Report on DSO & TSO value generation drivers

D7.5

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About OneNet

The project OneNet (One Network for Europe) will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

OneNet is funded through the EU's eighth Framework Programme Horizon 2020, "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

As the electrical grid moves from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. The project brings together a consortium of over seventy partners, including key IT players, leading research institutions and the two most relevant associations for grid operators.

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
DSO	Distribution System Operator – responsible for the local distribution grid and the delivery of customer grid connections
LT-P-C	Long term active power product
LT-P-C/E	Long term active power/energy product
MO	Market Operator – Responsible for the market in which each product is traded. The MO can be TSO, DSO or Independent Market Operator
NRT-P-E	Near real time active energy product
SO	System Operator
ST-P-C	Short term active power product
ST-P-E	Short term active energy product
T&D CP	TSO-DSO Coordination Platform
TSO	Transmission System Operator – responsible for the national grid and the balance (frequency quality in the grid)

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Executive Summary

This report embarks on a comprehensive exploration of the flexibility needs and flexibility-enabling tools showcased by the OneNet Northern Demonstrator.

Firstly, the mapping and analysis of the flexibility needs inherent to system operators are carried out. One pivotal outcome of this exploration is the identification and definition of five distinct harmonized flexibility products: long term active power product, long term active power/energy product, short term active power product, short term active energy product and near real time active energy product. All these five flexibility products can be universally applicable to both transmission and distribution system operators irrespective of country borders. These products are suitable to address multiple grid challenges, encompassing domains such as balancing, congestion management, voltage control, and other critical areas.

Following the mapping of flexibility, different flexibility enabling tools are identified that are either developed or used in Northern demonstrator Flexibility Register, TSO-DSO Coordination Platform, market platform, other internal tools (used by SOs) and generic values that are created by using all flexibility tools but not one in specific (for instance cost-effective network utilization, increasing liquidity of flexibility market, etc.).

Further analysis of flexibility enabling tools provided findings that the main values drivers emerging from using these tools are: transparency and visibility, eased FSP prequalification in the regional market, increased resource quality, process automation, process interoperability, constraint setting process, optimization process, unified flexibility call for tender process, value stacking, harmonized product definition, centralized activation process, cost-effective network utilization, interoperability of flexibility market, increased liquidity and healthy competition between market actors.

It was also discovered that there might be possible constraints that can hinder the full exploration of value drivers. These concrete limitations are regulatory barriers, uncertain market conditions, technological limitations and risks, financial barriers, data privacy and security, lack of skills and expertise. Therefore, to achieve the highest value from flexibility enabling tools, these constrains should be carefully investigated and considered when applying flexibility solutions in real life environment.

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1 Introduction

This report is written within OneNet's Northern Cluster, Work Package 7 task 7.5. Northern Cluster consists of 16 partners from Sweden, Finland, Norway, Lithuania, Latvia, Estonia and Ireland. The Northern Cluster connects multiple Transmission System Operators (TSOs) and Distribution System Operators (DSOs) that seeks to enable market driven flexibility. There are four TSO-DSO pairs from different countries in this cluster: Fingrid and Kymenlaakson Sähköverkko (Finland), Elering and Elektrilevi (Estonia), JSC Augstsprieguma Tikls and JSC Sadales Tikls (Latvia), Litgrid, AB and Energijos Skirstymo Operatorius, AB (Lithuania).

The vision for the Northern demonstrator is to seamlessly integrate a wide range of diverse flexibility needs with both existing and emerging markets, while ushering in a higher level of coordinated network operation enabled by flexibility. The Northern Cluster's primary objective is to craft an end-to-end process that optimally leverages market-driven flexibility for grid services, surpassing previous implementations and unlocking the potential for value stacking.

1.1 Task 7.5

Task 7.5 focuses on investigating how market driven flexibility and the tools enabling flexibility that are developed and demonstrated by the Northern Demonstrator generate value for both transmission and distribution system operators. The work in Task 7.5 was carried in three main phases:

- Mapping and analysis of flexibility needs of system operators;
- Determination of expected value drivers of flexibility enabling tools;
- Evaluation of demonstration outcomes and comparing it to previously defined value drivers.

1.2 Objectives of the Work Reported in this Deliverable

The primary objective of this deliverable is to identify the value drivers of flexibility enabling tools. Moreover, the deliverable examines any factors or conditions that may act as obstacles, preventing these tools from reaching their full potential or delivering the expected value. This comprehensive analysis helps in understanding the full spectrum of possibilities and challenges associated with flexibility enabling tools in the context of their value generation.

1.3 Outline of the Deliverable

Chapter 2 examines the flexibility requirements of system operators and provides five concrete flexibility products that can be used by TSOs and DSOs.

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Chapter 3 presents which flexibility enabling tools Northern Cluster SOs are going to use in the demonstrations.

Chapter 4 provides value drivers emerging from flexibility enabling tools.

Chapter 5 outlines how value drivers defined in previous chapter will be evaluated in the Northern Cluster demonstrations.

1.4 How to Read this Document

This deliverable is part of the WP 7, the Northern Demonstrator documentation. To understand the whole concept of flexibility enabling tools it is recommended to familiarize oneself with Flexibility Register description in Deliverable 7.2 [1] market functionalities analysis in Deliverable D7.3 [2], and TSO-DSO coordination module description in Deliverable D7.4 [3] . The conclusive outcomes of the entire Work Package 7 can be located within the document D7.6, which is set to be released at the end of the project.

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2 Flexibility needs of System Operators

The aim of this chapter is to examine the flexibility requirements of system operators. Firstly, a brief overview of OneNet D2.1 “Review on markets and platforms in related activities” and D2.2 "A standardized product set for system services within the TSO-DSO-consumer value chain," will be provided, since one of its main objectives was to analyze existing system services and products within the context of OneNet [4] [5] .

Additionally, this chapter presents the flexibility needs identified by System Operators within the Northern Cluster. These needs were pinpointed through the mapping of flexibility requirements during various workshops that involved all four distribution system operators and four transmission system operators from the Northern cluster.

2.1 Methodology for flexibility needs mapping

The initial workshop focused on identifying the flexibility products relevant to both TSOs and DSOs, using input information from OneNet Work Package 2 (WP2) "Products and services definition in support of OneNet.". WP2, in its initial working state, had conducted an analysis of related Horizon 2020 initiatives to gather information about potential flexibility products and had created a matrix of suggested products for system operators to consider. Additionally, suggestions from one Northern Cluster member – to use three dimensions of time frame, purpose and type – were incorporated.

During the workshop, partners combined information from both sources to identify products relevant to their operations and agreed upon common terminology for these products. Subsequent workshops provided more detailed specifications for these products by defining their attributes. At this stage, the emphasis was on defining relevant attributes rather than specifying concrete values for each attribute. The attribute list was initially derived from WP2 but was supplemented with attributes from other projects, such as CoordiNet [6]. Each system operator then provided information on product attributes from their perspective, and the answers were subsequently aligned.

2.2 OneNet harmonized approach for flexibility needs, services and products

Before commencing the analysis of flexibility requirements, it is crucial to establish a shared vocabulary. In this document, the terms 'system need,' 'service,' and 'product' will be interpreted in alignment with the definitions provided in OneNet Work Package 2 (as outlined in Table 2.1).

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Table 2.1 Definitions of system need, service and product

System need	Requirement of a high-level strategical action or set of actions for the better operation and/or planning of the grid (in terms of security and quality of supply) related to a specific grid aspect [5].
Service	The action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks [4].
Product	A tradable unit that the network operator acquires from the flexibility providers and that entails the option to deliver a service in case of activation (this activation can be automatic) [5].

The examples of system needs encompass congestion management, voltage management, and frequency control, among others. These needs can be addressed through the procurement of flexibility services, such as services designed to mitigate congestion issues. Various products can offer these services, and while these flexibility products may share similar characteristics, they may be referred differently by system operators. OneNet Work Package 2 has carried out an overview of services and products from different H2020 projects and has identified the relevant ones to OneNet partners (Figure 2.1).

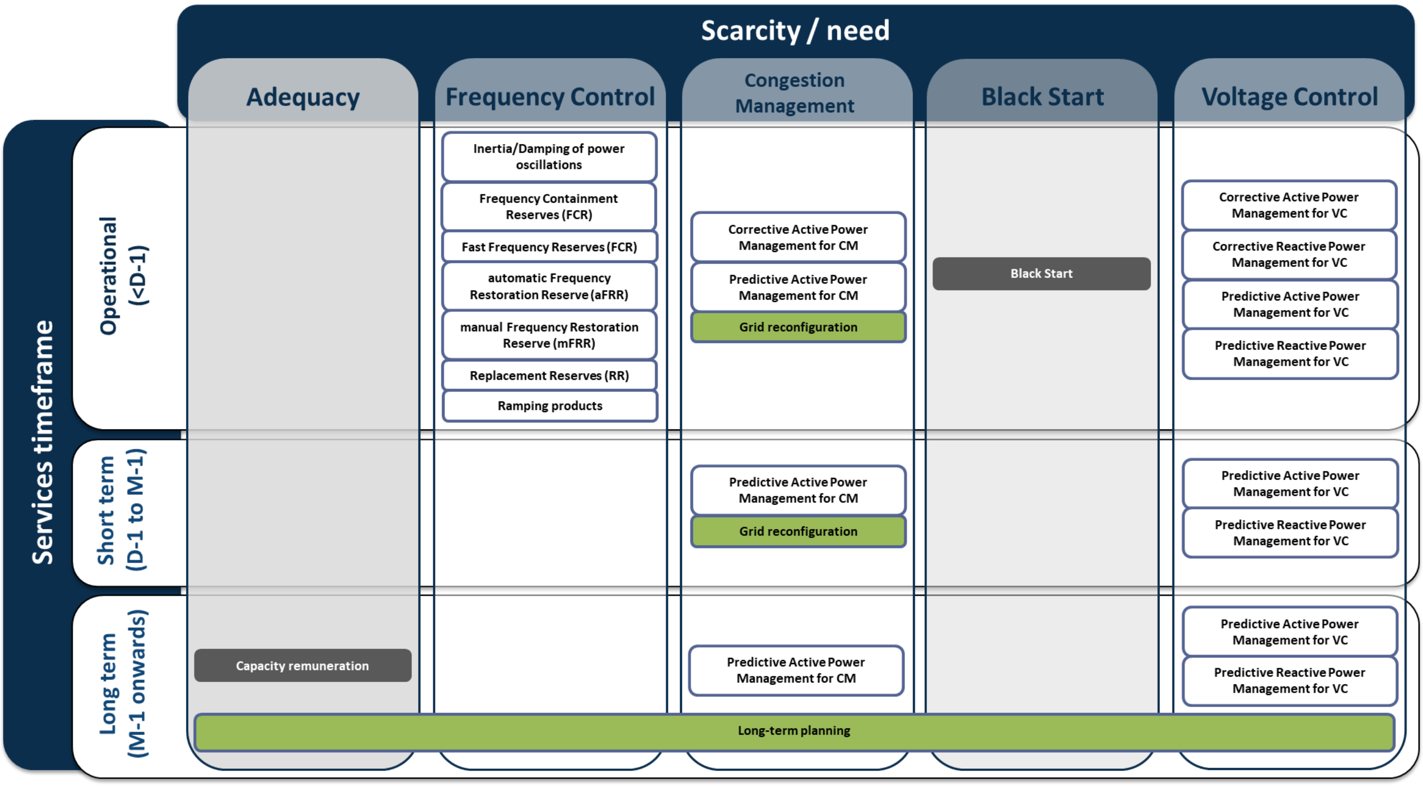

Figure 2.1 System services and products in OneNet [5]

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The products that have been identified may not be identical across all partners. OneNet D2.2 offers an overview of various products identified within the four OneNet Clusters. This same document proposes a set of standardized products, comprising six frequency control services and six non-frequency control services. The Northern Cluster has opted for a slightly different approach in mapping their flexibility needs, as the objective of the Northern Cluster was to develop more adaptable flexibility products capable of simultaneously addressing multiple requirements, rather than allocating a single product for each specific system need. Nevertheless, despite the disparities in the products suggested by the Northern Cluster and Work Package 2, they still can be aligned, which will be elaborated upon in Sub-chapter 3.5.

2.3 Flexibility needs in Northern cluster

In establishing a framework for flexibility products, WP2 aimed to address three key questions:

- the intended use of the product by the System Operator (SO);
- the pertinent attributes associated with the product;
- the specific values associated with these attributes.

As detailed in the preceding sub-chapter, system operators encounter the need to resolve specific issues within their grid. To address these challenges, they can procure services from the market. Furthermore, there might be several products capable of delivering these services and meeting the system's requirements. However, these products exhibit substantial similarities in their fundamental nature. What sets them apart are their intended purpose (the system need they are meant to address), the duration for which they are procured, and their individual attributes.

During the process of mapping flexibility needs, Northern Cluster partners observed that certain diverse services could be facilitated by acquiring the same or very similar flexibility products. Consequently, the Northern Cluster decided that rather than categorizing products based on their specific needs, it would be more advantageous to create unified flexibility products that could be utilized by different system operators across country borders.

As a result, partners in the Northern Cluster introduced three aspects to characterize a flexibility product: time frame, purpose and type. The first dimension of time frame indicates how far in advance of the actual need the flexibility product is acquired. Within this dimension, WP7 identified three potential timeframes long-term (LT), short-term (ST), or near-real-time (NRT). The second dimension describes product type, it can be active power (P) or reactive power (Q). Lastly, the third dimension clarifies the purpose of the flexibility product capacity (C) or energy (E), respectively it also defines how the product will be measured: capacity measured in kW (MW) and energy measured in kWh (MWh).

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By combining these three dimensions, it is possible to delineate twelve distinct flexibility products. There are also further possibilities to join some of the dimensions and receive different types of flexibility products, which were done in some cases.

Following an examination of possible flexibility product options, it was determined that only five of them would be further assessed within the Northern Cluster context:

- Long term active power product (LT-P-C)
- Long term active power/energy product (LT-P-C/E)
- Short term active power product (ST-P-C)
- Near real time active energy product (NRT-P-E)
- Short term active energy product (ST-P-E)

Among the five selected flexibility products, the choices were primarily influenced by the specific requirements of TSOs and DSOs within the Northern Cluster. Notably, reactive power products were excluded from the selection for various reasons. For instance, some operators, particularly DSOs, currently do not have a demand for these products, as they effectively manage reactive power through established grid connection rules or by utilizing integral grid components."

These five flexibility products enable multiple system operators to meet flexibility need in order to resolve the grid issues they encounter.

2.4 Product attributes

As noted in the previous sub-chapter, five flexibility products of Northern system operators were identified as having the potential for operational use. These products are further analyzed through different attributes. The attribute list is taken from OneNet D2.2 and was adjusted by Northern demonstrator partners to reflect the concept of Northern Cluster. The list of attributes and their explanations are provided in Table 2.2.

For each five flexibility products concrete attribute values are assigned as outlined in Sub-chapter 2.4.

Table 2.2 Definitions of flexibility product attributes

Attribute	Definition	Adjustment made in Northern demonstrator
Capacity/energy	This attribute determines whether the product account for the possible acquisition of capacity (in MW) or energy (in MWh)	Labelled as “**Product type**”

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Active / reactive energy	Type of power that will be acquired by the SO	Instead "Quantity **unit**" is proposed. The value can be MW/kW or MVAr/kVAr.
		Additional attribute labelled "**Link to energy product**" is proposed. Link to energy product indicates which requirements have to be met by the FSPs resources and placed bit in order to be able to participate in subsequent energy trading.
Location information included	This attribute determines whether certain locational information needs to be included in the bid (e.g. identification of Load Frequency Control (LFC) area, congested area...)	Not applied as separate attribute, because each resource in the flexibility register must entail the locational information by default.
Certificate of origin	This attribute determines whether the FSP would be required to deliver a certificate of origin of the energy they sell.	Not relevant
Level of availability	When there is uncertainty about the capacity of a FSP, this attribute would determine the percentage of time that the FSP would be able to deliver the product.	It is proposed to use this attribute as part of Flexibility Need or Flexibility Call for Tender, this way SOs can decide the availability need each time.
Preparation period	The period between the request by the SO and the start of the ramping period.	
Ramping period	The period during which the input and/or output of power will be increased or decreased until the requested amount is reached.	
Full activation time	The period between the activation request by the SO and the corresponding full delivery of the concerned product.	
Delivery period	The minimum/maximum length of the period of delivery during which the service provider delivers the full requested change of power in-feed to, or the full requested change of withdrawals from the system.	

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		Additional attribute labelled "**Minimal duration of** delivery **period**" is proposed.
Deactivation period	The period for ramping from full delivery to a set (pre-agreed) point, or from full withdrawal back to a set point.	
Recovery period	Minimum duration between the end of deactivation period and the following activation.	It is proposed to use this attribute as part of Flexibility Call for Tender, relevant to define only for procuring capacity products.
Maximum number of activations	Maximum number of times a SO can activate a FSP during a period of time	Expected number of activated hours is relevant only for LT-P-C/E product and is proposed to be defined in Flexibility Purchase Offer.
Mode of activation	The mode of activation of bids, i.e. manual or automatic. Automatic activation is done automatically during the validity period (with little or no direct human control), whereas a manual activation is done at the SO's request.	
Quantity	The power (or change in power) offered at the end of the full activation time. This quantity can be limited by a minimum and/or maximum amount of power to be included in a bid. The minimum quantity represents the minimum amount of power for one bid. The maximum quantity represents the maximum amount of power for one bid. These values could reflect technical constraints faced by the SO and/or the MO as well as the FSPs.	Instead, only the attribute labelled "**Minimum** quantity" is proposed.
Divisibility	The possibility for a system operator to use only part of the bids offered by the service provider, either in terms of power activation or time duration. A distinction is made between divisible and indivisible bids.	The SOs is let to predefine divisibility related requirement (labelled as "Bid type") each time in the Flexibility Call for Tender, applies to capacity products. FSPs are allowed to define their capability in Flexibility Bid for all products.
Granularity	The smallest increment in volume of a bid.	Labelled as "**Quantity step**"

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Maximum / minimum price	Maximum and minimum price the market operator accepts for the clearance of the market.	The SO is let to predefine maximum and minimum prices each time in the Flexibility Call for Tender, applies to capacity products.
Availability price	Price for keeping the flexibility available (mostly expressed in € /MW/hour of availability).	Not considered relevant because the attribute "Product type" already defines whether the product is about availability (capacity) or activation (energy).
Activation price	Price for the flexibility actually delivered (mostly expressed in € /MWh).	Not considered relevant because the attribute "Product type" already defines whether the product is about availability (capacity) or activation (energy).
Symmetric/asymmetric product	This attribute determines whether only symmetric products or also asymmetric products are allowed. For a symmetric product upward and downward volumes have to be equal. For asymmetric products, upward and downward regulation volumes can be different.	Labelled as "**Symmetry**"
Aggregation	This attribute determines whether a grouped offering of power by covering several units via an aggregator is allowed.	Not relevant, because aggregation is always allowed.
Baseline methodology	Methodology used to estimate the volume of energy delivered by an FSP compared to the case if the product would not have been activated.	It is left for the FSPs themselves to decide what kind of baseline (ex-post or ex-ante) they prefer to choose. FSPs need to submit this as part of resource information. If the FSP opts for ex-ante baseline it has the freedom to define its own methodology.
Measurement requirements	This attribute describes the systems to be used to measure the unit traded as a result of the product.	Not relevant, the FSP has to submit the metering point ID together with the resource information. This can be both main meter or sub-meter.
Penalty for non-delivery	This attribute would determine the penalty that the FSP would face if they fail to deliver the energy agreed on the product.	Not relevant, it is up to the buyer (SO) or national regulation to decide the penalty.

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		Additional attribute labelled "**Pricing method**" (marginal, pay-as-bid) is proposed.
		Additional attribute labelled "**Price unit**" is proposed. It defines the currency used in pricing.
		Additional attribute labelled "**Price resolution**" is proposed. It defines the price value accuracy.
Validity period of the bid	The period when the bid offered by the FSP can be activated, where all the characteristics of the product are respected. The validity period is defined by a start and end time. The duration should be, at least, the full delivery period of the bid but it could extend over longer periods of time.	Labelled as "**Validity**". Energy bids have to be submitted for each trading period separately. The value is expressed in minutes.
		Additional attribute labelled "**Gate closure time**" is proposed. It is the deadline for bid submission by FSP, alteration and removal from the closest delivery period.
		Additional attribute labelled "**Activation type**" is proposed. It is relevant for NRT-P-E product only to define whether it is about scheduled activation or direct activation in case of balancing.

2.5 Flexibility needs identified by DSOs and TSOs used in Northern Cluster

This sub-chapter will outline the five flexibility products selected by the Northern Cluster. A brief description of their intended purposes and their associated attributes are provided as well.

2.5.1 LT-P-C product

Long term active power product (LT-P-C) – is an active power product procured months to years ahead, the procured product is measured in capacity (kW). LT-P-C product is acquired by SOs and is used for congestion management, frequency control and adequacy. This product can also serve as power reserve, and this product bids can be extended to other markets, including short and near-real-time product markets, as other products have link to these products, for example, LT-P-C could be delivered as mFRR bids under NRT-P-E.

Table 2.3 Attributes of LT-P-C product

Attribute	Value
Product type	Capacity
Link to energy product	NRT-P-E/ ST-P-E / N/A
Quantity unit	MW
Activation type	N/A
Preparation period	≤7 min
Ramping period	≤12 min
Full activation time	≤12.5 min
Delivery period	15 min
Minimal duration of delivery period	≤5 min
Deactivation period	≤10 min
Mode of activation	Manual
Minimum quantity	0.01
Quantity step	0.01
Symmetry	Symmetric / Asymmetric
Pricing method	Pay-as-bid or marginal
Price unit	EUR
Price resolution	0.01
Validity	15 min
Gate closure time	Defined in tender

2.5.2 LT-P-C/E product

Long term active power product (LT-P-C/E) – is an active power/energy product procured months to years ahead, the procured product is measured in capacity (kW). LT-P-C/E product is acquired by SOs and is used for congestion management, frequency control and adequacy. The distinction between LT-P-C and LT-P-C/E product lies in the inclusion of an energy component in the latter. LT-P-C/E products are reserved in advance for specific future time periods. When the designated time arrives, SOs have the option to either activate or deactivate the product based on the grid's condition. If activation is necessary, the specific energy provided is accounted for separately.

Table 2.4 Attributes of LT-P-C/E product

Attribute	Value
Product type	Capacity /energy
Link to energy product	N/A
Quantity unit	MW
Activation type	N/A
Preparation period	360 min
Ramping period	N/A
Full activation time	60-360 min
Delivery period	60 min
Minimal duration of delivery period	N/A

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Deactivation period	N/A
Mode of activation	Manual
Minimum quantity	0.001
Quantity step	0.001
Symmetry	Symmetric / Asymmetric
Pricing method	Pay as bid
Price unit	EUR
Price resolution	0.01 EUR/unit
Validity	N/A
Gate closure time	Defined in tender

2.5.3 ST-P-C product

Short term active power product (ST-P-C) – is an active power product procured day to a month ahead and is used by SOs for balancing and congestion management purposes. ST-P-C is a single product that is applicable for manual frequency restoration reserves (mFRR) and congestion management (CM). FRR part of mFRR is defined as ''active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC area, to restore power balance to the scheduled value'' (Commission Regulation (EU) 2017/1485 Network Code on System Operation Article 3(2)(7) [7]) and the ''m'' part stands for mode of activation, which represents manual activation. CM lacks agreed definition but, in its essence, it is used to mitigate HV, MV and LV grid element congestion issues by avoiding overloading.

Table 2.5 Attributes of ST-P-C product

Attribute	Value
Product type	Capacity
Link to energy product	NRT-P-E / N/A
Quantity unit	MW
Activation type	N/A
Preparation period	≤7 min
Ramping period	≤12 min
Full activation time	≤12.5 min
Delivery period	15 min
Minimal duration of delivery period	≤5 min
Deactivation period	≤10 min
Mode of activation	Manual
Minimum quantity	0.01
Quantity step	0.01
Symmetry	Asymmetric
Pricing method	Pay-as-bid or marginal
Price unit	EUR
Price resolution	0.01
Validity	15 min
Gate closure time	Defined in tender

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2.5.4 ST-P-E product

Short term active energy product (ST-P-E) – this product procured day to a month ahead and can be used to react with active energy to unexpected incidents that require correction ahead of delivery. The product is tradable via modified power exchange intraday markets or other platforms. In addition to current bidding area level utilization, this product can be used to solve more local problems by introducing more granular locational information. By this modification to the intraday trading, market parties' access to different markets can be enhanced, when simultaneous participation to the wholesale and congestion management markets is enabled.

Table 2.6 Attributes of ST-P-E product

Attribute	Value
Product type	Energy
Link to energy product	N/A
Quantity unit	MW
Activation type	N/A
Preparation period	Defined in tender
Ramping period	Defined in tender
Full activation time	Defined in tender
Delivery period	15-60 min
Minimal duration of delivery period	Defined in tender
Deactivation period	Defined in tender
Mode of activation	Manual
Minimum quantity	0.01
Quantity step	0.01 MW
Symmetry	Asymmetric
Pricing method	Pay as bid
Price unit	EUR
Price resolution	0.01
Validity	When the intraday market is open
Gate closure time	Before NRT products

2.5.5 NRT-P-E product

Near real time active energy product (NRT-P-E) – is an energy product that is procured near real time and used by SOs responsible for balancing and congestion management. It is inspired by the mFRR product which is defined as "the active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC area, to restore power balance to the scheduled value".

Table 2.7 Attributes of NRT-P-E product

Attribute	Value
Product type	Energy
Link to energy product	N/A
Quantity unit	MW

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Activation type	Scheduled activation / Direct activation
Preparation period	≤7 min
Ramping period	≤12 min
Full activation time	≤12.5 min
Delivery period	15 min
Minimal duration of delivery period	≤5 min
Deactivation period	≤10 min
Mode of activation	Manual
Minimum quantity	0.01
Quantity step	0.01
Symmetry	Asymmetric
Pricing method	Pay-as-bid / Marginal
Price unit	EUR
Price resolution	0.01
Validity	15 min
Gate closure time	25 minutes

2.6 Northern cluster needs and OneNet harmonized approach

As mentioned in Sub-chapter 3.1, D2.2 has developed a set of harmonized flexibility products designed to meet the requirements for common system services. These products have been systematically mapped and standardized in accordance with the products intended for demonstration across all project clusters. While all five products defined within the Northern Cluster can also be aligned with the standardized products, it is important to acknowledge that the specifications of Northern Cluster products may not perfectly match those of the harmonized ones, as variations can exist in terms of attributes and applications.

The reconciliation between Northern Cluster and OneNet harmonized products are provided in the Table 2.8.

Table 2.8 Northern cluster products match with OneNet Harmonized Products

Products proposed by Northern Cluster	Harmonized Products
Near Real Time Active Energy	Corrective local active
Short Term Active Energy	Predictive short term local active
Long Term Active Capacity/Energy	Predictive long-term local active
Long Term Active Capacity	Predictive long-term local active
Short Term Active Capacity	Predictive short term local active

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2.7 The usage of defined products in WP7

The overall representation of flexibility products defined in Sub-chapter 3.4 is shown in Figure 2.2. This figure provides an overview of the initial selection of products and illustrates their connections within the energy market. As previously explained, these products are characterized by three dimensions: the time frame can be long-term (LT), short-term (ST), or near-real-time (NRT), the purpose can be capacity (C) or energy (E), and the type can be active power (P) or reactive power (Q). Additionally, "TD" indicates that the flexibility can be linked to both the transmission and distribution networks, while "A" means an availability product (please note that although the term "availability" (A) is used in Figure 2.2, the rest of this deliverable employs the term "capacity (C)." In the current context, both terms convey the same meaning.

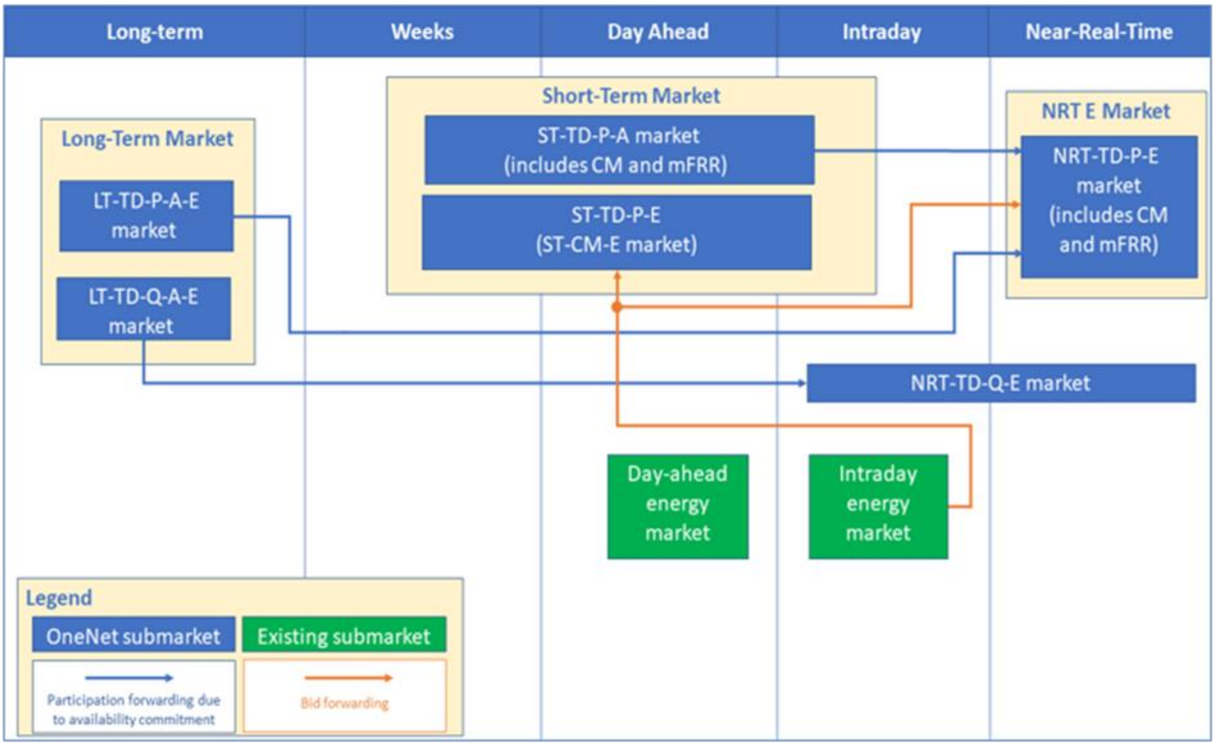

Figure 2.2 Overall representation of Northern Cluster flexibility products [8]

Some of the flexibility products outlined in Sub-chapter 2.5 are better suited for TSOs, while others are more aligned with the needs of DSOs. Nevertheless, these products are versatile and can be employed by both types of operators. Current trends in the flexibility market indicate that TSOs, for instance, have a greater demand for flexibility products tailored to frequency control, which must be acquired in the near real-time market. Meanwhile, DSOs often encounter location-specific issues and require flexibility products to address congestion and voltage-related challenges. For example, the NRT-P-E product is more focused to the needs of TSOs, but it's possible that, as the flexibility market evolves, DSOs may also require shorter-term products to resolve their grid-related issues. On the same note, LT-P-C/E product seems to be more suited for DSOs as it can be used to

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in concrete grid areas where congestion can be foreseen, however, it can be used in TSOs grid bottlenecks as well.

Table 2-9 shows which flexibility product is going to be demonstrated by which Northern Cluster country and their respective SO.

Table 2.9 Northern cluster demonstrations plan

Demo products		NRT-P-E	ST-P-E	LT-P-C / ST-P-C	LT-P-C/E
Finland					
	Fingrid	x	x		
	KSOY	x	x		
Estonia					
	Elering	x		x	
	Elektrilevi	x		x	x
Latvia					
	AST	x		x	
	ST	x			x
Lithuania					
	Litgrid	x			
	ESO				x

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3 Flexibility enabling tools in Northern Cluster

3.1 Concept of Northern Cluster

The flexibility needs discussed in Chapter 2 must be fulfilled through the utilization of specific instruments designed to facilitate flexibility. These tools serve multiple purposes: they not only streamline the entire procurement process but also encompass the preparatory measures leading up to it, along with the coordination among various stakeholders within the market. When addressing flexibility needs, it's essential to have well-defined mechanisms or systems in place that not only allow for the actual acquisition of flexibility resources but also encompass the necessary steps taken before procurement, such as planning and assessment. Moreover, these tools facilitate collaboration and communication among the various parties involved in the market to ensure a smooth and efficient process.

The flexibility products and tools outlined earlier serve to simplify and standardize processes, ultimately reducing the barriers of entry for providers of flexibility resources. These innovations introduce new possibilities, allowing for intricate interactions involving multiple actors across various domains. This means that the solutions developed by the Northern Cluster facilitate the integration of multiple markets, span different network areas, and even transcend national boundaries. The focus on international solutions, as opposed to strictly national ones, promotes collaboration, and enables the joint development of flexibility products and coordinated procurement efforts between TSOs and DSOs. In essence, this approach fosters a more interconnected and efficient energy ecosystem.

In pursuit of the objectives outlined above, the Northern Cluster has devised a well-rounded flexibility market framework that incorporates all key stakeholders. This includes the involvement of system operators, flexibility markets operators, flexibility services providers and new tools to enable smooth processes between all market parties.

To achieve above mentioned goals the Northern Cluster introduce two innovative platforms within this new market structure: the Flexibility Register and the TSO-DSO Coordination Platform. These platforms are envisioned to serve as pivotal components in enabling a smooth and efficient functioning of the market. The flexibility register will act as a central repository for crucial data related to flexibility resources, streamlining their accessibility and utilization. The TSO-DSO Coordination Platform, on the other hand, will facilitate collaborative efforts between Transmission System Operators (TSOs) and Distribution System Operators (DSOs), promoting synchronized and effective grid management.

Moreover, the Northern Cluster is committed to ensuring seamless integration for existing market participants by providing interfaces and connections to their relevant systems. This inclusivity and

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interoperability are central to creating a cohesive and adaptable energy market ecosystem. The concept of Norther Cluster is depicted in Figure 3.1.

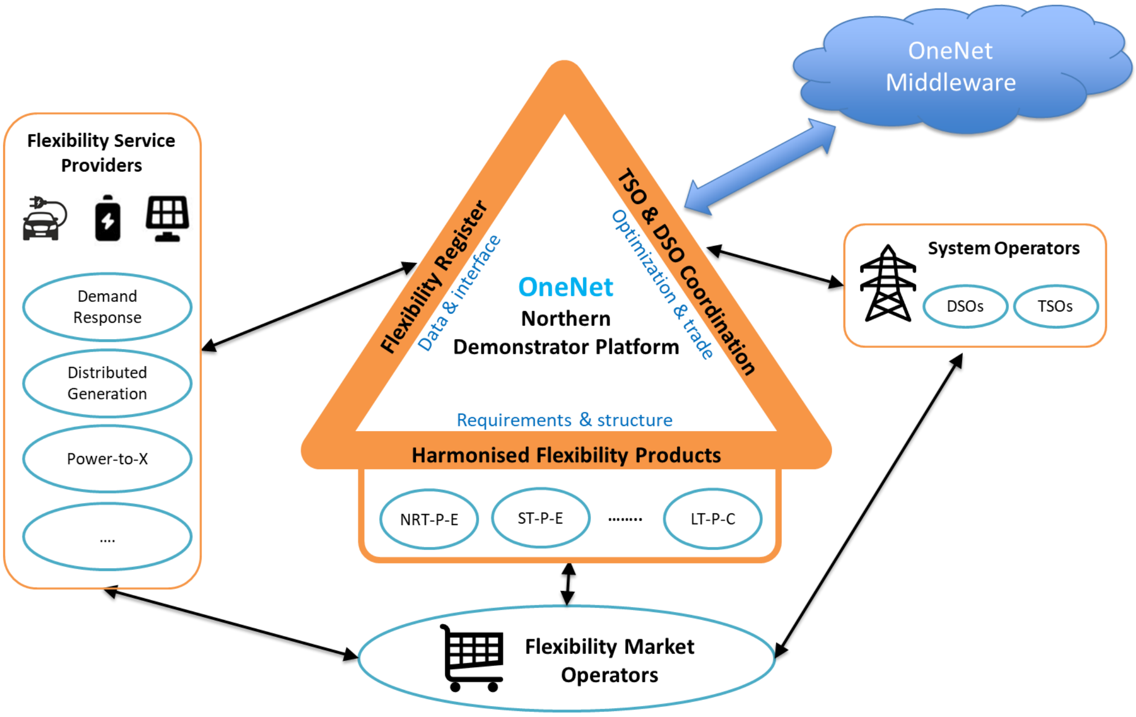

Figure 3.1 General overview of Northern Cluster concept

Besides the new two tools which are developed in the Northern Cluster two additional tools should be mentioned that are already existing in real live flexibility market structure. Thus, within the framework of the Northern Cluster four key tools were selected to further investigate:

- Flexibility Register
- TSO-DSO Coordination Platform
- Market Platforms
- Other Internal Tools and Generic Values

These tools play a crucial role in enabling and enhancing the flexibility-related capabilities and operations of System Operators.

3.2 Flexibility Register

Flexibility Register – main objective of Flexibility Register is to manage flexible resource information e.g. technical capability, connection point to the power system and qualification related information. Furthermore, additional key functionalities are giving the SO the ability to view all registered flexibility resources connected

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to their grid, support of flexible resource grouping and support of flexibility service settlement between market parties. The most relevant functionalities of Flexibility Register are:

- Manage flexible resource information;
- Provide visibility to SOs about the flexible resources in their grid;
- Product prequalification;
- Store prequalification data;
- Calculate baseline;
- Verify delivered energy;
- Support information exchange of aggregated bids.

Further details about the Flexibility Register are available in the deliverable D7.2 “Flexibility register description and implementation” [1].

3.3 TSO-DSO Coordination Platform

TSO-DSO Coordination Platform (T&D CP) – the main objective is to ensure coordinated utilization of available system resource e.g., flexible resources. Coordinated utilization of flexible resources by multiple system operators means that all involved parties jointly procure flexibility in the most cost-effective way, while guaranteeing that the selected flexibility resources won’t jeopardize the involved grids. The three main tasks of the tool are:

- to ensure that flexibility activations do not cause congestions in any network level.
- to prioritize flexibility bids/activations that are not only economical but also technically cost-effective, and;
- to maximize the use of flexibility by doing value stacking, i.e. to find the most optimal mix of available flexibilities to be activated by running an optimization algorithm based on socio-economic value.

In order to ensure the accomplishment of all the tasks mentioned above, an optimization module has been devised. This optimization module is an algorithm crafted to enhance the efficiency of flexibility bids, promoting multilateral flexibility markets through improved TSO-DSO coordination, thereby facilitating cross-border markets. The optimization module fosters transparency, provides a clear rationale for bid selection, and promotes fairness in bid purchases, ultimately encouraging increased participation from both flexibility service providers and consumers.

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It's worth mentioning that TSO-DSO coordination is linked to the OneNet Middleware [9]. Market Operators have the option to connect to the T&D CP either directly or through the OneNet Middleware ecosystem interface, which is being developed as part of the OneNet project in WP6. This middleware ecosystem connector enables Market Operators to access T&D CP services without the need for direct integration with T&D CP.

Additional details regarding the TSO-DSO Coordination Platform are available in the deliverable D7.4 "TSO-DSO Coordination module description and Implementation" [3].

3.4 Market platform

A proposal made in BRIDGE Initiative's report for updating the definition for harmonized Electricity Market Role Model determines MO as "a party that provides a service whereby the offers to sell electricity or electricity flexibility are matched with bids to buy electricity or electricity flexibility" [10]. Therefore, in the context of this report, Market Platform will be understood as the platform through which MO operates. The Market platform are an essential tool in flexibility and brings great value because it serves as a critical interface for various stakeholders in the energy market. Such platforms establish a marketplace where buyers, such as system operators can identify and procure the specific flexibility products required to address specific grid challenges. Market platforms also promote transparency in price discovery, enabling flexibility service providers to competitively offer their services. This competitive environment helps determine fair and equitable prices, benefiting both buyers and sellers and ensuring that flexibility products are procured at reasonable costs. Moreover, the presence of market platforms fosters competition among flexibility service providers, driving innovation and the creation of more efficient solutions for grid management. This competition also motivates providers to enhance the quality and reliability of their services. Furthermore, these platforms grant access to a wide array of flexibility resources, encompassing demand response, distributed energy resources, battery storage, and more. This diversity of resources equips system operators with a comprehensive toolkit to effectively tackle various grid challenges.

It's important to highlight that market platforms are considered as established entities, and the project does not center around their development. Consequently, the project takes into account the presence of pre-existing market platforms. There are several different MOs considered in Northern Cluster, mainly SOs, MARI, NordPool and Piclo. However, other MO platforms would not be eliminated from the consideration.

3.5 Other internal tools and generic values

While examining various tools designed to facilitate flexibility, it became evident that some added values do not stem from a specific tool but rather emerge as a result of System Operators' (SOs) utilization of flexibility in general. Therefore, the combination of various tools can generate added value. Additionally, SOs employ a range of other tools and platforms for their internal operations. For instance, to effectively employ the Flexibility

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Register and the TSO-DSO Coordination Platform, SOs must initially calculate their needs and possess comprehensive data about their grid infrastructure, among other factors.

To obtain this essential data, SOs rely on various internal tools such as data hubs, network modeling systems, network information systems, and supervisory systems. Many of these tools are not exclusively dedicated to flexibility but serve multiple purposes and may vary from one SO to another. Consequently, it was decided not to specify particular tools in this context, but rather to have a Sub-chapter that consolidates the value derived from these diverse internal tools and the broader utilization of flexibility itself.

In summary, the value generated from the use of flexibility is not limited to individual tools but is often a result of their interplay, in conjunction with internal tools and processes employed by SOs.

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4 Flexibility enabling tools value drivers

4.1 Flexibility enabling tools and value generating drivers

In Chapter 3, four flexibility tools were discussed, each of which offers distinct advantages to system operators. The Northern Cluster conducted an in-depth analysis of these four different flexibility-enabling tools outlined in this Chapter, identifying specific value drivers that benefit both TSOs and DSOs. These value drivers are relevant to both types of operators and are not limited to one or the other. In essence, this analysis underscores the concrete benefits and advantages that system operators can derive from the utilization of these flexibility tools, regardless of whether they are TSOs or DSOs. The identified value drivers serve as a valuable resource for operators seeking to optimize their grid management and operational efficiency. The concise summary of these value drivers for each flexibility tool can be found in Table 4-1. For a more comprehensive understanding, a detailed elaboration of this list is provided in Sub-chapters 4.2-4.5. While the previous sub-chapter delves into a qualitative explanation of value drivers, Chapter 5 outlines the evaluation of these drivers through the utilization of key performance indicators.

Table 4.1 Flexibility enabling tools and their value drivers

Flexibility register	TSO-DSO Coordination Platform	Market platform	Other internal tools and generic values
Transparency and visibility	Constraint setting process	Value stacking	Cost-effective network utilization
FSP prequalification in regional market	Optimization process	Harmonized Product definition	Interoperability in general
Resource Quality / Integrity	Flexibility Call for Tender process	Centralized activation process	Increasing liquidity
Process automation			Competition between the market operators
Process interoperability			

4.2 Value drivers of Flexibility Register

4.2.1 Transparency and visibility

The utilization of the Flexibility Register offers several significant advantages, particularly in terms of transparency and visibility within the flexibility market. Here's a breakdown of how it achieves this:

- **Transparency and Accessibility:** The Flexibility Register provides a transparent platform where all relevant information is readily accessible to all participants in the flexibility market. This information is

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easily reachable, available instantly, and presented in a machine-readable format (a computer-readable file containing a digital representation of data or information that can be imported or accessed by a computer system for additional processing). It can be accessed through a user-friendly interface, making it convenient for system operators (SOs) and other market players.

- **Information Availability:** The Flexibility Register ensures that aggregated and non-private information can be made public. This means that data related to the availability of flexibility resources and other pertinent market details are openly accessible. This transparency fosters trust and facilitates informed decision-making among market participants.
- **Privacy Protection:** While open access to non-private information is encouraged, private information is safeguarded. Access to private information is granted based on explicit or implicit consent, ensuring that sensitive data remains secure and is only disclosed with appropriate authorization. The Flexibility Register employs an intermediary agent known as the 'Data Exchange Platform.' This platform primarily ensures the secure transfer of data from data providers [1].
- **Resource Availability Check**: One of the most significant values for System Operators (SOs) lies in their ability to use the Flexibility Register to check the availability of flexibility resources. SOs can readily ascertain which resources are available for procurement and are suited to meet their specific needs.
- **Market Participant Overview:** The platform also provides SOs with an overview of market participants, including Flexibility Service Providers (FSPs) interested in offering their services. SOs can gain insights into the identities of FSPs, details about their available resources, the technical capabilities of these resources, and the prequalification status of these assets.

In summary, the Flexibility Register enhances the transparency and accessibility of information within the flexibility market. It empowers SOs and other market participants by offering clear visibility into resource availability, market participants, and their capabilities, thereby facilitating more informed and efficient decision-making in the dynamic energy landscape.

4.2.2 FSP prequalification in regional market

The Flexibility Register offers an additional valuable feature: the prequalification process. Here's how this process works and why it holds significant advantages:

- **Simplified Prequalification:** Within the Flexibility Register, Flexibility Service Providers (FSPs) are required to undergo a prequalification process. This process is designed to assess the suitability of FSPs to participate in the flexibility market.
- **Cross-Region and Cross-Country Recognition:** if an FSP successfully completes the prequalification process in one country or region, there is no need for them to repeat this process when entering another country or region. This is referred to as the "once-only principle." Similarly, this principle can

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also apply at the System Operator (SO) level. If an FSP is prequalified by one SO, they are not required to go through an additional prequalification process when providing the same or similar services to another SO.

- **Time and Efficiency Gains:** The primary advantage for SOs lies in time savings. They can avoid the duplication of the qualification process, which can be time-consuming and resource intensive. By not having to repeat this process, SOs can significantly increase their operational efficiency.
- **Cost Savings:** The avoidance of redundant prequalification procedures can also lead to cost savings for SOs. They do not need to allocate additional resources to conduct repetitive assessments, which can positively impact their budgets.
- **Increased Market liquidity:** FSPs also benefit from the streamlined prequalification process. Since they don't have to undergo the same process repeatedly, they are more likely to be willing to enter markets in different countries or regions. This increased willingness to participate can enhance market liquidity for SOs.

To sum up, the prequalification process implemented within the Flexibility Register simplifies and expedites the onboarding of Flexibility Service Providers (FSPs) into the flexibility market. It saves time and resources for both FSPs and System Operators (SOs), encourages market participation, and ultimately contributes to a more efficient and liquid market environment.

4.2.3 Resource Quality / Integrity

The requirement for all Flexibility Service Providers (FSPs) and their resources to undergo the same prequalification process brings another important advantage – resource quality and integrity:

- **Quality Assurance:** By subjecting all FSPs and their resources to a uniform prequalification process, a level of quality compliance is established. This process confirms that all participants meet the required standards set by the system operators. As a result, SOs can have confidence that FSPs that have successfully completed the qualification process possess high-quality resources.
- **Consistency:** A standardized prequalification process ensures consistency across the market. It means that all FSPs are assessed under the same criteria and standards, eliminating potential variations in quality or capability. This uniformity simplifies the decision-making process for SOs when selecting FSPs to provide flexibility services.
- **Risk Mitigation**: The prequalification process acts as a risk mitigation strategy for SOs. It helps reduce the risk of engaging with FSPs that may not meet the necessary technical or operational requirements. SOs can be more confident that the FSPs they chose have undergone a thorough assessment and are capable of delivering reliable flexibility services.

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- **Resource Reliability:** Ensuring that FSPs have high-quality resources is crucial for the stability and reliability of the grid. Grid operations depend on the availability and performance of flexibility resources, so having well-qualified FSPs contributes to the overall grid's dependability.
- **Market Trust**: A consistent and rigorous prequalification process enhances trust in the market. Allowing only quality-compliant FSPs to participate builds credibility and trust among stakeholders, including market regulators, investors, and consumers.

Therefore, the uniform prequalification process not only validates the quality of FSPs and their resources but also enhances consistency, reduces risks, and fosters trust in the flexibility market. It is a fundamental mechanism for ensuring the reliability and effectiveness of grid operations and the broader energy ecosystem.

4.2.4 Process automation

The Flexibility Register facilitates the process of preparing FSPs and their resources before trading phase can start. Currently this process has many steps which might require manual tasks from different parties. The aim is to automate these processes. Since the process is automated, SOs do not need to allocate additional resources (such as human resources) to check or monitor FSPs.

4.2.5 Process interoperability

The Flexibility Register provides a crucial value to the flexibility market, which is interoperability. This means that the platform is designed to ensure seamless interaction and compatibility among various stakeholders, including FSPs and SOs. Here's why interoperability is so important:

- **Consistency in Requirements and Processes:** The Flexibility Register enforces a consistent set of requirements and processes that apply uniformly to all FSPs. These requirements are jointly defined and agreed upon by SOs. This means that the technical specifications, operational procedures, and other aspects are standardized and consistent across the entire market. This standardization eliminates confusion and ensures that everyone involved understands the rules and expectations.
- **Unified Understanding:** Because the requirements are established collectively by SOs, there is a shared understanding of technical requirements and other essential aspects. This unified understanding extends to both SOs and FSPs, ensuring that everyone speaks the same language when it comes to flexibility services. It creates a common ground for communication and collaboration.
- **Clarity and Predictability:** Market participants, including FSPs, have a clear understanding of the processes and technical requirements set forth by the SOs. This clarity leads to predictability in market interactions. FSPs know what is expected from them, and SOs understand what to anticipate from FSPs. This reduces the likelihood of misunderstandings or disputes.

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- **Reduced Uncertainty:** The standardized and clear processes minimize uncertainties and ambiguities in the market. SOs do not need to allocate additional effort to clarify uncertainties or teach/train other parties on the market's intricacies. This streamlines market operations and reduces administrative burdens.
- **Efficient Market Functioning:** Interoperability enhances the efficiency of the market. When all participants are on the same page regarding requirements and procedures, transactions can proceed more smoothly and swiftly. This efficiency benefits the overall functionality of the flexibility market.
- **Cross-Border Cooperation:** Interoperability is especially valuable in situations involving cross-border or regional cooperation. When multiple regions or countries share a common understanding and standardized processes, it facilitates collaborative efforts and market integration, further enhancing the effectiveness of the flexibility market.

In essence, the Flexibility Register's commitment to interoperability ensures that the flexibility market functions smoothly and efficiently. It reduces complexity, minimizes confusion, and fosters a collaborative environment where all stakeholders can operate effectively and confidently.

4.3 Value drivers of TSO-DSO Coordination Platform

4.3.1 Constraint setting process

The primary objective of the TSO-DSO Coordination Platform is to facilitate and coordinate the activities between TSOs and DSOs concerning the procurement and utilization of flexibility services. This coordination is crucial because the assets used in flexibility services can have both positive and negative effects on one or more interconnected SOs. Let's delve into the reasons why this coordination is essential and how the platform achieves it:

- **Resource Location and Impact:** In the context of flexibility services, a scenario may arise where a TSO decides to purchase flexibility to balance its grid operations. However, the assets providing this flexibility are physically located within the DSO's grid. When these flexibility assets are activated, they can potentially lead to congestion or voltage-related issues within the DSO's grid. And vice versa, flexibility activations in DSO grid can have impact for TSO operations.
- **Minimizing Negative Impact:** To prevent such situations, when one SO's actions can have impact on other SO, the TSO-DSO Coordination Platform plays a critical role in estimating the potential impact of flexibility assets before and during the procurement and utilization, this is done by evaluating the impact of flexibility activation in another SO's grid. By doing so, it aims to minimize the adverse effects on the SO's grid, avoiding and resolving congestion, voltage or balancing problems that could disrupt the stability of the network.

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- **Assessing Positive Impact:** Beyond mitigating negative impacts, the platform also assesses the potential positive impacts of flexibility assets on multiple SOs. This means that while procuring flexibility to address specific needs, the platform evaluates how these resources can benefit not just the requesting SO but also other interconnected SOs.
- **Network Element and Flow Information**: To accomplish these objectives, the TSO-DSO Coordination Platform requires access to essential network element connection data and information on flow restrictions within the grid (grid topology, power transmission distribution factors). This data helps the platform make informed decisions about the deployment and activation of flexibility assets.

The coordination platform serves as a vital bridge between TSOs and DSOs, ensuring that the procurement and utilization of flexibility services are conducted in a way that minimizes negative impacts, maximizes positive contributions, and maintains the overall stability and reliability of the energy grid. It achieves this by requesting crucial network information from concerned SOs and conducting impact assessments before the actual deployment of flexibility resources. Moreover, T&D-CP acts as an optimization operator of flexibility for multiple SOs. It represents multiple SOs on multiple marketplaces cross-borders.

4.3.2 Optimization process

The TSO-DSO Coordination Platform delivers significant value through its optimization process, which is instrumental in enhancing the efficiency of flexibility service procurement. Here's how this optimization process works and why it is so valuable:

- **Consideration of Multiple SO Needs:** The optimization process takes into account the flexibility service requirements of multiple System Operators (SOs). Rather than addressing each SO's needs in isolation, it seeks opportunities to identify flexibility assets that can simultaneously fulfill the requirements of multiple SOs. This consideration of multiple needs is crucial for maximizing the utilization and value stacking of potential flexibility resources.
- **Reducing Resource Consumption:** By identifying flexibility assets that can address the needs of multiple SOs, the platform reduces the overall consumption of available system resources. This optimization ensures that these resources are used efficiently and effectively. It minimizes the duplication of procurement efforts, ultimately conserving valuable system resources.
- **Limiting Over-Procurement:** Over-procurement of flexibility services can lead to excess resource usage and unnecessary costs. The optimization process helps prevent over-procurement by economically matching multiple SO requirements with available flexibility bids. This reduces the risk of excessive purchases of flexibility services, which could strain the grid and inflate operational expenses.
- **Most cost-effective solutions**. The optimization process is a strategic approach aimed at identifying and implementing solutions that maximize economic efficiency. It primarily centers on addressing the

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requirements of all SOs involved in the process, ensuring that these solutions offer the highest level of cost-effectiveness while meeting their individual and joint needs.

Example Scenario: the DSO procures a flexibility service to alleviate congestion in its grid. Simultaneously, this same flexibility service has the potential to address the balancing needs of a TSO. The optimization process would recognize this synergy and suggest that the flexibility service be deployed to benefit both the DSO and TSO enabling value-stacking. This joint usage optimizes resource allocation and maximizes the value derived from the flexibility asset.

The TSO-DSO Coordination Platform's optimization process offers substantial value by considering the flexibility needs of multiple SOs. It identifies opportunities for resource sharing, reduces resource consumption, and limits the risk of over-procurement. This collaborative approach enhances the efficiency and cost-effectiveness of flexibility service procurement while ensuring that system resources are used judiciously to meet the diverse needs of the energy grid.

The optimization module operates during every market session, corresponding to each market clearing event aimed at procuring flexibility through a distinct market product. In the Northern demonstration, there are several products designed to meet various requirements of system operators. The optimization module is created using a general and scalable approach that can be employed for various flexibility products, ensuring alignment with the system operators' needs associated with that particular product. The optimization module role in the Northern cluster is depicted in Figure 4.1.

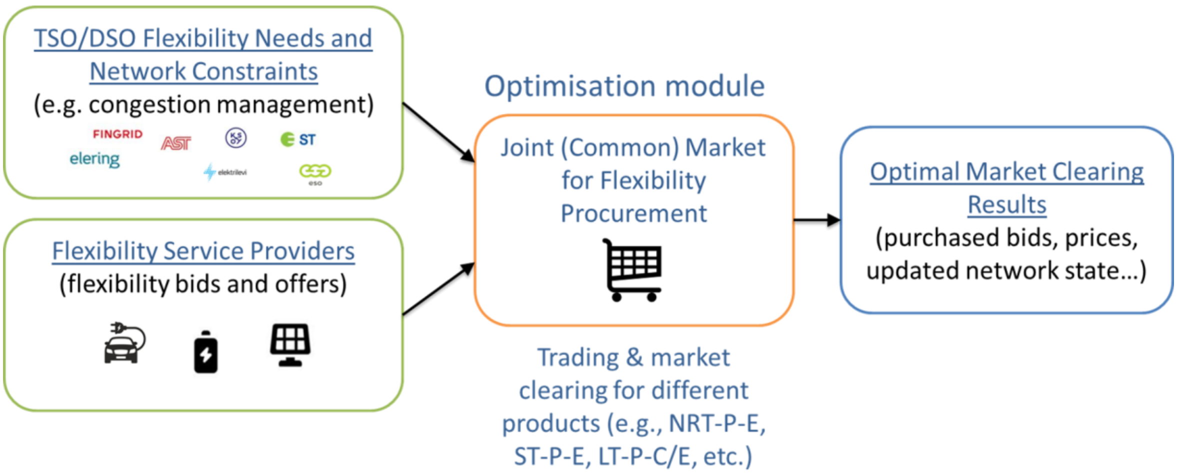

Figure 4.1 General overview of the optimization module [3]

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4.3.3 Flexibility Call for Tender process

The TSO-DSO Coordination Platform can start a Flexibility Call for Tender, which can be initiated in response to a System Operator (SO) need. Here's how this process works and why it offers valuable advantages:

- **Initiating a Tender:** An SO identifies a specific need for flexibility services and communicates this need to the coordination platform. This could be a requirement to address balancing, congestion, voltage issues, or any other grid-related challenge. The SO specifies the details of this tender to the coordination platform.
- **Information Sharing:** The coordination platform plays a crucial role by disseminating this tender information to both MOs and other impacted SOs. This sharing of information ensures that all relevant parties are aware of the SO's requirements and intentions.
- **Existing or New Tender:** Following the information sharing step, MOs respond to the coordination platform. They indicate whether a similar or relevant tender for the identified need already exists within the market, or if a new tender is initiated. This step allows for a streamlined decision-making process.
- **Efficient Communication:** This flexible process eliminates the need for direct communication between SOs and MOs to open a new tender. Instead, the coordination platform acts as an intermediary, simplifying and automating the process. SOs can efficiently communicate their needs without the administrative overhead of direct interactions.
- **Expanded Pool of MOs:** By involving the coordination platform, SOs can reach a broader spectrum of potential MOs capable of conducting the tender. This expanded reach increases the chances of finding suitable MOs who can efficiently organize and manage the procurement process.

In brief, the Flexibility Call for Tender process, facilitated by the TSO-DSO Coordination Platform, streamlines the initiation of tenders in response to SO needs. It enhances information sharing, reduces administrative burdens, and broadens the pool of potential MOs, ultimately contributing to a more efficient and responsive flexibility market.

4.4 Value drivers of market platform

4.4.1 Value stacking

Value stacking refers to a situation where a single product or flexibility resource can serve multiple purposes or satisfy the needs of multiple SOs. This concept has several important implications and benefits:

- **Versatility of Products**: When a product can be used to address various SOs' needs, it underscores the versatility and adaptability of that product. Instead of developing specialized solutions for each individual requirement, a single product can serve multiple purposes.

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- **Optimized Resource Utilization:** Value stacking optimizes the utilization of flexibility resources. Rather than dedicating resources to highly specific needs, which may not always be in demand, products that offer value stacking can be applied more broadly. This ensures that resources are used efficiently and effectively.
- **Multi-Service Products:** Some products can be designed to provide multiple services simultaneously. For instance, a product may be suitable for both balancing the grid and managing congestion. This versatility simplifies the procurement process and reduces the complexity of managing multiple products.
- **Streamlined Procurement:** Different DSOs and TSOs can procure the same product to fulfill their distinct requirements. This harmonization means that FSPs do not need to customize their assets / resource groups for each SO, reducing the administrative overhead and simplifying procurement procedures.
- **Market Liquidity:** The availability of products with value stacking capabilities increases market liquidity. SOs have more choices when acquiring flexibility services because they can select products that are adaptable to their specific needs. This variety fosters competition among FSPs and ensures that services are procured at competitive prices.
- **Resource Availability:** Value stacking also ensures that resources are available to address a wide range of grid challenges. SOs can tap into a pool of resources that offer multiple benefits, enhancing the grid's resilience and reliability.

In short, value stacking is a strategy that maximizes the utility of flexibility products and resources by allowing them to fulfill multiple roles and meet various SOs' needs. This approach streamlines procurement, promotes resource efficiency, and enhances the overall liquidity and flexibility of the market.

4.4.2 Harmonized Product definition

The Flexibility Register provides harmonized definition of flexibility products. These harmonized products are established through a consensus among SOs that are part of the platform. All MOs that are using the Flexibility Register must comply with these values. Here's why this harmonization process is valuable and how it benefits market participants:

- **Agreed-Upon Standards:** The harmonized products represent a set of standardized definitions that have been collectively agreed upon by all participating SOs. This consensus ensures uniformity and consistency in how flexibility products are defined and understood across the market.
- **Compliance Requirement for MOs:** MOs using the Flexibility Register must adhere to these standardized product definitions. This requirement enforces the use of common terminology and specifications, reducing the risk of misunderstandings or discrepancies in product descriptions.

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- **Accessible Understanding**: The products are formulated in a way that is comprehensible to all market participants. This ensures that the product descriptions are clear and easily understood, regardless of the region or organization involved. Consequently, SOs do not need to expend additional effort specifying flexibility products that are tailored exclusively to their needs.
- **Resource and Time Savings**: By adopting harmonized product definitions, SOs can save resources and time. They avoid the need to individually develop and document product specifications. Instead, they can rely on the established harmonized definitions, streamlining their operational processes.
- **Market Expansion for FSPs:** Harmonization of products benefits FSPs as well. Since the products are consistent across all regions participating in the platform, FSPs can more easily expand their activities into different markets without the burden of adapting to varying product definitions. This promotes market access and encourages the growth of FSPs. The use of harmonized product definitions simplifies market interactions. It encourages more FSPs to participate because they can offer services based on standardized product definitions.

The harmonization of flexibility product definitions within participating MOs ensures clarity, consistency, and accessibility in the market, reduces administrative burdens for SOs, promotes FSP expansion, and ultimately enhances market liquidity, making it a valuable asset for efficient and effective grid management.

4.4.3 Centralized activation process

SOs relay their activation requirements for all flexibility products to the TSO-DSO Coordination Platform, which subsequently transmits this information to MOs. This means that SOs are not required to directly engage with flexibility providers, as MOs handle this task on their behalf. Here's a breakdown of the advantages this process offers to SOs:

- **Streamlined Communication:** The process centralizes communication related to flexibility service activation needs. SOs can report their needs efficiently and conveniently to the MOs through TSO-DSO Coordination Platform, ensuring a structured and organized communication channel.
- **No Direct Contact Requirement:** A significant benefit for SOs is that they are not obliged to directly reach out to flexibility providers. The market platform acts as an intermediary, handling the communication between the SOs and FSPs. This eliminates the need for individual direct interactions, saving time and effort.

In summary, the process of informing about flexibility service needs and issuing activation orders through the market platform offers notable advantages to SOs. It simplifies communication, improves efficiency, eliminates the requirement for direct contact with FSPs.

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4.5 Value drivers of other internal tools and generic values

4.5.1 Cost-effective network utilization

The primary motivation for using flexibility services arises from the need to enhance the cost-effectiveness of utilizing existing energy infrastructure. This is a crucial consideration for SOs for several reasons, and one of the most compelling aspects is the ability to optimize the current infrastructure without resorting to substantial physical investments. Here's a more detailed exploration of this concept:

- **Cost Optimization:** The fundamental objective behind deploying flexibility is to maximize the utility of the energy grid while minimizing operational expenses. This is especially vital in an environment where infrastructure upgrades or expansions can be prohibitively expensive. By using flexibility, SOs can achieve their grid management objectives in a more economical manner.
- **Capacity Enhancement:** Flexibility enables SOs to enhance the capacity and efficiency of their existing infrastructure. They can transmit more energy through the power system without the need for extensive capital investments in new substations, lines, or other physical assets. This capacity enhancement is achieved by dynamically adjusting grid operations.
- **Grid Resilience and efficiency:** Flexibility solutions contribute to grid resilience by empowering SOs to respond swiftly to changes in demand and generation. This adaptability reduces the risk of grid overloads or disruptions during periods of high demand or unforeseen events, ultimately improving the reliability of the energy supply. By effectively utilizing flexibility, SOs can fine-tune grid operations based on real-time conditions. This results in more efficient energy transmission and distribution, reducing energy losses and improving overall system performance.
- **Environmental Impact:** Cost-effective utilization of existing infrastructure also has positive environmental implications. It can lead to reduced resource consumption and emissions associated with constructing and maintaining new infrastructure, aligning with sustainability goals.

Essentially, employing flexibility allows SOs to fine-tune grid operations, best utilize energy transmission capacity, and improve the cost-efficiency of energy management. This strategy reflects a wise and environmentally mindful approach to navigating the ever-changing energy landscape while efficiently utilizing existing infrastructure.

4.5.2 Interoperability in general

The architecture of the flexibility market, when designed as a cohesive system, offers several advantages, particularly in terms of information management and operational processes. Let's delve into the key points behind this concept:

- **Efficiency through Standardization:** One of the central benefits of a well-designed flexibility market architecture is the standardization of processes, products, and information exchange. This standardization streamlines market operations, making them more efficient and predictable. Standardized procedures reduce complexities and uncertainties, leading to smoother interactions among market participants, moreover it simplifies the process for new entrants to participate in the market.
- **Enhanced Market Efficiency:** By standardizing these aspects, the market becomes more efficient overall. Market participants can navigate the processes with greater ease, which in turn accelerates decision-making and transactions. This efficiency is crucial for ensuring that flexibility resources are used where they provide the most value within the energy system.
- **Geographical Expansion:** When flexibility market processes are designed on a larger scale, they extend their benefits to a broader geographical area. This means that multiple regions or countries can collaborate on the design and implementation of these processes. This expansion leads to more comprehensive and efficient cross-border markets.
- **Optimal Resource Allocation**: A well-structured flexibility market allows for the optimal allocation of resources across a wider area. It facilitates the identification of available flexibility sources and their utilization in a way that maximizes the benefits for all participating regions or countries. This, in turn, contributes to improved grid management and resilience.
- **Cost Savings**: Standardization and efficiency improvements often lead to cost savings. Market participants can reduce administrative overhead, compliance costs, and the complexity of navigating various regional requirements. These cost savings can be passed on to consumers, ultimately leading to more cost-effective energy services.
- **Adaptation to Evolving Energy Landscape:** The flexibility market architecture is designed to adapt to the dynamic nature of the energy landscape. As new technologies, regulations, and market dynamics emerge, a well-structured architecture can be updated and modified to accommodate these changes, ensuring its continued relevance and effectiveness.

A well-planned flexibility market architecture, characterized by standardization, efficiency, and cross-border collaboration, offers multiple advantages. It promotes more efficient market operations, facilitates optimal resource allocation, and adapts to the evolving energy landscape. This approach ensures that flexibility resources are harnessed where they provide the greatest value, benefiting both market participants and the overall energy system.

4.5.3 Increasing liquidity

An effective flexibility market design operates as a cohesive system that optimally connects buyers (SOs) and sellers (FSPs). This synergy between buyers and sellers is crucial for enhancing the overall efficiency and

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effectiveness of the market. Here's a detailed explanation of how this integrated market design benefits both SOs and FSPs:

- **Efficient Matching of Supply and Demand:** When the flexibility market is well-designed, it facilitates the efficient matching of supply (flexibility services offered by FSPs) and demand (flexibility needs of SOs). This means that SOs can readily access a broader pool of available flexibility resources that meet their specific requirements.
- **Expanded Market Opportunities:** FSPs benefit from an integrated market design as it provides them with enhanced opportunities to conduct trades. With demand originating from different regions or markets, FSPs have a larger customer base and a wider market reach. This diversification of opportunities can lead to increased trading volumes and revenue potential for FSPs.
- **Enhanced Liquidity:** A well-connected flexibility market boosts liquidity by bringing together a multitude of buyers and sellers. Increased liquidity is advantageous for all market participants as it ensures that there are ample trading opportunities and readily available resources. This fosters a more dynamic and competitive marketplace.
- **Profitable Participation:** The higher liquidity and expanded market opportunities make participation in the flexibility market more profitable for all market players, including both SOs and FSPs. SOs can source flexibility at competitive prices, optimizing their grid operations, while FSPs can secure more contracts and revenue streams.
- **Market Resilience:** An integrated market design also contributes to the overall resilience of the flexibility market. By connecting various areas, regions and participants, it reduces the risk of localized market disruptions. In some cases, if one area experiences a shortage of flexibility, resources from other areas can step in to compensate, ensuring grid stability.
- **Innovation and Competition:** An efficient market design encourages innovation among FSPs. To remain competitive and attract customers from diverse markets, FSPs may develop new and improved flexibility solutions. This competition fosters the development of innovative technologies and services that benefit the entire energy ecosystem.

A well-structured flexibility market that seamlessly connects buyers and sellers, channeling demand from different regions or markets, has several advantages. It provides SOs with greater access to flexibility resources, offers FSPs expanded trading opportunities, enhances market liquidity, increases profitability for all participants, improves market resilience, and stimulates innovation and competition. This integrated approach contributes to a vibrant and dynamic flexibility market that benefits the energy industry as a whole.

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4.5.4 Competition between the market operators

A market design that enables flexibility offers to reach the SOs from multiple MOs brings competition among MOs, such a framework introduces a competitive dynamic that drives innovation and benefits all market players:

- **Competition among MOs:** When multiple MOs are involved in delivering flexibility services to SOs, they naturally compete with each other to attract and serve their respective customer base. This competition is highly beneficial as it motivates MOs to continually innovate and enhance their services. In a competitive environment, MOs are compelled to offer more efficient, reliable, and cost-effective solutions.
- **Choice for FSPs:** FSPs benefit from this competition among MOs as it provides them with a wider range of options when selecting a MO to work with. FSPs can evaluate the services, pricing structures, and reliability of different MOs and choose the one that aligns best with their specific needs and business goals. This choice empowers FSPs to optimize their costs and select the most suitable partner for their flexibility services.
- **Market Development:** Competition among MOs fosters the development and maturity of the flexibility market. It leads to the establishment of standardized practices, transparent pricing models, and efficient market mechanisms. These factors contribute to the growth and stability of the flexibility market, making it more attractive for all participants.

In summary, a market design that encourages competition among MOs has a cascading effect on the entire flexibility ecosystem. It spurs innovation, promotes cost efficiency for FSPs, offers choices to FSPs, contributes to market development, and ensures the delivery of high-quality and reliable flexibility services to SOs. This competitive environment is instrumental in advancing the flexibility market and driving improvements in grid management.

4.6 Possible constraints limiting value generation

An essential aspect to take into account when assessing potential value drivers associated with flexibility-enabling tools is the identification of constraints that could hinder or restrict the anticipated benefits. By identifying and addressing these constraints, the value generated by flexibility-enabling tools can be truly maximized. This sub-chapter will therefore outline the key factors that may have negative impact on the value drivers.

4.6.1 Regulatory Barriers

The presence of regulatory barriers poses a noteworthy constraint on the implementation of flexibility-enabling tools. Government regulations and policies that impose restrictions on the utilization of new technologies or the provision of specific services can significantly impede the progress and adoption of these

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tools. Such regulations can create barriers that hinder the smooth integration of innovative solutions, limiting the benefits that could otherwise be realized from these tools. These regulatory hurdles may encompass various aspects, such as compliance requirements, legal limitations, or the need to obtain permits, all of which can slow down or complicate the implementation process. It's imperative to navigate these regulatory challenges effectively to ensure the successful deployment and realization of value from flexibility-enabling tools.

4.6.2 Market Structure and uncertain market conditions

The current configuration and dynamics of energy markets are crucial factors to consider in understanding constraints on value generation through flexibility-enabling tools. When these markets are characterized by monopolistic entities or feature limited competition, the ability to fully harness the benefits of such tools may be hampered. Monopolies, for example, often result in limited innovation and reduced incentives for efficiency. The presence of few competitors may restrict the availability of diverse and cost-effective flexibility options. In such environments, introducing new tools or enabling flexibility could face resistance or limited adoption due to vested interests or market control, potentially constraining value generation.

On the other hand, too rapid development of new markets can bring uncertain conditions. The volatile and ever-evolving nature of energy markets introduces a different set of challenges. Rapid changes in market conditions, economic fluctuations, and unexpected events can all have a profound impact on the value generated by flexibility-enabling tools. These uncertainties may manifest themselves as sudden shifts in energy demand or supply, changes in market prices, or unforeseen grid disturbances. This unpredictability can make it challenging to realize the full potential of flexibility tools, as the ability to forecast and optimize operations can be compromised. Adapting to rapidly changing circumstances is a critical consideration when assessing the constraints that uncertain market conditions may impose on value generation.

4.6.3 Technological Limitations and risks

An essential aspect to consider when assessing constraints on value generation is the presence of technological limitations in the systems and resources used by SOs or market participants. Outdated or incompatible technology infrastructure within energy systems can significantly impede the effective use of flexibility-enabling tools. Outdated systems may not seamlessly integrate with modern technologies or the latest flexibility solutions. Incompatibility can result in data transfer issues, communication breakdowns, or inefficient operations, all of which can hinder the value these tools can bring. Moreover, aging technology can be more susceptible to cybersecurity threats, potentially exposing critical systems to vulnerabilities. The need for enhanced security measures can consume resources that might otherwise be used for value-generating purposes. Modern flexibility solutions often rely on extensive data collection and analysis. Outdated technology may struggle to manage, process, and analyze large volumes of data effectively. Inadequate data handling can hinder the optimization and decision-making processes, limiting the value generated.

To mitigate these technological limitations, it may be necessary to invest in upgrading or modernizing the existing technology infrastructure and systems. Such efforts can not only enhance the value of flexibility tools but also improve the overall reliability and efficiency of energy systems.

Another important aspect to consider is that some risks may arise associated with implementing new technologies or the potential for technical failures. This can include issues related to integrating these tools into existing systems, ensuring data compatibility, and managing the transition. Any challenges during the implementation phase can lead to delays and potentially hinder the tools' ability to generate value promptly. The risk of technical failures or malfunctions is ever-present when working with new technologies. Such failures can disrupt system operations, resulting in service outages, data losses, or other undesirable consequences. In the context of flexibility tools, technical failures can reduce their reliability and overall value.

4.6.4 Financial Barriers

Financial barriers are a significant constraint that can impede the ability of flexibility-enabling tools to generate value. These barriers encompass various aspects, including the substantial upfront capital investments required for implementing these tools, as well as ongoing operational costs related to maintenance and support. The allocation of financial resources among competing priorities can limit the availability of funds for flexibility solutions, especially when budgets are stretched thin. Uncertainty regarding the expected return on investment can lead to hesitancy in making financial commitments, delaying the realization of value. Cost-benefit analyses must demonstrate that the benefits of flexibility tools outweigh their costs to secure investment. To overcome these financial barriers, strategies like seeking external funding, comprehensive return of investments assessments, strategic budgeting, cost-sharing, and emphasizing long-term value should be explored.

4.6.5 Data Privacy and Security

Data privacy and security issues can significantly impede the adoption of flexibility solutions and tools in various ways. First, there may be concerns related to the collection, storage, and sharing of sensitive data. For instance, flexibility tools often require the exchange of real-time or historical data related to energy consumption or production, grid conditions, etc. However, stakeholders may worry about how this data is handled, who has access to it, and whether it might be vulnerable to unauthorized access or breaches. These concerns can result in reluctance to participate in flexibility programs. Additionally, regulatory compliance can be a significant challenge. Meeting these requirements can be complex and costly, acting as a constraint to the adoption of flexibility tools. Furthermore, there is a broader issue of trust. When consumers or energy providers are uncertain about the security of their data and the privacy of their information, they may be less inclined to participate in flexibility programs or use enabling tools. Trust is essential for the successful implementation of these solutions.

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In summary, data privacy and security concerns can hinder the adoption of flexibility solutions by raising questions about how data is handled, whether it complies with regulations, and whether it can be trusted to remain secure and confidential. Addressing these concerns is crucial to overcoming these constraints and fostering the adoption of flexibility tools.

4.6.6 Skills and Expertise

The availability of skilled personnel and expertise in using flexibility tools is pivotal, significantly influencing the tools' effectiveness and successful deployment. A shortage of skilled professionals who comprehend these tools can impede their efficient use in several ways. Firstly, it can result in the underutilization or inefficient operation of these tools due to their often intricate features and functions. Moreover, skilled experts play a crucial role in optimizing these tools, fine-tuning configurations, and implementing strategies for grid stability, energy efficiency, and cost savings. Their absence can hinder the achievement of desired outcomes. Skilled personnel are also vital for troubleshooting technical issues, performing necessary maintenance, and interpreting data effectively for valuable insights. Integrating these tools with existing infrastructure, providing training, and ensuring seamless knowledge transfer are additional areas where expertise is essential. In summary, the presence of skills and expertise is integral to realizing the full potential of flexibility tools, whereas their absence may pose constraints in leveraging the tools' capabilities to address grid challenges and enhance energy management.

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5 Evaluation of Northern Cluster demonstration results

One of the objectives of Task 7.5 was to evaluate and compare the outcomes of the demonstrations' efforts against the defined value drivers that were established in Chapter 4 above. This evaluation holds the key to assessing the overall success of the demonstration and serves as a crucial step in determining the real-world impact of Northern Cluster initiatives.

The estimation is carried out by the use of Key Performance Indicators (KPIs), which have been thoughtfully selected from D2.4 "OneNet priorities for KPIs, Scalability and Replicability in view of harmonized EU electricity markets" [11]. Moreover, some additional KPIs were added by Task 7.5. These KPIs offer a numerical framework for gauging various aspects of Northern Cluster demonstration's performance and value delivery.

It's important to note that while KPIs offer valuable quantitative insights, their results are intrinsically tied to the scale and scope of the demonstration itself. As such, they may not fully encapsulate the entire spectrum of value generated.

The list of KPIs which will be used to evaluate Northern Cluster demonstration is provided in Table 5.1. It's worth highlighting that the values stemming from "Other internal tools and generic values" will not be evaluated. This decision was made taking into account the fact that not all SOs are utilizing internal tools during the demonstration, rendering it challenging to comprehensively represent the value associated with these internal tools in the assessment.

Table 5.1 KPIs list for value drivers

Value driver	KPI / question
Flexibility Register	
Transparency and visibility	Time required for access to information about flexibility availability, market participants, FPS resources, FPS resources' technical capability, FPS resources' prequalification status (Added by T7.5)
	Number of iterations (number of steps) to find information about: flexibility availability, market participants, FPS's resources, FPS resources' technical capability, FPS resources' prequalification status (Added by T7.5)
FSP prequalification in regional market	Number of demonstrated cross border products
	Number of demonstrated joint products
	Number of FSPs participating in more than one country
Resource Quality / Integrity	Number of FSPs
	Percentage of successfully prequalified FSPs
	Verification method accuracy
Process automation	Level of automation of SUC process steps (the ratio of automated steps to all process steps)

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Process interoperability	Number of requests for clarification of market requirements
TSO-DSO Coordination Platform	
Constraint setting process	Number of conflicts resulting from flexibility product activation
	Number of avoided technical restrictions (congestions)
Optimization process	Speed of bid optimisation algorithm
	Speed of grid qualification algorithm
Flexibility Call for Tender process	Number of coincident tenders for flexibility services (Added by T7.5)
	Number of times SO needed to contact MO to open a new tender (Added by T7.5)
Market Platform	
Value stacking	Number of implemented cross border products
	Number of implemented joint products
Harmonized Product definition	Number of implemented products
Centralized activation process	Number of activated products/ services (Added by T7.5)

It's important to highlight that at the time of writing this report, the demonstrations within the Northern Cluster have not been concluded yet. It was decided not to conduct a partial evaluation of the demonstration, as such an assessment would be incomplete and wouldn't offer a comprehensive perspective. Consequently, the evaluation will be undertaken once all four Northern Cluster countries have successfully completed their demonstrations. The outcomes of this evaluation will be detailed in OneNet Deliverable D7.6.

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6 Conclusions

In the pursuit of advancing the understanding of market-driven flexibility and the transformative potential of flexibility-enabling tools, this report has undertaken a systematic exploration of the value landscape for TSOs and DSOs. Throughout this investigation, several key insights have emerged, shaping comprehension of the tangible benefits brought forth by these innovative approaches.

The mapping of flexibility needs has provided a critical foundation for this exploration, ultimately leading to the identification and scrutiny of five distinct flexibility products that will be demonstrated in Northern Cluster. These products, with their universal applicability to both TSOs and DSOs, offer a versatile toolkit for addressing a vast array of grid challenges, encompassing areas such as balancing, congestion management, voltage control, and more. Their adaptability and relevance underscore their significance in the evolving energy landscape.

Simultaneously, the examination of flexibility-enabling tools has illuminated their pivotal role in generating value for SOs. The tools in focus, including the Flexibility Register, TSO-DSO Coordination Platform, market platforms, and various internal tools, have been found to contribute significantly to the efficiency and effectiveness of grid management. Their impact is multifaceted, encompassing aspects such as transparency and visibility, simplified qualification processes for FSPs, resource quality assurance, process automation, interoperability, constraint management, optimization, and value stacking, among others. These tools, as demonstrated, not only streamline operations but also foster innovation and collaboration.

While creating and integrating flexibility enabling tools, it is vital to remember the potential limitations and constraints that may limit value generation. Therefore, regulatory barriers, market structure and uncertain market conditions, technological limitation and risks, financial barriers, data privacy and security and finally skills and expertise should be taken into account and addressed in timely manner when applying flexibility enabling tools out of OneNet scope.

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