# Distributed Flexibility
## Lessons learned in the Nordics

Nordic Energy Research

# Contents



This publication is also available online in a web-accessible version at https://pub.norden.org/nordicenergyresearch2022-05

# Foreword

Distributed Flexibility is a key tool to integrate growing shares of renewable electricity in the electricity system and a complement to costly investment in distribution grids. Accessing distributed flexibility makes the green transition more efficient. It also makes it more inclusive since it typically includes demand from small, distributed resources such as households and SMEs. While the Nordic TSOs have long experience using flexibility, this is a new development for the distribution system operators.

This report aims to support DSOs and all those who want to explore and use their local flexibility resources. It contains stories from successful pilot projects in the Nordic countries and draws the common lessons from them. The report was written based on the experiences of the stakeholders participating in those projects who came together in the Flexibility Working Group from the Nordic Electricity Market Forum. As such, the report is oriented towards practical advice for others developing flexible assets, but it can also be used to analyze whether relevant regulations need adjustments. The Electricity Markets Group hosts the Nordic Electricity Market Forum and we are glad to be able present this report to a wide readership audience.

**Tatu Pahkala, chair of the EMG**

# The five key recommendations on distributed flexibility

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## Different local problems require different solutions for distributed flexibility

This means, that DSOs who consider buying flexibility first should have a clear picture of grid issues that are to be solved with flexibility. Parameters such as the frequency, size and location of the challenge should be known, then the DSO can choose a suitable tool to address it. Is it for instance a reliability of supply issue in certain weather situations, local congestion in the distribution grid appearing with a certain frequency or something else? While a local flexibility market is well suited to address frequent local congestion, it might not be necessary for smaller and temporary issues that can be solved in other ways.

From a regulatory perspective that means that detailed regulation to determine specific tools should be avoided at this stage. It would limit the options available to system operators and thereby it could prevent innovation and the development of suitable solutions. Regulation should on the contrary encourage testing and piloting of new tools and solutions by building a "Regulatory Sandbox" where DSOs get the possibility to try out new solutions without risking penalties, I.e that operational costs spent on pilot projects do not deteriorate a DSOs rating in the Regulators´ efficiency score.  In addition some regulation at "principle level" could be needed to ensure respect of unbundling provisions and well-functioning flexibility markets. For instance, market monitoring obligations and independent governance requirements on local flex market platforms, similarly to those on NEMOs, could still be needed.

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## Regulation on cost recovery and tariffs impacts a DSOs incentive to purchase flexibility

The tariff structure can incentivise use of flexibility and many distinguish between implicit flexibility, which could be a consumer's adaption to a tariff structure (shifting consumption off-peak) and explicit flexibility which typically is sold and bought in a market. This paper focuses on the latter, but we have examples of tariff structures that incentiviseuse of flexibility markets.  This is the case in Sweden where the TSO charges the DSO peak tariffs if capacity over a certain threshold is used. These tariffs create a risk for the DSO and thereby an incentive to seek other measures, such as flexibility, to avoid those costs.

In the Norway and Finland, the DSOs face penalties in case of a black out. Thus, DSOs have strong incentives to avoid blackouts through measures such as flexibility. DSOs as monopolies have regulated cost. There are examples as in Sweden and Finland, where it is easier to recover the cost of grid investments (CAPEX) via their tariff, than the cost for purchasing flexibility (OPEX), even if both measures solve the same problem. In that case, there is little incentive for a DSO to purchase flexibility, even if it would be more economically efficient than an investment. Regulators should analyse the regulation and work on a system where CAPEX and OPEX are treated in a neutral way. This approach, sometimes called TOTEX (total expenditure).  It can be combined with benchmarking as in Norway and Denmark, to give the DSOs incentives to find the most efficient solution to their respective problems, be it a flexibility market or grid investment. However, benchmarks are not always neutral, as in Denmark where one of the outputs is a proxy for grid size, thus incentivizing grid investment. So even "neutral" approaches need to be carefully calibrated to remain neutral.

From a regulatory perspective the analysis and potentially adjustment of the DSO tariffs should be a priority. This applies both to tariffs incentivising the avoidance of certain events (e.g. power-based tariffs) and to general tariffs on cost recovery.

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## The flexibility provider should be allowed to offer its resources to several bidders

From a flexibility provider perspective this is obvious: being able to offer into several markets, also known as value stacking, creates a better business case for an investment. It should be possible to offer the resource on several markets to several bidders. In the flexibility markets in Norway and Sweden, the providers are also active in the day ahead and intraday markets with their assets. It also makes for a more efficient use of the resources, as for example in the Finnish case, where the battery would be very little used, if it would be just acting as a backup for the DSO. All in all, this approach reduces the cost of distributed flexibility. However, for security of supply reason it is important to clarify and commit in which market the flexibility is used. It should not be possible to receive payment twice for the same flexibility.

Suppose in addition the contrary case: it is impossible to offer the flexibility resource to both the DSO and the TSO for technical and/or regulatory reasons. In that case, it significantly increases the threshold to demonstrate flexibility, as in the case of Åland. The market demand on Åland is low, making a local flexibility market infeasible. In addition, no options exist to export flexibility to neighbouring areas with higher demand, slowing down local development and showcasing the increased need for interconnected flexibility markets.

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## Priority access for the DSO to distributed flexibility connected in the distribution grid as an acceptable compromise to solve the coordination between the DSO and the TSO

Value stacking reduces the cost of flexibility, but it requires coordination and information exchange between the DSOs and the TSOs who might be interested in the same resource in the operational hour.

This problem is currently solved in the Swedish and Norwegian local flexibility market by allowing the DSO the first right to purchase the flexibility resource until 2 hours before the operational hour and opening the market afterwards to the TSO for the reminder of the offers. Moreover, the day-ahead markets for these platforms are either entirely or mostly settled in advanced of the wholesale DA auctions allowing for uncalled flex to also bid into the DA market if it is able and qualified to do so. In the case of NorFlex the NODES platform aggregates uncalled bids and offers them automatically. In addition, both the DSO and the TSO have access to the information on the planned activation of the resources and their location.

In an ideal world, both the DSO and the TSO could be active on the local flexibility market/access the resource at the same time. However, since the grid operators haven't found a solution to make that competition possible yet, they agreed on a priority of needs, with the DSO having a priority access to the small distributed resources to make the market development possible. The Coordinet and SthlFlex pilots will be reviewing this issue and considering the technical possibilities of allowing simultaneous rather than parallel markets. Any such developments will need to have safeguards against market manipulation as both markets will be impact by each other.

Considering regulation existing regulation needs to be assessed whether it requires sufficient information exchange for the coordination between DSOs and TSOs. If markets are developed further and both TSO and DSO trade simultaneously there seems to be a need to develop safeguards against market manipulation, but that could be done at the marketplace(s) using existing regulation such as REMIT. Where there is no local market such as in the battery case in Finland, contractual agreements between the battery provider and the DSO allow the DSO to reserve the battery in certain cases and prevent sale of flexibility to the TSO. In that case no special regulation is needed.

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## Don't compromise on the requirements for data quality and automation especially if local flexibility markets are established

DSOs and TSOs need reliable provision of flexibility services to guarantee their operational security. Good data standards and common definitions are necessary to communicate between all involved parties both on the grid operation side and the flexibility provider side.

If the challenge is of a recurring nature like local congestion or high peak consumption and local flexibility markets are considered as a solution, the Norwegian and Swedish cases indicate that it makes sense for commercial actors to invest in state-of-the-art sensors and two-way communication to ensure high data quality and the possibility for automation. It is not recommended to just use the household meters, even if they are "smart", since they don't measure in seconds, cover the consumption of both flexible and inflexible assets within a household and don't allow control of a specific assets. Besides the DSO-monopolies in the Nordics own the smart meters making the commercial actors access to the meter rather regulatory complicated. Instead  additional sensors per flexible asset (for instance the EV charger) measure per second and can control the specific asset. That set – up guarantees that the DSOs and TSOs get the services they need in the quality they need, and in general, good quality services are more interesting for customers and create demand. Additional advantages of this data driven approach are, that it allows for automation. Sharing the grid and provider/asset data in the cloud also facilitates the establishment of detailed statistics necessary for control, baselines and forecasts and the settlement with the flexibility providers.

This approach means a higher up-front investment for every party involved, but in the Norwegian and the Swedish case it was a fundamental precondition for a establishing a functioning market. Both in Norway and in Sweden, national and European funding for pilot programmes was used to cover part of the higher investment cost. Regulators and national energy agencies should assess their funding for pilot programmes to see how these kinds of projects could be supported.

This approach has an additional advantage for grid operators and flexibility providers – once it is established in one region it can be relatively easily scaled up and used in a neighbouring region, as long as the sensors and the cloud can communicate with each other and use the same protocols. Efforts at standardization should focus on communication protocols and data standards i.e. on the software rather than the hardware. Regulation concerning interoperability standards would also contribute to avoid vendor lock-in and foster competition.

# 1. Introduction

The Nordic Electricity Market Forum decided in its march 2021 session to establish an ad hoc working group to give recommendations to the Nordic NRAs and grid operators on how local flexibility can be accessed in a market based manner.

Most Nordic scenarios agree that the green transition to a carbon neutral society will lead to an increasing share of intermittent renewables and an increased electrification of society. These developments will make network operations more challenging for grid operators in general. We want to underline that flexibility is not a goal but a means, one of several, to enable more active grid management and handle challenges following from the green transition.

The ad hoc working group has worked from Q3 2021 to Q2 2022 and presents with this report it's five recommendations on how to facilitate the use of distributed flexibility.

## The scope

Distribution System Operators (DSOs), specifically, need to evolve in their role and become proactive operators of their own network. Market based flexibility is one of the key tools that allows DSOs to increase both their efficiency and their security of supply. Therefore, we choose to focus this report on how the DSOs can meet their flexibility needs in a market-based manner. This is also in line with the implementation of the Clean Energy Package, more specifically Directive 2019/944 Art 32 that shall incentivise DSOs to use flexibility in their networks.

Of course, also the Transmission System Operators (TSOs) face a more challenging environment. However, TSOs have a long experience in operating their grid and purchasing flexibility in the balancing markets unlike the DSOs.

Regarding the flexibility providers, we are neutral to who is providing the flexibility and we assume that flexibility providers have the right to sell their flexibility to both the DSOs and TSOs. In addition, our recommendations are based on the Nordic context with functioning retail markets and customers receiving price signals. This context makes it less interesting to look at the motivation of the flexibility providers, and more interesting to look at the creation of flexibility demand from the DSOs.  It is also interesting to address the questions concerning the relationship between DSOs and TSOs and between neighbouring DSOs that are competing for the same flexibility resource.

## The methodology

We start with a short overview of the regulatory environment in the respective countries in chapter 2. Then we describe in the following chapters a few successful working pilot projects in the Nordics following a common set of questions to extract the main lessons from them. These lessons were discussed to see how far they are applicable to the other Nordic countries and are forming the recommendations of the Nordic Electricity Markets Forum, that were presented at the start of this report. We added a short chapter on market design questions in the young flexibility markets.

# 2. Regulatory environment in each Nordic country

## Norway

DSOs are regulated to operate efficiently and can use instruments they deem efficient including flexibility as long as this doesn´t compromise the requirement for neutrality. I.e. there is a strict separation between monopoly and competitive functions. The revenue cap regulation gives reasonable return given efficient operations and is calibrated to give strong incentives towards investment in grid reinforcement and new grid. The Norwegian regulation is so-called TOTEX regulation where the total costs of DSOs are measured against output delivered. Many DSOs, however, claim that incentives for using new measures as alternative to investments are less clear than the investment incentives. It seems easier and more profitable for them to increase capital expenditure by choosing investment rather than increasing their operating expenditure to use new tools such as flexibility. Norwegian DSOs are also regulated to have strong incentives to maintain a high operational security, i.e., they are penalised for outages and interruptions ("KILE").

In 2019 the Norwegian regulation opened a "regulatory sandbox" for piloting projects. DSOs can apply for exemption from the current regulation and as such can try out new technology with low risk. DSOs can also recover costs associated with the pilot over the R&D allowance in the income frame. This has enabled DSOs to try out projects for technical feasibility and function on a small scale, and it enables new providers, such as flexibility market providers to test solutions in a real operating environment with low risk. Several flexibility projects have been tested under this scheme, and the learning and experience gained shall be documented and publicly made available to other DSOs.[1]

1. Energi Norge, CINELDI (2021) *Mulighetsstudie for bruk av fleksibilitet i nettselskap* https://www.energinorge.no/contentassets/72d407b08a0045b59de36c5545a58069/bruk-av-fleksibilitet-i-nettselskap-2021.pdf

## Sweden

DSOs are allowed to use flexibility services and receive cost coverage through the revenue cap regulation. The revenue cap regulation is providing a reasonable return on investment and an efficiency requirement is applied to operational expenditures which are specified as controllable. Thus, it is more profitable for DSOs to make grid investments generating capital expenditures, rather than procuring services generating operational expenditures. The revenue cap regulation also provides an incentive scheme for continuity of supply as well as for efficient grid utilization.

In 2020, the Swedish Energy Markets Inspectorate proposed changes to the national legislation aiming to incentivise network companies to work with the efficiency of both capital and operational expenditures by applying an efficiency requirement on total expenditures. This would mean that the network companies are incentivised to optimize between different alternative solutions, and thus will contribute to benefiting new and alternative solutions, such as flexibility services, when these are more cost-efficient than grid investments. Regarding article 32.1 in the Electricity Directive, the Swedish Energy Markets Inspectorate made the assessment that additional regulations could be needed, in addition to already existing legislation, to create stronger incentives to choose flexibility services over grid investments when flexibility services are the most cost-efficient alternative. In the implementation proposal to the Government, the Swedish Energy Markets Inspectorate stated that when the revenue cap is determined, the NRA must be able to consider the extent to which flexibility services are used to improve the efficiency of the network operations and that the NRA must be able to issue more detailed regulations on what this means. Currently, the Swedish Energy Markets Inspectorate is awaiting the ministry's response to the proposals.

## Finland

DSOs can purchase flexibility as a service. However, this type of action is not incentivized, as regulation is providing a reasonable return on investments, and at the same time, efficiency requirement is focusing on the operational expenses. Hence, it is more profitable for a DSO to use capital costs rather than operational costs, and thus, investments are preferred over the purchase of the services. Key driver for use of flexibility is in the use cases for improving the security of supply. Finnish electricity market act is requiring DSOs to develop their network so that weather related issues are not causing interruptions longer than 36 hours for customers in rural area and over 6 hours for customers in urban area. These requirements must be fulfilled by year 2036. In addition to that, DSOs must pay direct compensation for customers for interruptions, which last longer than 12 hours. Furthermore, economic regulation includes quality adjustment, which is providing bonus for improved quality of supply (measured as cost of energy not supplied for customers) and a decrease in allowed return in case of decreased quality.

Based on above presented, regulation is providing very strong incentives for improving the power quality, but due to the different role of operational and capital costs, investments are preferred over the services.

## Åland

The Åland islands are a self-governed part of Finland but are mainly connected to SE3 in Sweden from an electricity market perspective. Kraftnät Åland is the local TSO operating on Åland along with two local DSOs. Therefore, SE3 includes the operation of two TSOs: Svenska kraftnät (SVK) and Kraftnät Åland. This is the only exception in the Nordic power system, where more than one TSO operates in a price area. Consequently, a separate agreement exists between Kraftnät Åland and SVK, which is often not included in public documentation. If Kraftnät Åland is unable to handle an imbalance locally, they have a contract with SVK to supply unidirectional regulatory power for the price of the reserve markets. This means that local flexibility resources on Åland cannot participate in any reserve markets, decreasing the economic incentive to showcase a flexibility resource for additional services like peak shaving or avoiding grid investments. Creating a local flexibility market on Åland is a possibility. Still, it has been deemed infeasible from an economic perspective due to the low volumes of traded electricity and the current demand for local flexibility. However, there is ongoing work to access these markets via improved legislation and innovative demos showcasing a local flexibility market[2] (Lind & Nordlund, 2021).

## Denmark

There are no legal problems as such for procuring flexibility, but in line with the Clean Energy Package, this requires the development of market-based mechanisms that must be approved by the utility regulator. The revenue caps of the DSOs do not incentivize procurement of flexibility solutions and are in itself neutral between operational expenditure (OPEX) and capital expenditure (depreciation and a reasonable return on the regulatory asset base). The regulator however sets annual efficiency requirements to the DSOs, and the benchmarking model used for this purpose, although based on total expenditure, distorts the incentives for the DSOs to procure flexibility, because one of the outputs in the model is increased only if the DSOs invests in the physical grid. The distribution networks are currently providing a high degree of quality of service, and in the short term the networks will as a general rule be able to cope with the new additions to the network (solar cells, land-based windmills, central heating pumps). Therefore, given the regulatory disincentives, the demand for flexibility has been limited, and therefore market-based mechanisms has not been developed yet. Instead, tariff-based incentives to reduce peak usage have already been implemented with time-differentiated tariffs. Furthermore, the first DSOs will introduce effect-based tariffs for industrial-segment customers from 2023. Also, through an acceptance of new users to be disconnected in a fault situation (a reduced connection charge is applied), it is possible to reduce the peak load. However, many of the components are ageing, and a fall in the quality of service is expected in the next 10 years. In addition, the usage of electricity is expected to double in the same period. Currently, a few pilot projects regarding market-based procurement are being performed.

2. Lind, E., & Nordlund, E. (2021). Determining the Technical Potential of Demand Response on the Åland Islands (Dissertation). Retrieved from http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-451184

# 3. Promising pilots: Swedish local flex markets

Due to an increasing share of intermittent energy production, closing of nuclear power plants as well as the emerging of more and new types of power consumers, the distribution system of Sweden needs to be expanded and reinforced. Since the process for grid reinforcement is long, grid congestions have become more frequent in the metropolitan regions, hindering the electrification. Flexibility has therefore been identified as a highly potential option to ease or even solve these challenges which typically occur during winter seasons with high consumption and low generation from local power resources.

The two major flexibility pilot projects in Sweden; CoordiNet and SthlmFlex are both focusing on enabling purchase of marked-based flexibility by large-scale demonstrations in metropolitan areas suffering from congestions mainly in the transmission grid. Each grid area has a subscripted limit to the overlaying grid which can't be exceeded due to technical and/or security reasons. In most cases, there is an economical punishment if these limits are exceeded. But furthermore, the DSOs cannot connect new customers to the grids if these limits don't allow for it. This creates additional incentives for using flexibility apart from avoiding a punishment fee.

## The setup of CoordiNet

CoordiNet is an EU-funded Horizon 2020-project with flexibility demonstrations in Spain, Greece and Sweden. The main partners in the Swedish demonstration are Vattenfall, E.ON and the TSO Svenska Kraftnät. The project started in 2019 and will end in June 2022. During this period, there have been market pilots in Sweden in the grid areas around Uppsala and Skåne each winter. In both areas flexibility have been procured via the platform SWITCH, developed by E.ON as a part of the project.

Minor demonstrations on the island of Gotland as well as in the rural areas of Västernorrland have also been performed within CoordiNet. In these pilots, SWITCH has been used for peer-to-peer trading between producers and consumers in cases of grid maintenance causing limitations and curtailment by renewable power production.

In the area of Uppsala, Vattenfall is the leading the pilot and together with Uppsala Energi and the municipality of Uppsala, they have recruited flexibility service providers (FSPs) which could ease the congestions in the area.

In the area of Skåne, E.ON has collaborated with the local DSOs Öresundskraft, Landskrona Energi, Kraftringen and Ystad Energi to set up local flexibility markets and recruit FSPs with impact on the relevant market areas.

In both Uppsala and Skåne, the FSP resources have consisted of CHP plants, back-up generators, heat pumps, industrial consumers, batteries and aggregators of residential loads.

Different pricing models (pay-as-cleared and pay-as-bid) as well as contract structures have been tested. One tested contract form is called "free bids", meaning that the FSPs don't have any contractual obligations regarding flexibility volumes, availability nor pricing, but is compensated only upon activation. This is the most frequent contract form due to that the concept of flexibility is rather new and that the FSPs don't yet feel secure enough to sign "availability contracts" which is another form tested in CoordiNet. The availability contract is similar to the LongFlex contract described below and implies that the FSP have to have offer certain flexibility volumes to the market. As compensation, the FSPs are renumerated for both being available during the season as well as upon activation.

## Relationship between neighbouring DSOs and TSO

Within CoordiNet, forecasts covering the load in the congested areas for the next few days have been developed. These forecasts, together with threshold values typically representing the subscripted off-take limit from the overlying grid, are visualized in SWITCH and used as decision support for the grid operators for if, when and how to buy flexibility. For each FSP resource, an impact factor based on grid simulations is applied on the flexibility offers. This is to represent the grid topology in an effective way while ensuring that only offers impacting the relevant point of congestion can be activated.

The local flexibility markets within CoordiNet is mainly traded on a day-ahead basis and coordinated in time so that the local DSO have exclusivity on the relevant local FSP resources during a certain time window each morning. After that, the regional DSO has the possibility to purchase flexibility from all FSPs with an impact on the regional grid. The day-ahead flexibility market is cleared and closed at approximately 10:30 a.m. leaving a window for the balance responsible parties to make necessary adjustments prior to the Nordpool Spot market. After the day-ahead market, the DSOs in the same market area have the possibility to purchase flex from a joint intraday market. If the FSP resource is prequalified by the TSO, unused flexibility offers can be forwarded to the national market for mFRR.

## The setup of SthlmFlex

SthlmFlex started in 2020 as a joint project between Svenska Kraftnät and the two regional DSOs operating the Stockholm area, Vattenfall and Ellevio. Within this project, Nodes is used as the market platform as well as the interface for the FSPs, utilizing the same contract structures as described in the chapter below about the Norwegian case. In SthlmFlex, E.ON supplies SWITCH as decision support for the DSOs. E.ON also has the role as a flexibility buyer since they are operating local distribution grids within the area.

In addition to the flexibility services that are traded within CoordiNet, a flexibility product called "subscription swap" have been developed within SwhlmFlex. This product enables neighbouring DSOs to trade grid capacity between grid areas connected under the same transmission point.

## How did the DSO motivate flexibility providers to provide their flexibility?

The monetary benefits from both being available and activated on the local flexibility markets as well as on the national mFRR market have been promoted as additional revenue sources for the FSPs. Also, PR and the possibility to ease the energy transformation and societal growth have been lifted as motivation. For real estate owners, an incentive that has been identified is that certain certification systems promotes and rewards properties selling flexibility services.

# 4. Promising pilot: The Norwegian case

NorFlex is a pilot project established and led by Agder Energi, together with Glitre Energi, Nodes (independent market platform) and Statnett (Norwegian TSO). The project receives 40% financial support from Enova, the Norwegian sustainable energy agency.

Agder Energi is testing the purchase of flexibility at Nodes, an independent local markets platform. This report concentrates on this part of the NorFlex pilot called Demo Agder.

Agder Energi observes increasing hours with peak load of electricity which lead to congestion in their distribution grid. Since the congestion happens in well under 1000 hours it is still not very often seen over the whole year, therefore it is considered to be inefficient and too costly to invest in new grid, which would be fully used in under a 1000 hours. Instead Agder Energi's project aims to reduce the consumption peaks to manage the congestion in the distribution grid, thereby reducing the need for grid re-investment in the long run.

The project is currently running in the distribution grid owned by Agder Energi Nett, part of Agder Energi, in the area around Arendal, Grimstad, Lillesand and Kristiansand in Southern Norway. The problem the project solves is limited to this area, but other Norwegian DSOs have similar problems in their grid.

## How was the project set up

The project started in 2019 with Agder Energi looking for aggregators that could offer local flexibility in the project area, contracts were signed with 8 aggregators. The rest of 2019 and 2020 was used to prove that the concept worked (first half of 2020, only 7 aggregators managed), to prove that the marked could work (second half of 2020) and to establish a flexibility register. Commercial trading of flexibility started in January 2021 successfully. The flexibility assets consist currently of batteries (1MW), electric boilers, ventilations systems, greenhouses, EV chargers (400 private AC and one public DC), other household devices and since October 2021 one large industrial load.

In the proof of concept and proof of marked phase in 2019/2020 all parties needed to demonstrate that they had sufficient good quality data on their assets (both the flexibility assets and the grid) i.e. data measured every single minute for every single asset, that this data could be communicated and understood by the others project partners in real time through a common cloud, that the grid automatically could issue warnings on upcoming local peaks and that automatic activation i.e. downregulation of the flexibility assets worked. IT tools to automatise the treatment of both the flexibility data and grid data were developed to this end. A common flexibility register called "AssetHub" was established, where all the data for the grid and every asset, i.e. every single charger and household device, is quality checked and then available in a standardized form that works for all involved partners. It was underlined that the data was connected to every single asset, since the activation needed to happen asset based, and that data from household meters collected on the "Elhub" could not be used since it had not the necessary granularity both in time and asset specificity. A common API was developed by the project since there is no common standard. Questions were raised on how this flexibility register should be regulated to meet GDPR, data security and interoperability/standardization challenges. Developments are ongoing to establish CIM as the common standard.

## How does NODES deliver flexibility?

January 2021 the commercial trading of the reduction of load between Agder Energi Nett (the DSO) and the aggregators started on Nodes. Two contracts are on offer: LongFlex and Short Flex. LongFlex is a long-term availability agreement, where the DSO pays the flexibility provider a fixed sum to guarantee that the flexibility asset is available for automatic downregulation at a certain pre-agreed activation price, which is paid in addition if the bid is activated. ShortFlex is a contract for physcial reduction of load a few days or hours before the operational hour – there is no payment for availability of the asset, which is therefore not guaranteed, but if the asset is activated an activation price is paid. ShortFlex prices for activation tend to be higher since the situation was unforeseen but are of increasing importance for the DSO. Both contracts are interesting for flex providers – LongFlex gives a guaranteed income and short flex allows flexibility service providers to sell their services when there is a demand from the DSO's side without committing their assets far in advance. At Nodes effect is traded as pay-as-bid, since the marginal cost for the assets/resources varies very much. Summer seems to be more challenging to see a price cross appear, since heating resources are not in operation. After the reduction of load the payment goes from the DSO via NODES to the aggregator and end-consumers.

During the trading it was discovered that they needed to introduce rules for how assets that have been taken out could come back on to avoid rebound effects that would destabilise the grid. They ended up with a three-step rule to avoid a rebound.

They discovered as well, that it was the easiest to use the available good quality data on the flexibility hub, called"AssetHub", to create the baselines i.e. consumption forecasts for each asset, based  on the actual consumption statistics.

## Relationship between the DSO and the TSO

Agder Energi Nett and Statnett discovered that there is a need to inform Statnett if higher amounts were downregulated, to avoid automatic rebalancing actions from Statnett. To this end new communication channels had to be established between the local grid management and the national grid management.

In addition, there is the assumption that flexibility providers should be able to offer their resources to both the DSO and the TSO, which also requires communication.

Currently in the pilot phase, the DSO is trading on Nodes until two hours before the operational hour, then Nodes can sell the remaining non-activated resources on the mFRR market to the TSO, that can trade on the remaining two hours and buy the remainder of the resources. One big industrial consumer has the option to offer its services at the same time to both the DSO and the TSO in this test phase.

The DSO just buys congestion management on Nodes, but NODES sells both balancing power (mFRR) and congestion management services to the TSO, since economically and physically speaking they are the same product (downregulation i.e. reduction of consumption or decoupling).

Regulatory speaking this is however raising a few questions, since the cost of balancing is passed on to those market actors causing the imbalance, whereas the cost of congestion management is paid by the DSO.

In the long term, there is the ambition to develop a solution where both DSO and TSO can trade at the same time by using the flexibility register to manage the competition.

## Relationship neighbouring DSOs

This is theoretically simple, if the DSOs are also set up to use Nodes: Nodes has detailed locational details in all bids, which would avoid the bids in the wrong location are activated. It requires however use of the same API and would be facilitated if there would be a common standard.

The motivation of flexibility providers is different on which sectors are considered. Household customers tend to sell their flexibility to an aggregator for a rebate in their electricity bill, the aggregator gains from offering their flexibility portfolio to the markets. With larger commercial customers, who require bigger investments, it depends on who pays for the original investment in the sensors and controls. Those paying receive the benefits until the investment is paid down, then the customer and the aggregator tend to share fifty/fifty. NorFlex expects economies of scale and a significant reduction of cost once there is a standardization of IT protocols and cloud to cloud solutions have been established.

# 5. Promising pilots: Finnish cases

## Battery energy storage system as a service for a DSO

Present challenge among the Finnish DSOs is to improve the security of supply, as illustrated above. Although more traditional approaches, such as replacing the overhead lines with underground cables, are typical, there is also an interest to implement some new solutions, which may turn out to be more cost-efficient than conventional ones. Here, one option is to have an islanding capability, provided by battery energy storage system (BESS), for a part of the distribution grid, to ensure the continuation of the supply also during the fault in the feeding network. The economic feasibility can be promoted by value stacking, so that during the normal operation conditions, the very same BESS is operating in frequency containment reserve market (FCR) to provide additional incomes for BESS operator[3]. Furthermore, battery supply time can be improved by the demand response of the end users during the network outage[4].

European regulation is not allowing DSOs to own and operate batteries, except with a special justification under specific rules. Hence, the business model here is that a third-party company (here Fortum) owns the battery, sells system level flexibility (FCR) for a TSO (here Fingrid) in reserve markets, and local level flexibility for a DSO (here Elenia) by the service-level agreement (SLA). Economical feasibility is based on the incomes from FCR markets and savings in regulatory outage costs by DSO.

The first pilot case of such battery service for a DSO was installed in the medium voltage feeder of Elenia (a Finnish DSO). Network area covered by the battery system contains more than 100 customers and the average power of the area is 71 kW. In this pilot, Fortum made investments to the battery system related components, while the grid components and power conversion was invested by Elenia. During the normal operation, battery system is providing its capacity for FCR market, and in case of the sudden grid outage, it will provide energy for islanded part of the distribution network. If weather conditions are such that network outages are likely (high winds or heavy snow), Elenia can reserve battery solely for grid support, and during such situation, SoC (State of Charge) of the battery will be full, in order to provide maximum supply time.

As the needs of the DSO for a battery are only occasional, direct investment for a battery might not be economically justified, even if it was allowed by regulation. However, more value can be generated for battery investment by stacking the value of different use cases of the same battery. Hence, socio-economic costs of the

3. Alaperä, I. et al. (2019). *Battery system as a service for a distribution system operator*. Proceedings of 25th International Conference on Electricity Distribution CIRED 2019. https://www.cired-repository.org/handle/20.500.12455/91
4. Manner, P. et al. (2021). *Extending grid battery supply time by controlling residential heating loads*. Proceedings of International Conference & Exhibition on Electricity Distribution CIRED 2021. https://doi.org/10.1049/icp.2021.1708

battery investment can be decreased, if it is used for multiple services, such as for both TSO and DSO flexibility.

Although regulation is prohibiting DSOs to own and operate battery energy storages, they can buy this as a service. However, as discussed above, present regulation model applied in Finland is incentivizing capital expenses over the operational costs. Hence, it is more profitable for a DSO to improve the quality of supply by network investments than by services. In this case, a part of the costs of the system (grid connection and converters) are actually DSO investments, which make it more profitable for a DSO.

There is lots of research and development, as well as ongoing discussions, about the local flexibility markets. However, solution illustrated here is more B2B type of contract than an open market. Nevertheless, this will not diminish the need for local flexibility market.

# 6. Promising pilots: Danish cases

## EcoGrid 2.0

EcoGrid 2.0 is a project that demonstrates how flexibility can be utilized to offer power system services to both the TSO and DSOs. It is the continuation of the EcoGrid EU project, where the use of real-time minute price signals to shift consumption, and thus balance the power system, was studied[5].

Over three heating seasons, the market has been tested live on Bornholm and in Horsens. 800 consumers on Bornholm have made their heat pumps and electric heating panels available to the project. The municipality of Horsens has allowed the project to manage the consumption in selected municipal buildings (schools, kindergartens and nursing homes). The flexible units are controlled by three aggregators that have managed the electrical heating systems and have competed on the market to provide flexibility services.

The market design is based on the Danish "Supplier-centric Model" (Engrosmodellen) and designed in a way so that integration with the existing markets.

A goal in EcoGrid 2.0 was to test whether existing smart meters could be used as the only data source to monitor and manage flexibility in private households. The existing measurements also need to be accurate enough to validate delivery of services in the market, because the cost of sub-metering would be prohibitive for small consumers.

EcoGrid 2.0 assumes that flexibility products for the DSO are traded 1-12 months in advance. Long lead times enable DSOs to consider flexibility as an option during their network planning procedures. As it is not possible to forecast during which specific day flexibility services will be necessary, provision time is expected to be in the order of weeks to months.

Two types of DSO services are introduced: scheduled services or conditional services. A scheduled service is activated regularly at a specified time period, whereas a conditional service may be activated by the DSO during that time period, if deemed necessary. Payments for conditional services are split into a reserve part and an activation part. If a conditional service is not activated, the DSO only pays the reserve price. However, there were no payment in the project.

The DSO successfully requested and acquired conditional baseline flexibility services 63 times; 36 of those were activated and delivered. Services were not requested with a lead time in the order of months, because of the time constraints imposed by the duration of a heating season (roughly six months).

An objective of the EcoGrid 2.0 project was to investigate the impact of different smart meter temporal resolutions (5-minute, 15-minute or hourly). The conclusion

5. Dansk Energi (2019). EcoGrid 2.0 - Main Results and Findings (2019). http://www.ecogrid.dk/src/EcoGrid%202.0%20Main%20Results%20and%20Findings.pdf?dl=0

was that the complexity of the aggregator's job is simplified when moving to 15-minute and hourly resolutions. Lower metering resolution, however, hides large peaks and dips in consumption and production, but 15-minute metering is considered acceptable for the DSO.

To verify if a flexible service has been delivered, baselines to predict consumption if flexibility is not activated was developed. The baselines are based upon historical data from the meters and external variables that influence electricity consumption. Machine learning techniques were used to generate high quality forecasts for baselines, with average prediction errors of roughly 5 % for the high and medium voltage grid.

## Project in Lolland

The Danish TSO Energinet, the DSO Cerius, Dansk Energi and the balancing responsible parties, have cooperated in a pilot project on the island of Lolland, which often has a surplus of renewable energy and where bottle neck problems arises in the transmission network in windy and sunny hours. 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.

The pilot project took place in Q3-Q4 2020. The conclusion was that the DSO (Cerius) should be warned by the TSO (Energinet) at least two hours before the activation. The DSO believes that it is necessary to require a ramp of between 5 to 15 minutes. In extreme case or in case of faults in the distribution network, the DSO have the possibility to stop the activation, in which case the DSO will have to follow the emergency procedure, where local consumption is reduced.

## Flexibility from EVs via an aggregator (True Energy) – Local Battery

This project called "local battery" was carried out by Radius the largest DSO in Denmark focused on testing and demonstrating flexibility from EVs via an aggregator, True Energy. True Energy is a new company that helps customers use electricity when it is climate-friendly and cheap automatically and regardless of the customers supplier.

The project aimed to test how flexibility needs can be specified by a DSO and provided by an aggregator. The purpose was to gain knowledge about whether flexibility from EVs via an aggregator is predictable, accessible, and reliable which is three key properties to enable value creation for the DSO from flexibility.

A simple and operational dashboard was established by True Energy that made it possible to easily communicate and exchange data. The experiment succeeded in demonstrating how flexibility needs for the electricity grid can be specified and utilized, and it was demonstrated how a service provider such as True Energy can provide the flexibility. It was proved that a service provider can react to a signal from the DSO (Radius) when asked to down-regulate power.

Thus, flexibility was available from electric vehicles. On the other hand, the project also revealed that there is uncertainty about the predictability and reliability of the flexibility. This is partly because it is difficult to validate what is provided by the service provider. This is because there is no reference for consumption in the scenario with no activation which makes it difficult to estimate what has actually been delivered. This is the baseline problem – a well-known challenge when trading flexibility from small units where no precise plan for consumption has been reported to the market.

Although the project did not provide a full solution to the baseline problem, the experiment showed that there are ways that can resolve the baseline problem. However, the solutions may come with considerable uncertainty which can make it harder to contract flexibility that can unlock value from postponing grid reinforcement investments. The question of whether flexibility can create value thus also remains unresolved with this project. The customers willingness to pay or to accept for providing flexibility is not known and thus it is uncertain whether it can compete with the costs of the traditional solution of net reinforcement.

# 7. Lessons learned and open questions on the flexibility market design

## A combination of “availability” and “effect” products seems to work

The availability product (in Norway “long flex” or in Sweden “availability contracts”) gives the DSO the safety needed to rely on the market to solve its operational problems. There is always a minimum amount of flexibility available. For the provider it gives a steady income. The “effect” product (in Norway "short flex" and in Sweden “free-bids”) allows flexibility providers to bid in spontaneously available resources without having to commit themselves. This allows for example heating to come in spontaneously in summer, when permanent availability is not guaranteed. For the DSO more available flexibility means an option to reduce its activation costs.

## Expect difficulties with flexibility pricing in the start phase

Flexibility markets are very young – neither the DSOs nor the flexibility providers have an experience on how products should be priced, so in the beginning it might be difficult to find a price cross. Further there are big differences in activation cost due to the widely different nature of the flexibility providers. So “pay as bid” is being used at the moment.

## Consider simplifying your flexibly market – allow flexibility in one direction i.e. just the reduction of load (or an increase of production) not an increase in load/a decrease of production

Depending on the DSOs challenge that needs to be solved and depending on the nature of the flexibility providers, it might make sense to open a flexibility market only in one direction (reduction of load) as opposed to two directions (reduction of load and increase of load). This makes the process easier. The increase of load following a planned reduction, i.e. the rebound effect, can be addressed separately in the product definitions as is the case in NorFlex in Norway.

## Avoid splitting markets along different products if the same distributed asset is used

When the same asset can be purchased and activated for both local countertrading/peak reduction by the DSO and for countertrading/balancing purposes by the TSO and the product (reduction of a specific load for a predetermined period) is similar, then try to use the same market. The volumes are comparatively small, splitting the market will reduce them further. In addition, the flex providers are comparatively small and this might be their first experience on a market, they might not be able to offer their resource on two different markets but the income from both markets makes a difference in their business case.

DSOs and TSOs should try to solve eventual issues on pricing (marginal pricing for balancing versus pay as bid for instance) and cost (who pays in the end – is it a market party who is in imbalance or the grid operator) through for example a priority clearing for one product (first trade the DSOs countertrading needs, then the TSOs needs), tagging the purchase per reason of activation and buyer and by adapting algorithms determining the prices and the settlement.

# 8. Acknowledgements

Distributed Flexibility is the final report resulting from the discussions at the ad hoc Working Flexibility under the Nordic Electricity Markets Forum.

The Nordic Electricity Markets Forum decided in its online session 2021, that there was enough common ground to produce more detailed recommendations of how local flexibility can be accessed. To this end key stakeholders nominated experts to participate in the Working Group to contribute with their knowledge.

Andrea Stengel at Nordic Energy Research was the coordinator of the project and the convener of the group.

**The following experts participated:**

- Alexander Kellerer, RME (Norwegian NRA)
- Conny Johansson, Stora Enso
- David Freed, Energimarknadsinspeksjonen (replaced by Jennie Nyberg)
- Edvard Nordlund, Flexens
- Filip Marott Sundram, Dansk Energi (replacing Michael Arentsen)
- Jeannette Møller Jørgensen, Energinet
- Jonathan Hallinder, E.On Sweden
- Line P. Schmidt, Dansk Fjernvarme (replacing Nina Detlefsen)
- Samuli Honkapuro, Lappeenranta University
- Vivi Mathiesen, Energi Norge (now Heimdall Power)

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# About this publication

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*Nordic Energy Markets Forum, ad hoc Working Group Flexibility*
*(convener Michael Arentsen and Andrea Stengel)*


http://doi.org/10.6027/NER2022-05

Photos: iStock
Layout: Mette Agger Tang

Published: June 2022

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