-market approaches
- Continued cooperation between DSOs and TSOs to develop methods for information exchange, and clearer allocation of responsibilities where necessary
- Cooperation between DSOs on product development

- Continuing to monitor and learn from existing initiatives
- Nordic cooperation in involvement in the broader European debate

7.1 Regulatory framework

The survey and the interviews carried out in this project suggest that the DSOs may need stronger incentives to procure flexibility. Without sufficient willingness to pay, there is little point in building potentially expensive market platforms. A natural step would therefore be to assess the regulatory models for DSOs in the Nordic countries. The point of this would not be to introduce changes that favour flexibility unfairly over other alternatives, nor to inflate its importance versus other DSO concerns. Rather, an assessment could consist of checking the extent to which the model treats investment and operational costs in a balanced way, and, if sources of bias are found, to consider possible revisions.

Another action could be to assess in more detail the extent to which administrative solutions for flexibility, like interruptible tariffs and conditional connection agreements, may hinder the development of markets for local flexibility. In Norway, it has been argued that interruptible tariffs should not be phased out before a viable alternative (flexibility markets) is in place.[109] If so, and if they do hinder the development of flexibility markets (which is also debated),[110] this may raise the question of whether flexibility markets should be given additional support in an interim period. A debate over conditional connections may also turn into a broader debate about who it is that really should pay for network capacity – or alternatives to it.

Finally, for reasons explained in chapter 3, it seems valuable to continue to develop implicit demand response through price signals from the wholesale markets and from network tariffs.

7.2 DSO-TSO information exchange and defined responsibilities

The new and developing DSO role is meant to become a more active system operator of its own network, in large part due to the growing number of distributed energy and flexibility resources. With or without markets for local flexibility, this suggests a need for closer coordination between system operators (DSOs and TSO). A key part of this approach is to develop systems for improved information exchange about the state of each network, on both the long and the short time scale. While this is not a part of the flexibility market itself, it will make flexibility markets run more efficiently.

109. Energi Norge (2020): *Fleksibel tariff er viktig for elektrifiseringen.*
110. Ibid.

7.3 DSO cooperation on common denominators for flexibility products and parameters

While many flexibility products at the distribution level may have to be customised due to various differing local needs, it seems likely that there are certain product characteristics and processes that are likely to be useful to most or all DSOs. This may include standard product parameters for common use cases, as well as prequalification procedures and ways to express and disseminate geographical information. Cooperation to develop these, or at least typical minimum requirements, is probably more effective than that every DSO develops them from scratch and in parallel. In practice, this may entail sharing of experience especially from DSOs that are or have been involved in pilot projects.

7.4 Continuing to monitor and learn from existing initiatives

The review of existing pilots and new flexibility markets in this report shows clearly that much development is currently going on, with new products, processes being tested and an increasing number of DSOs being exposed to market-based procurement solutions. The pace of development suggests that this process is not over yet, and that there is more to learn. Hence, the development of the initiatives described in this report should be monitored.

7.5 Nordic cooperation in involvement in the broader European debate

The European projects are likely to form the European regulatory framework for DSO flexibility markets through the political process which incorporates industry representatives such as the new DSO entity and ENTSO-E. If the Nordic stakeholders are able to establish a common Nordic view, the Nordics would have a stronger voice in EU. In order to form that common vision and accelerate wide-scale implementation, it is useful to share information among the DSOs and other stakeholders by establishing forums. The Nordic Electricity Market Forum would be a natural forum for aligning the national views and establishing common Nordic principles in the new DSO role and in DSO flexibility procurement.

7.6 Sequence

The order in which these steps are taken also matters. For example, balanced incentives between network investment and operational costs in the regulatory models would be a natural early step, as it would make incentives more aligned with the "true" socio-economic cost of flexibility in comparison with the cost of network reinforcement. A review of interruptible tariffs may also be a part of this process, given DSOs' access to this kind of flexibility today. A more informed view of the actual value of distributed flexibility, along with regulatory incentives that reflect these, should guide the development of new markets. Given that the value of flexibility turns out to be high enough, DSOs will begin to look for flexibility providers and marketplaces that can address their needs.

However, in parallel with this process, it is important to continue the learning and development from pilot- and research projects. This will enable more developed solutions when DSOs are ready to take the leap. The very broad stages of what could be a viable sequence is shown in the figure below:

Figure 17. Development process for flexibility procurement platforms

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