Use Case 7—Integrated markets for energy and flexibility
Digital workshop 1—February 17th, 2022

Workshop summary

Knowledge gaps for successful integrated markets for energy and flexibility

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Workshop goal

Identify the most important knowledge gaps
within integrated markets for energy and flexibility.

Topics

- What is the status on understanding the flexibility needs, the flexibility resource potentials, and how to best organize flexibility trading in the coming years?
- What do we need to know more about to support the energy transition with integrated markets for energy and flexibility?

Session 1

We presented and discussed state-of-the-art practices regarding integrated markets for energy and flexibility.

The need for flexibility
Asgeir Tomasgard, NTNU

Flexibility resources across the sectors
Hanne Sæle, SINTEF

Organizing flexibility trading
Endre Bjørndal, NHH

Session 2

We organized a panel discussion and group work to discuss where more research is needed.

Panel discussion
Hallstein Hagen, NODES
Jan Bråten, Statnett
Håkon Egeland, Statkraft
Marius Kolby, Statsbygg

Breakout rooms, followed by a wrap-up

Workshop Summary

This workshop is an opening event for the NTRANS Use Case 7, exploring integrated markets for energy and flexibility. The explicit goal of the workshop was to provide research guidelines, in the form of literature gaps, to be further explored in subsequent work. This event is intended as a collective work of synthesis, with participation from different sectors of the power market providing first-hand accounts of the challenges related to flexibility in the current power system.

The program of the workshop consisted of presentations targeting an academic overview of the status quo, industry experiences across sectors, panel discussions, and direct conversation uniting different views into a common direction. Topics of discussion ranged from the European power market design to future technologies that might affect it. This workshop served to gather practical information and direct experiences from market participants in the supply, demand, grid management and market sides. The workshop format facilitated the collection of relevant information through collaborative work, and the identified knowledge gaps are listed in Table 1 below. Some of the relevant research gaps will be summarized in the following paragraphs.

On the demand side of the power market, the increased participation of distributed and renewable energy sources increased the complexity of forecasting the cost of flexibility, as well as its availability. Improved methods for forecast was identified as a research need and might incentivise the development of in-house demand response solutions, e.g., battery or thermal storage. Those assets might allow for a more inexpensive direct participation, especially due to the emergence of new technologies, yet it remains to be defined to what extent the consumers can be directly involved.

The participation of active consumers ties directly with the supply side of the market, for which the forecast of flexibility pricing is also relevant. Large and established players want to make investment decisions on flexibility assets, while small participants are more concerned with how, due to low expected profit margins, the distributed flexibility resources will be integrated into the market, and if they might have to be coordinated by aggregators.

Distributed flexibility resources can be valuable for grid management and the coordination of power flows at different levels. A related research question is defining the role of the electricity grid as a flexible resource and how to best integrate it with other networks, due to potential substitution and complementary aspects between flexibility products and grid investments.

A common thread uniting all sectors is the power market design. Local energy markets can offer incentives to relieve congestion and postpone investment, yet how to organize those markets remains to be researched.

Flexibility is a term with a broad meaning, and the definition of it varies across different sources in academic literature, even within the partner research centres. Different angles of flexibility are more relevant for each participant in the power market, and this suggests that further exploration should be done with a specific focus on each sector. However, there are aspects of flexibility that affects the power market as a whole, as the sectors are tightly interconnected.

Research on flexibility should, therefore, be organized around particular aspects that are relevant for specific sectors, and at the same time in a manner that all participants will be invited to contribute, because of the interconnected nature of flexibility. Future workshops will be organized by sector but without losing sight of the complete picture.

Knowledge gaps

Table 1 summarizes the identified knowledge gaps from the workshop. Future workshops will address these topics. The knowledge gaps span across different sectors, and we intend to focus on further exploring cross-sectoral knowledge gaps in the continuation of Use Case 7. We will prioritize a wide sectoral scope to facilitate the exchange of ideas "across the silos" and accelerate sector coupling.

Table 1 Overview of identified knowledge gaps during the workshop.

Knowledge gap	Description	Relevance
Organization of new flexibility stakeholders, demand response, and aggregators	It is unclear how stakeholders with flexibility potentials (e.g., households) can successfully provide their flexibility services where and when it is needed. It is still unclear how to best organize demand response from smaller stakeholders, and how end-users should interact with an aggregator.	Demand side, market solution
Prognoses of balancing/flexibility needs	We need to understand flexibility needs along different dimensions. Tools and methods to forecast balancing needs at different levels are needed, both short-term and long-term.	Grid, supply, and demand sides
A comparison of flexibility resource potential and costs across sectors (from a market perspective)	We need to consolidate and compare the different flexibility resources and what they cost—not just resource-by-resource and sector-by-sector. This includes flexible resources related to supply, demand, and the grid.	Supply and demand sides
The interaction between different flexibility stakeholders and their resources	We need to better understand how the use of flexible resources interacts across the market, especially across different sectors. For example, it is unclear how emerging demand response affects strategies and operations for large-scale supply response and vice versa.	Supply, demand side, grid, and market solution
Social justice and end-user involvement when flexibility becomes priced in the market	There seems to be a lack of information to the end-user on the value of flexibility, e.g., revision of grid tariffs meets opposition. We need to understand how different end-users react to these developments and how to best inform end-users about opportunities for flexibility trading.	Demand side and market solution
New designs for flexibility trading in local flexibility markets	We need to understand how to ensure efficiency, liquidity, and the best integration of flexibility trading with current and future markets. We should not only think about short-term allocation, but also market designs that incentivize long-term investments.	Market solution
The value of market coupling and alternative energy carriers for fuel switching	There is a growing need for *energy* system flexibility as an extension of power system flexibility. We need to understand how to avoid lock-in of inflexibility, and how long-term flexibility are incentivised in the market, e.g., long-term seasonal thermal energy storage and hydrogen.	Supply and demand sides
Substitution effects between grid development and flexibility resources	There is a potential substitution between local energy supply, flexibility resources, and grid infrastructure. We need more understanding of the reliability of distributed flexibility resources in local energy systems compared to traditional grid infrastructure. We also need to understand how grid operators can best utilise external flexibility.	Grid, supply, and demand sides

Workshop overview

Organized by:	FME NTRANS + PowerDig
Number of participants:	74

Participants included researchers and partners of FME NTRANS and PowerDig. Researchers and partners from related research centres were also invited, including FME CINELDI, FME HydroCen, and FME ZEN.

The workshop was structured according to three pillars (sub-topics) related to "Integrated markets for energy and flexibility":

The need for flexibility

Organizing flexibility trading

Flexibility resources across the sectors

In Session 1, three presentations were given to introduce the three pillars and briefly elaborate on the status of recent and ongoing research.

In Session 2, panellists from different sectors presented shortly their most relevant observations on the relevance of flexibility markets and the most important knowledge gaps from their perspective. The participants were invited to join three different breakout rooms, organised according to the three pillars. The discussion was facilitated in each breakout room by the speakers from Session 1. Finally, the relevant topics were summarized in the wrap-up

The discussions and input during the workshop are presented in this white paper, and it will be used to identify topics for future workshops within Use Case 7 throughout 2022.

Session 1A

The need for flexibility

Prof. Asgeir Tomasgard, NTNU/FME NTRANS

Key takeaway—
The need for flexibility
There is a growing need for different types of flexibility, and these flexibility needs must be characterized and linked to their potential flexibility resources. Many questions remain regarding how to properly match the need for flexibility with different resources, and if new agents such as aggregators will be needed.

The need for flexibility in the coming decades is growing, driven by decarbonisation and the substitution of fossil-fuel to renewables. The need for power system flexibility grows because of: (1) disappearing dispatchable power plants, (2) increasing penetration of variable renewables, and (3) increasing electricity loads due to electrification.

Norwegian hydropower remains an important flexibility provider to balance growing wind variability towards 2050 in northwest Europe through international power exports[1]. Model results also indicate a massive increase in cross-border transmission capacity between European countries, and there is a need for more flexibility resources with less cross-border transmission. Demand response flexibility[2] has a large potential, and it could be an explicit product traded via an aggregator[3] or an implicit market response by individual units. Large-scale explicit demand response will require changes in the electricity market, including new contract types, business models, market participants, and rules.

Flexibility needs can be characterised[4] along four dimensions: spatiality, time, resource, and risk profile. Spatiality defines the geographic scope, ranging from the individual consumer/prosumer to the neighbourhood, city, national, and international levels. Time of activation ranges from long-term (years, months) to short-term (hour, milliseconds), and it is related to different markets. Resources can be linked to demand, supply, storage, or the grid. Risk related to developing and providing flexibility for the future is often neglected in existing literature, and it needs to be better understood.

How is the need for flexibility in power systems changing compared to historic flexibility needs?
Research results indicate more need for flexibility response on an hourly to weekly basis compared to historic needs. New flexibility needs also do not come at the same time everywhere, which could require more localized organization of flexibility trading.

How can large-scale flexibility needs be covered by small-scale flexibility resources?
There is an increased relevance of end-user participation, and it is yet unclear how to involve all participants, what it will cost, and how it may benefit the participants.

How can the need for flexibility be impacted by politicians reacting to the present price crisis, and what would you advise them to avoid?
We should avoid destroying the wholesale power market, e.g., by introducing price caps. They should rather focus on ensuring optimal resource allocation in the short-run and the long-run. On the other hand, there is a need to re-distribute record revenues to publicly owned power plants, and such welfare distribution can be solved with other policy instruments than tampering with the market.

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[1] Skar, C., Jaehnert, S., Tomasgard, A., Midthun, K., & Fodstad, M. (2018). Norway's role as a flexibility provider in a renewable Europe. *Center for Sustainable Energy Studies*, *62*.
[2] Marañón-Ledesma, H., & Tomasgard, A. (2019). Analyzing demand response in a dynamic capacity expansion model for the European power market. *Energies*, *12*(15), 2976.
[3] Ottesen, S. Ø., Tomasgard, A., & Fleten, S. E. (2018). Multi market bidding strategies for demand side flexibility aggregators in electricity markets. *Energy*, *149*, 120-134.
[4] Kara, G., Tomasgard, A., & Farahmand, H. (2022). Characterizing flexibility in power markets and systems. *Utilities Policy*, *75*, 101349.

Session 1B

Flexibility resources across the sectors

Hanne Sæle, SINTEF/FME CINELDI

Key takeaway—
Flexibility resources across the sectors
There is growing literature on the classification of flexibility resources from different sectors by their technical aspects. More research is still needed on how to organize and utilize flexibility resources spread across the different sectors, and it is unclear how the use of one flexibility resource impacts other flexibility resources.

In the future power system, we will get fewer situations where generation follows consumption and more situations where consumption follows generation. Flexibility can be defined as:

"*The capability and willingness to modify production and/or consumption pattern, on an individual or aggregated level, often as a response to an external signal, to offer a service to the power system or contribute to stable grid operation*"[5].

Technical aspects of flexibility in the electricity markets can be classified according to the power capacity, the ramping and service durations, the direction of electricity flow, and the rebound effect shown by loads that must compensate for being deactivated[6].

Types of flexibility activation include peak clipping (load reduction), load shifting, valley filling (load increase), or energy conservation. Flexibility can be obtained from different assets owned by different stakeholders, each flexibility provision ideally handled by a specific load management technique. An important consideration is that different flexibility services come at different costs. Some flexibility can be activated with zero activation cost (e.g., unnoticed load shifting of water heaters), while other flexibility services have medium activation cost (e.g., noticeable load reduction related to heating/ventilation) or high activation costs (e.g., load reduction of non-flexible appliances and lighting). Flexibility solutions can also be classified by the resource itself and by how the resource can be enabled.

How can markets and regulations facilitate flexibility services from different sectors?
There are several ways for a DSO to procure flexibility on a local level[7]. Some examples are trading in a flexibility market, price signals through grid tariffs, and conditional terms when connecting new loads. Different aspects could be framed depending on the perspective and flexible resources can be organized accordingly, both for market and regulatory purposes.

How can trust be ensured between buyer and seller when flexibility services are provided from non-professional stakeholders (e.g., households)?
Trust is built over time when the provision of the flexibility service is done successfully, both from the seller's and the buyer's perspectives. Knowledge and experience will also help build trust, and this is backed by recent surveys. Consumer awareness is also important, although certain technological development can enable some flexibility services from non-aware consumers (e.g., unnoticeable load shifting).

[5] Vefsnmo, H., Hermansen, T. S., Kjølle, G. H., & Sand, K. (2020). Scenarier for fremtidens elektriske distribusjonsnett anno 2030-2040. *SINTEF Rapport*.
[6] Degefa, M. Z., Sperstad, I. B., & Sæle, H. (2021). Comprehensive classifications and characterizations of power system flexibility resources. *Electric Power Systems Research*, *194*, 107022.
[7] Distribution Systems Working Group. (2020). CEER paper on DSO procedures of procurement of flexibility. Ref.: C19-DS-55-05

Session 1C

Organizing flexibility trading

Prof. Endre Bjørndal, NHH/FME NTRANS

Key takeaway—
Organizing flexibility trading
Flexibility market platforms for power systems already exists in many countries, but it is still unclear how the platforms can be cost-efficiently integrated into current power markets. Issues include how to prevent strategic gaming and how to strengthen incentives for DSOs.

A flexibility trading platform is a market to settle imbalances close to real-time. Many flexibility trading platforms for power systems already exist in different countries[8]. Coordination schemes for flexibility trading in power systems can be based on perfect coordination between power system operators or some hierarchical approach. Perfect coordination relies on a nodal representation of the power market, and it becomes computationally challenging for large systems. The hierarchical approach uses an aggregator to pool the needs of the distribution system operators (DSOs) and their flexibility resources.

The hierarchical approach has desirable attributes as a flexibility trading platform, namely: computational scalability, the possibility of gradual implementation, and institutional compatibility, i.e., it preserves roles, responsibilities, and the availability of information. The hierarchical approach also allows the utilisation of flexibility resources that standalone would provide negligible market volumes. The main drawback of the hierarchical approach is the potential inconsistency of pricing and dispatch instructions, which can create opportunities for market manipulation and gaming.

Much of the research on flexibility trading revolves around inconsistent grid modelling, which in turn gives incentives for strategic gaming. Without a nodal market, the day-ahead market needs a redispatch market to resolve potential congestions. The potential for gaming with the existence of a redispatch market can reduce social welfare[9].

Regulated DSOs have weak incentives to use flexibility markets due to having a regulated revenue cap. The DSOs can procure flexibility by redistributing tariffs among customers according to their flexibility. Alternatively, DSOs can buy flexibility directly, adding flexibility payments to the regulatory cost base.

How can strategic gaming be prevented in flexibility markets?
The short answer is to avoid zonal markets and uniform pricing when redispatch volumes are high. In principle, it is not difficult to implement nodal pricing in the day-ahead market. Nodal pricing could even lead to more stable electricity prices for certain regions than current zonal pricing.

Do we need the DSOs in future power markets?
Without the DSO, there would be the need for some actor to assume its role, which could be for example a single grid operator for a whole country. However, it would eliminate the gains obtained by competition between DSOs.

Why should end-users bother with flexibility markets when they have other stuff to do?
It is not the end-user that is bidding into these markets, but some institution that is representing the flexibility resources of the end-user. The end-user could be faced with automatic solutions under contractual terms.

[8] N-SIDE. (2021). Market approaches for TSO-DSO coordination in Norway. Project report for Statnett
[9] Bjørndal, E., Bjørndal, M., & Rud, L. (2013). Congestion management by dispatch or re-dispatch: flexibility costs and market power effects. In 2013 10th International Conference on the European Energy Market (EEM) (pp. 1-8). IEEE.

Session 2A

Panel discussion

Hallstein Hagen, NODES

As an independent market operator, NODES develop and operate the NODESmarket to enable trading of flexibility reservations in the long-term and activations in the short-term. We allow localized trading and pooling of resources such that any flexibility asset can take part in supplying central flexibility needs. NODES provides verification and settlement and have been operating in projects in Europe and Canada. The key aspect of flexibility market design is transparency, which will allow market participants to get information and react accordingly. Transparency will allow more types of resources to participate on the market, and it provides equal access to flexibility providers.

Jan Bråten, Statnett

Reducing *balancing* needs will also reduce flexibility needs. Energy efficiency can reduce the balancing needs because it could reduce electricity demand during cold periods. We need to understand the characteristics of flexibility resources that will be available in the future, and we need to link them to grid development. Short-term flexibility can allow more intensive grid use, while long-term flexibility is needed to counteract external events, such as cold periods with little wind. We need knowledge on how market incentives and the regulatory framework impact both the availability and the need for flexibility. It is important to avoid lock-in of inflexibility; if industries rely on one energy carrier, a higher share of electricity load is inflexible.

Marius Kolby, Statsbygg

At Campus Evenstad, we have developed different innovative energy solutions towards a zero-emission neighbourhood. Some of these solutions have energy flexibility potential, including battery banks, hot water tanks, and electric vehicle-to-grid chargers. In our experience, it is complex to combine all the different technologies to create operational flexibility potential. It is more natural and economic to work towards reducing energy consumption rather than increasing the flexibility potential or selling flexibility services from a building.

Håkon Egeland, Statkraft

Several new regulations affecting flexibility are being passed in Europe, including network codes and flow-based market design. Being on the supply side, we have seen an increased value of hydropower flexibility due to more interconnection capacity between Norway and neighbouring countries. We are also considering more pumped hydropower and increasing output as part of the refurbishment. There is a need to compare the cost and value of increasing the flexibility potential. Further, we need to identify technical, economic, and regulatory barriers that may hinder the best socio-economic development of flexibility investments, and we need to consider different geographical scopes for this, e.g., Norway and Europe.

What is important to enabling resources from buildings to deliver flexibility?

The DSO is important because they have an overview of the local balancing needs. Long-term flexibility is provided by reducing electricity consumption in the winter—which is a more traditional energy efficiency measure. Flexibility from doing traditional energy efficiency is important to communicate, also from a social science perspective, such that end-users realize their opportunities.

How will power prices change in the future, and how can we start planning for that?

Prices will be higher in winter than summer, and there will be stronger seasonal variations. Grid tariffs will also become more cost reflective. This should be communicated clearly now so that decision-makers can start planning for this and invest in technologies to deal with this.

How can we ensure that consumers and producers are clustered according to flexibility needs?

If we can get more local prices, it will be easier to respond locally. This can be ensured by emerging flexibility market platforms, e.g., NODES, and these platforms can be key to providing local flexibility to where it is most needed, including higher levels.

Session 2B

Breakout rooms

After the panel, the participants were invited to join breakout rooms, where they were divided into smaller groups. Researchers and partners teamed up to come up with their perception of knowledge gaps, and relevant research directions regarding market design for flexibility.

Room #1: The need for flexibility

There is a need to understand the demand for flexibility along the different dimensions, as shown in Session 1B (presentation by Hanne Sæle). The opinion is that market design should focus not only on the short-term allocation but also incentivise the right long-term investments.

The need for flexibility

The importance of the interaction between the short- and long-term scopes was mentioned, as well as local markets designed to work with short-term activation and long-term reserve capabilities which can give the desired price signals.

It was noted that the definition of flexibility varies across research centres FME NTRANS, FME CINELDI and FME HydroCen. When focusing on hydropower producers' needs, the uncertainty regarding demand for flexibility and how much flexibility suppliers will earn was explained as the cause for hydropower producers to postpone investment in new turbine technology, which is needed to provide on-demand flexibility to markets. This uncertainty enhances the need for adequate price signals.

Also relevant is the need to understand the interaction between different actors when trading flexibility, whether the trading involves consumers, producers, and/or the grid operators (TSO-DSO levels). Different trading profiles, given their characteristics, should be allocated to different markets.

The issue of poor liquidity in flexibility markets was raised. An example is the possibility for a generator to rely on reserve markets to attenuate supply uncertainty, which will add liquidity to the electricity market as a direct consequence. It was mentioned that market solutions should be favoured to avoid complexities related to optimization.

A final question was asked on what is needed to get end-users to become flexible, and what would promote behavioural change. Because consumers are not willing to supply flexibility manually, this shows that the market is missing incentives.

Room #2: Flexibility resources across the sectors

There is a need for a secondary energy carrier to provide flexibility, like when oil was the main energy carrier and electricity would be used for flexibility. This could be achieved at the industrial level with hydrogen.

Flexibility resources across the sectors

The need for energy system flexibility instead of power system flexibility was pointed out, for example by integrating seasonal thermal power storage to supply long-term flexibility needs. This resonates with the EU strategy of sector coupling.

An observation was made on the current use of electricity for heating in Norway, and how it can be improved in the future. The challenges for

electric heating solutions in Norway and Europe overall are part of this discussion. It was noted that innovation should facilitate the transition in countries with integrated strategies to the electrification of heating, but this could be costlier for other countries without such initiatives.

Understanding and characterising each flexibility resource alone is currently existing and ongoing, but it seems to lack the overall calculation of different potential for flexibility in alternative sources and compare them against each other. Interaction and feedback effects were also mentioned as relevant points for research, as well as including the grid as a key element in the flexibility network. Finally, it was asked how can district heating and electricity systems interplay better.

Room #3: Organizing flexibility trading

While aggregators are accessing flexibility, there seems to be a lack of information to the end-user. End-users are not made aware of relevant information regarding flexibility value in existing platforms. Knowledge on the benefits of a new ENOVA project on managing heat sources, which is opening for aggregators and smart domestic water heaters, has failed to reach households. This is a central gap in flexibility market design, which seems to be even more relevant in Norway.

Apart from end-users, there is a need for different roles in flexibility markets, especially in trust-building. One research gap is how to develop the correct signalisation of flexibility needed from TSO and DSO. An incentive structure should be made for market actors to use, and this could be translated into a sustainable business case and provide value for research. There is a need, from the researcher's perspective, to separate the actors from the market.

Another gap lies in the long- and short-term procurement for flexibility, which are interrelated. Business models should be formulated that can provide incentives to flexibility provision in a sustainable and economically viable manner.

Finally, we need more knowledge on how hydropower should adapt participation in the market once new flexibility resources from the demand side become more valuable in the short term.

Concluding remarks and future steps

The first workshop in "Use Case 7—Integrated markets for energy and flexibility" was successfully completed, and several knowledge gaps related to three sub-topics[10] were identified. This opening event provided an overview of different perspectives from different sectors linked to the electricity market, and the event provided first-hand accounts of the challenges related to sourcing and contracting flexibility in the current and future power system.

The input during this opening workshop will be used to shape future workshops on more specific topics within "Use Case 7—Integrated markets for energy and flexibility".

Acknowledgements

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[10] The need for flexibility; flexibility resources across the sectors; and organizing flexibility trading