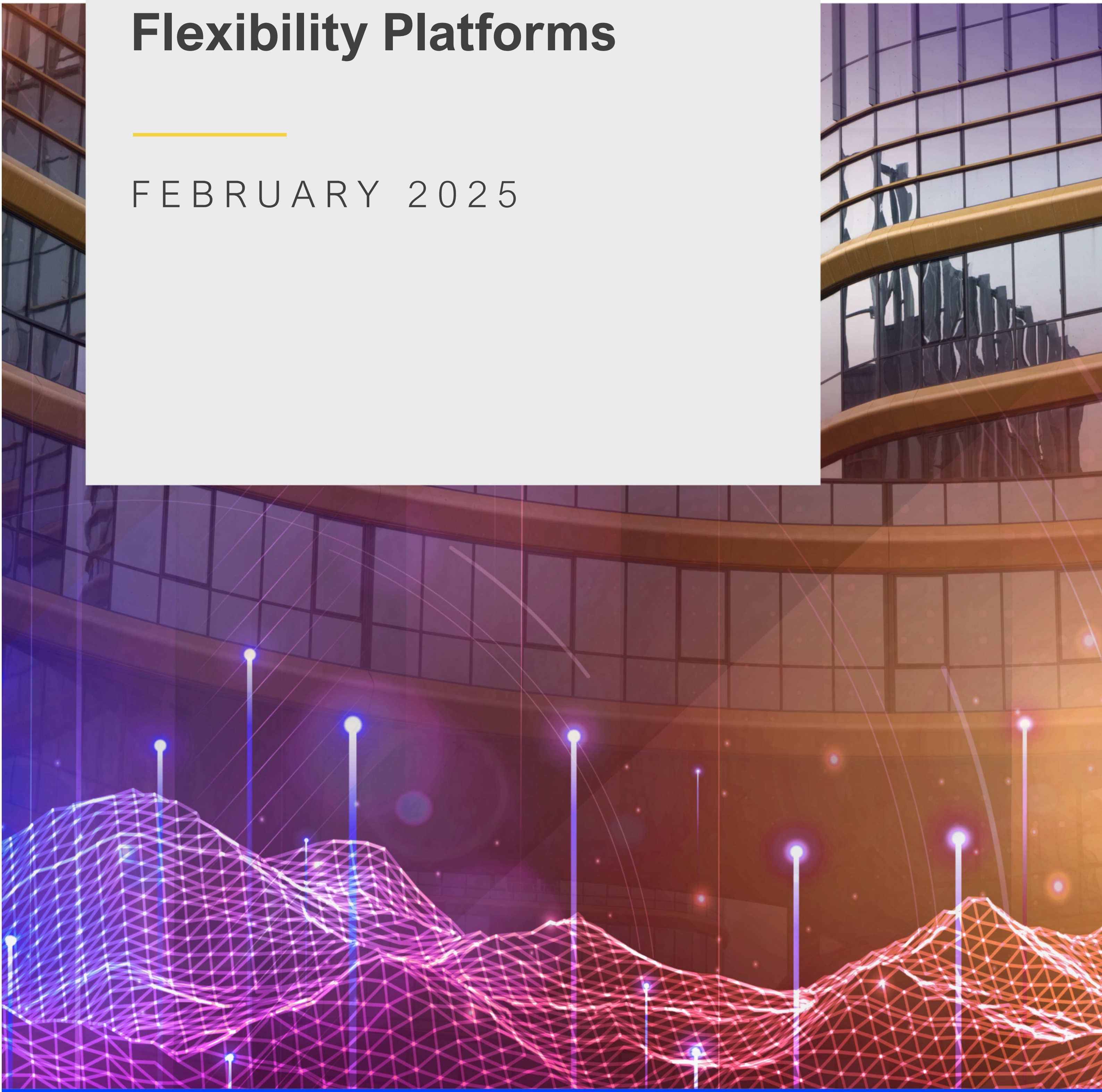
Efficient, Demand Flexible Networked Appliances EDNA

Overview of Flexibility Platforms

FEBRUARY 2025



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The Efficient, Demand Flexible Networked Appliances Platform of 4E (EDNA) provides analysis and policy guidance to members and other governments aimed at improving the energy efficiency and demand flexibility of connected devices and networks.

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EDNA - Efficient, Demand Flexible Networked Appliances

Overview of flexibility platforms

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Content

Abbreviations

BRP	Balancing Responsible Party
DER	Distributed Energy Resources
DFP	Demand Flexibility Platform
DSO	Distribution System Operator
EMS	Energy Management System
FSP	Flexibility Service Provider
TSO	Transmission System Operator
VPP	Virtual Power Plant

Definitions

Concept	Definition	Source
Flexibility	Power system flexibility is defined as the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales.	(IEA, 2018)
Distributed Energy Resources (DER)	DER are small-scale energy resources connected to the distribution grid and usually situated near sites of electricity use, such as rooftop solar panels and battery storage.	(IEA, 2022)
Transmission System Operator (TSO)	A TSO is mainly responsible for transporting energy at the national and/or regional levels while maintaining the security and stability of the power system. The responsibility of the TSO covers constraint management, adequacy, and balancing	(ISGAN, 2024)
Distribution System Operator (DSO)	A DSO manages the distribution of energy at a local or regional level. The responsibility of the DSO covers grid constraint management as well as operation and maintenance of equipment.	(ISGAN, 2024)
Balancing Responsible Party (BRP)	BRP is financially responsible for its portfolio imbalance settlement of access points called the balancing group. Each balancing group is assigned to a control area of a TSO, who monitors the frequency as an indicator for the electricity balance and thus for system stability. If a BRP causes imbalance in the system, the TSO charges them or vice versa reimburses if it counters a frequency deviation.	(ISGAN, 2024)
Balancing Service Provider (BSP)	Provides balancing services to help maintain the overall balance of the electricity grid; such as adjusting generation levels, activating reserve capacity, or participating in demand response programs	(gridX, 2024)
Prosumer	Is an entity who both consumes and produces energy.	(Office of Energy Efficiency and Renewable energy, 2017)
Active customer	A final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises.	(EU, 2019)
Passive customer	Is a consumer of energy that does not take an active role in the energy market. The opposite of an active consumer.	
Aggregator	An aggregator is seen as an intermediary between other electricity market players. The main function of aggregator roles can be seen as bundling of services such as aggregating flexibilities, providing automation, participating in energy markets, and managing risks.	(ISGAN, 2024)

Implicit Demand-Side Flexibility	This type of Demand-Side Flexibility is also known as "price-based" Demand-Side Flexibility. It involves consumers responding to price signals by adjusting their energy usage. When consumers have the option to choose hourly or shorter-term market pricing that reflects fluctuations in the market and the network, they can modify their behaviour - either through automation or personal decisions - to reduce energy costs.	(SEDC, 2016)
Explicit Demand-Side Flexibility	This form of Demand-Side Flexibility is also known as "incentive-driven" Demand-Side Flexibility. It involves committed, dispatchable flexibility that can be traded, much like generation flexibility, across various energy markets, including wholesale, balancing, system support, and reserves markets. It is typically facilitated and managed by an aggregator, which may be an independent service provider or a supplier.	(SEDC, 2016)
Upward flexibility	Refers to the ability to decrease demand or increase generation	(EEA & Ramboll, 2023)
Downward flexibility	Refers to the ability to increase demand or decrease generation	(EEA & Ramboll, 2023)

1 Introduction

The integration of more variable renewable electricity generation necessitates that the electricity system transitions to become both smarter and more flexible to manage the challenges that arises from the inherent intermittency of these resources. As an example, it is estimated that to keep up with the growth in variable energy production the flexibility in the European system needs to almost double by 2030 compared to today (ACER, 2023). In this context, flexibility refers to the electricity system's ability to quickly and effectively react to imbalances that occur between supply and demand, ensuring stability and reliability. The more flexibility in the system, the more resilient it is to sudden changes in supply or demand.

Flexibility markets have emerged as one approach to manage and increase the flexibility in the electricity system. It is also promoted by the European Commission as a way to reach the EU target of becoming climate neutral by 2050 (The European Commission, 2024). With this approach flexibility on the demand side becomes a service that end-users and other market actors can sell on the market, and in that way participate actively in making the system more stable and resilient. Flexibility platforms is a key player in the flexibility market to facilitate the coordination of flexibility services trading, dispatch and/or settlement, between system operators and flexibility service providers.

By improving the utilization of flexibility in the system, the platforms help address challenges regarding grid congestion and system balancing, creating value for both the flexibility service providers (FSP), the system operators and our societies as a whole.

This report is prepared on behalf of the Efficient, Demand Flexible Networked Appliances (EDNA) platform under the 4E Technology Collaboration Programme (TCP) of the International Energy Agency (IEA) between August 2024 and March 2025.

The report focuses specifically on the flexibility platforms' ability to unlock the use of flexibility from smart appliances in the household and commercial sector. Integrating flexibility from these sectors is challenging, but as the residential and commercial sector is responsible for around 27% and 21% of the world's electricity consumption, respectively, the potential is substantial (IEA, 2021).

The report starts by determining a working definition of flexibility platforms based on definitions proposed in literature. It then continues to delve into the characteristics of flexibility platforms, such as the services they provide and the value they create. This is followed by a short introduction to other topics, which are relevant to the function of flexibility platforms, which leads up to an assessment of the status of flexibility platforms, which is conducted as a combination of desk research and interviews with selected stakeholders.

The objectives and approach of the report are described below:

Objectives:

- Clarify for EDNA members how flexibility platforms can facilitate the utilization of flexibility from networked appliance.
- Identify the current challenges facing flexibility platforms that hinder the effective use of flexibility from networked appliances.
- Compare the identified challenges with EDNA's product policy framework and provide recommendations.

Approach:

- Provide an explanation of how flexibility platforms work.
- Outline the problems they solve and the value they provide.
- Review areas relevant to flexibility platforms.

- Investigate the market for flexibility platforms and conduct interviews with selected platforms.
- Review conclusions from other studies.
- Compare findings with EDNA's product policy framework and provide recommendations.

2 Definition and characterization of flexibility platforms

2.1 Definition of flexibility platforms

A growing amount of literature explores the novel concept of utilizing distributed energy resources to provide flexibility services to mitigate congestion and balancing issues, and on flexibility platforms as being a means to coordinate between system operators and flexibility service providers, to make it possible. However, only a few sources explicitly state a definition of the flexibility platform concept. Through the literature research conducted for this report, four reports were encountered, which contained definitions. The definition made by the Universal Smart Energy Framework (USEF) was also stated as the source for the definitions used in two of the other reports. The organization behind these two reports are The European Smart Grid Task Force and the energy regulator of Great Britain, Ofgem. The last definition is made by European TSO association ENTSO-E. This definition is less concrete but resembles that of the USEF in both phrasing and meaning. What is encompassed by the four definitions is thus understood to be the same. The definition from USEF is chosen as the working definition for this study.

The four definitions are (the selected one in bold, the other ones greyed):

"A flexibility platform is an IT platform where the trading, dispatch and / or settlement of flexibility is facilitated or coordinated." - (USEF, 2018)

"[a Flexibility Platform is…] an IT system that either facilitates or coordinates the trade, dispatch and/or settlement of demand-side flexibility." - (European Smart Grid Task Force, 2019)

"… a flexibility platform is an IT platform where the coordination, trading, dispatch or support services for flexibility markets take place…" - (Ofgem, 2019)

"[Flexibility Platforms are…] Digital platforms that facilitate the provision of flexibility services to System Operators from Distributed Energy Resources" - (ENTSO-E, 2021)

2.2 What needs do flexibility platforms fulfil

Maintaining a balanced and efficient power system is no easy task. It requires, among other things, constant system balancing, which today necessitates a reserve of flexible power plants, often using fossil fuels, and also requires congestion management, a service needed increasingly as more renewable energy is introduced in the grid. System balancing, and congestion management services are the two areas where flexibility platforms are typically highlighted as an enabling solution (USEF, 2018) (ENTSO-E, 2021). These topics will be further elaborated below, and the use for flexibility platforms explained. In short, the flexibility platform facilitates the coordination between system operators and flexibility service providers, to effectively utilize the flexibility of both industrial, commercial and domestic energy consumers, prosumers and storage systems.

2.2.1 System balancing

To avoid disruptions and blackouts in the system, the frequency in the grid must be kept at 50 / 60 hertz (depending on the electricity system) at all times (Smart Grid Task Force, 2015). This is obtained by constantly maintaining a balance between production and consumption of power in the grid. Ensuring this is the responsibility of the Transmissions System Operator (TSO) who delegates some of the responsibility to a Balancing Responsible Party (BRP). The Balancing Responsible Party (BRP) can be a producer, a large consumer, an energy supplier, or an energy trader. The BRP is responsible for managing imbalances within its portfolio of generation and consumption assets and is authorized to participate in electricity market trading. All suppliers and buyers of electricity are associated with a BRP and it is the BRPs' responsibility to match planned production and consumption of power within their portfolio of suppliers and consumers, and inform the TSO on this. If the planned production and consumption turns out not to match the actual production and consumption, imbalance occurs in the system. It is the TSOs responsibility to rectify these imbalances. They do this by procuring different balancing reserves (also known as balancing products or balancing resources) and activate them as needed. Different reserves exist such as frequency containment reserves (FCR), frequency restoration reserves (aFRR/mFRR), fast frequency reserve (FRR) and replacement reserves (RR). Units that are able to deliver these reserves consists of flexible power generating facilities (such as power plants using gas, coal or biomass), energy storage devices and consumers with flexible demand (Smart Grid Task Force, 2015). The reliance on fossil fuel driven power generation facilities as a balancing resource can be reduced, by better utilizing the potential of the energy storage devices and flexible consumers to deliver the needed balancing reserves.

2.2.2 Congestion management

Congestion in a power system can occur when power demand or generation exceeds the grid's transport capacity (Smart Grid Task Force, 2015). In a report prepared for the European Union Agency for the Cooperation of Energy Regulators (ACER) a definition of physical congestion was proposed to be:

"'A network situation on one or several network elements simultaneously where a further increase of power flows on this network element(s) would lead to, or increase, the violation of operational security limits" - (ACER, 2023)

For system operators to solve this congestion they can expand the transport capacity by building new transport infrastructure, however, this requires large investments and takes time, rendering it an infeasible solution for immediate congestion issues. Instead, the system operators must apply congestion management principles. This involves coordinating with the power consumers and producers of the congested area to either reduce consumption or generation of power. Here it is important that balance in the system is maintained, so that e.g. a reduction in consumption in one place is met with a reduction in generation or increase in consumption in another place. Congestion is a challenge that becomes apparent when planning for new sustainable energy capacity. The best locations for harnessing renewable energy are not always aligned with areas where energy demand is highest. As the distance electricity must travel increases, the risk of congestion grows, requiring more infrastructure and increasing the strain on the system. This issue can be mitigated by enhancing flexibility within the power system, allowing for better utilization of existing distribution and transmission structures. Therefore, addressing congestion is crucial to facilitating the integration of more renewable energy.

ACER highlights congestion management as one of the main drivers for unlocking the flexibility potential of DER, but that the market for congestion management services is in its infancy (ACER, 2023).

2.3 What is the value of flexibility services

The value of flexibility in the context provided is multifaceted and benefits various stakeholders, including consumers, market participants, and regulated entities like Distribution System Operators (DSOs) and Transmission System Operators (TSOs). The report 'Regulatory Recommendations for the Deployment of Flexibility' made by the Smart Grid Task Force in 2015, outlines the value for the various parties, see the following sections.

2.3.1 For Providers of Flexibility Services (e.g. household and commercial assets)

Owners of flexible assets can be financially rewarded, both through direct payments and savings on their electricity bill, by making their flexibility available to system operators as a service to meet system needs (Smart Grid Task Force, 2015). The savings on the electricity bill is due to the price of electricity being high when consumers are prompted to use less, and low when prompted to use more. When the consumers sell their flexibility, they also get compensation from the DSOs and TSOs, who use the flexibility to mitigate congestion or balance the grid. As flexibility utilization also results in system operators being able to avoid things like new grid investments, and curtailment of renewable energy, there is furthermore an indirect value creation, as the overall price of electricity and tariffs related to grid management will be reduced.

An analysis of the economic benefits of utilizing flexibility for European consumers in 2030, estimates that more than €71 billion (about 355 EUR/household/year) can be saved annually just for the providers of flexibility services from residential space electric heating, and that more than €300 billion (about 1500 EUR/household/year) can be expected in indirect benefits from demand-side flexibility as a whole, stemming from reductions in energy prices, generation capacity costs, investment needs for grid infrastructure, system balancing costs, and avoided carbon emissions (DNV, 2022). Although the analysis is based on a comparison between two modelled future scenarios, and thus associated with a high degree of uncertainty, it highlights the point that the benefits of increased power system flexibility has a potential that should not be overlooked.

2.3.2 For Users of Flexibility Services (e.g., BRPs, aggregators, TSOs and DSOs):

For TSOs and DSOs flexibility services helps to manage or avoid system congestion (Smart Grid Task Force, 2015). The value from improved congestion management is seen in things such as reduced investments and maintenance costs, as expansion of physical infrastructure can be postponed or sometimes avoided, if congestion issues can be mitigated or solved by utilizing system flexibility.

An example of this is the FlexPlan Horizon 2020 project, which established a grid-planning methodology considering the opportunity to introduce new storage and load flexibility resources in electricity grids as an alternative to building new grid elements (ISGAN, 2023).

An analysis by smartEN on the economic benefits of flexibility in the EU in 2030, estimates that DSOs could save between €11.1-29.1 billion each year between 2023 and 2030, from avoided investments in grid infrastructure (DNV, 2022).

Flexibility services can also be an effective tool for TSOs in balancing supply and demand in the energy system. By fully utilizing demand side flexibility the need for curtailing renewable electricity production when there is not sufficient demand can be reduced. Utilizing demand side flexibility can also reduce the total power generation capacity and the need for back-up power generation by e.g. moving flexible consumption away from periods with high demand or low generation.

Flexibility services could also help BRPs to more effectively manage the balance between supply and demand in their portfolio (Smart Grid Task Force, 2015). Here the value is determined by the avoidance of economic penalties that BRPs would otherwise face from the TSO due to imbalances they incur. However, it is worth noting that BRPs were not found to be active on any of the flexibility platforms reviewed by Frontier Economics in 2021 (ENTSO-E, 2021).

2.3.3 For society as a whole

Better utilizing demand-side flexibility and creating a more flexible electricity system comes with the largest benefits for society as a whole. Increased flexibility means that more renewable electricity can be integrated and better utilized. It further alleviates the reliance on fossil fuel generation by reducing the total need for generation capacity and the need for back-up generation capacity. All of this makes the electricity system more efficient, cheaper and greener. An analysis by SmartEN on the benefits of demand-side flexibility in the EU in 2030, estimates that utilization of demand-side flexibility could reduce GHG emissions in the EU by 37.5 million tonnes CO_{2eq} in 2030, the equivalent of an 8% reduction of the emissions from the EU power sector (DNV, 2022).

2.4 What types of flexibility platforms exists

In the report by Frontier Economics, three general types of flexibility platforms were identified based on their operational models: 1) Administrative flexibility scheme coordinators, 2) Market intermediaries and 3) Marketplaces (ENTSO-E, 2021).

2.4.1 Administrative flexibility scheme coordinators

This category relates to flexibility platforms that do not themselves provide allocation of flexibility services, but instead provides support for the allocation of flexibility by facilitating information exchange between relevant stakeholders (ENTSO-E, 2021) (OneNet, 2023).

2.4.2 Market intermediaries

This category relates to platforms that facilitates the procurement of flexibility services, without handling all the essential functions of a self-contained marketplace itself (ENTSO-E, 2021) (OneNet, 2023). Market intermediaries can provide enabling services such as handling the asset registration and prequalification process for Flexibility Service Providers (FSPs), or by being a gateway for FSPs to interact with grid operators and offer their flexibility on separate trading platforms. The market intermediary platform connects its users with an external marketplace to allow for selling and procuring flexibility services.

2.4.3 Self-contained marketplaces

A self-contained marketplace can handle the same functions as the other two, but is also responsible for market functions such as running auctions, clearing transactions and settling payments between system operators (SOs) and FSPs (ENTSO-E, 2021) (OneNet, 2023). This type of platform does not have to be connected to a separate trading platform to handle sales and procurement of flexibility, but they can have this option as a complementary feature. This type of flexibility platform tends to be focused around local flexibility services.

2.5 What functions can flexibility platforms perform

The report ‘Review of Flexibility Platforms’ made by Frontier Economics for ENTSO-E, identifies seven distinct functions that flexibility platforms can deliver (ENTSO-E, 2021). These are:

- Asset registration and prequalification
- Notification of flexibility requirements & submission of offers
- Coordinated grid impact assessment and priority of access
- Matching
- Price formation
- Issuing dispatching instructions and activation
- Validation and settlement

Whether a Flexibility Platform performs all or just some of the functions listed above, varies from platform to platform, and is related to the platform’s operational model as described in Section 2.4.

The various functions of flexibility platforms are elaborated below, based on the work done by Frontier Economics (ENTSO-E, 2021):

2.5.1 Asset registration and prequalification

Flexibility platforms play a role in managing the eligibility of flexibility service providers (FSPs) by hosting criteria for participation, collecting prequalification information, and sometimes overseeing approval (ENTSO-E, 2021), Physical testing may be required for approval on some platforms, and certain platforms maintain ‘asset registries’ with technical details of FSP resources. Approval can be handled by the platform, delegated to TSOs/DSOs, or the market operator.

2.5.2 Notification of flexibility requirements and submission of offers

Flexibility platforms enhance market participants' visibility of transaction opportunities through digital communication interfaces (ENTSO-E, 2021). All platforms provide interfaces for TSOs/DSOs, allowing them to upload flexibility requirements directly on marketplace platforms. Market intermediaries either act as a gateway to existing markets or engage with TSOs/DSOs after tenders are processed on marketplace platforms. Platforms also enable FSPs to upload asset availability.

2.5.3 Coordinated grid impact assessment and priority of access

Market intermediary platforms often have a focus on coordinating between TSOs and DSOs and may support a joint grid assessment before bid qualification and matching offers to requirements (ENTSO-E, 2021). Coordination can occur through hierarchy rules that prevent orders from causing congestion in other areas, or through optimization across network voltage levels, considering constraints for all T/DSOs involved. Self-contained marketplace platforms can be used by both TSOs and DSOs or only DSOs, with coordination for grid prequalification defined. Some platforms provide information to TSOs for intraday market procurement after DSO activations.

2.5.4 Matching

Efficient matching of flexibility service provider (FSP) offers to TSO/DSO needs requires joint optimization across various dimensions, including the asset's effectiveness, technological and locational constraints, and opportunity costs for both parties (ENTSO-E, 2021). Flexibility platforms first conduct a bid-qualification process to filter offers that meet technical and timing requirements, with additional screening for location criteria in congestion management. After qualification, platforms may allow TSO/DSOs to select offers manually or handle centralized matching. Others again might use a multi-transaction system that allows TSO/DSOs to execute buy and sell transactions simultaneously, with the price difference covered by the TSO/DSO.

2.5.5 Price formation

Marketplace flexibility platforms conduct internal auctions using either a closed auction format or a continuous market format (ENTSO-E, 2021). In closed auctions, TSOs/DSOs publish flexibility requests and set a bid cap if this option is available. They receive offers from FSPs, which they review and select after the bidding deadline. In continuous markets, both TSOs/DSOs and FSPs submit requests and bids continuously, and matching occurs under a pay-as-bid system, with contracts established without direct contact between the parties.

2.5.6 Issuing dispatching instructions and activation

The dispatch setpoint instructions or activation signal received by the FSP may come from either the T/DSO or the flexibility platform (ENTSO-E, 2021). Activation can occur manually by the FSP, automatically through a closed-loop control system with the TSO/DSO or platform operator, or a combination of both. In some cases, for market intermediary platforms, activation may be handled by adjoining markets.

2.5.7 Validation and settlement

Flexibility platforms may assist in validating delivery against a measured baseline and settling payments (ENTSO-E, 2021). Baseline measurement is usually agreed upon by market participants, who assign a responsible party to upload the values. Some platforms collect baseline and metering data for validation either within 24 hours or on a minute-by-minute basis, while in other cases, validation is handled by TSOs/DSOs outside the platform. Settlement is typically managed by marketplace operators, and platforms may impose penalties for discrepancies after validating delivery. Additionally, platforms may implement measures such as payment caps, long-term contracts, and market surveillance to prevent strategic gaming and market power abuse.

3 Topics relevant to flexibility platforms

3.1 Aggregators

3.1.1 The role of aggregators

An aggregator can be seen as an intermediary between FSPs and buyers of flexibility services, who bundles multiple costumers loads or generations to be traded on the flexibility market.

Owners of small and medium sized DERs might not be able to enter the market themselves, due to technical or regulatory barriers, or might not find it favourable when comparing the effort it requires with the value gained. From a market point of view having a lot of small flexibility owners with direct access to the energy market, would also increase complexity and decrease effectiveness (Danish Energy Agency, 2021). Aggregators can facilitate the access of these actors to the market and can bundle the flexibility to larger assets reducing complexity on the market. Thus aggregators are viewed as playing a crucial role in utilizing the flexibility of domestic and commercial DERs (ISGAN, 2024) (JRC, 2022) (Plaum et al., 2022) (Granado et al., 2023). This recognition is also expressed in the EU Directive 2019/944, which states that the participation of demand response through aggregation should be fostered and be allowed to participate in the electricity market in a non-discriminatory manner (EU, 2019).

Aggregators might, however, still face barriers to enter the market such as their roles and responsibilities not being clearly defined (ACER, 2023). Currently the definition of the aggregator role is a task engaged in on national level, but the organization ISGAN has recommended that common definitions should be made on European level.

The functions that aggregators typically provide are listed in the table below.

Table 1: Functions associated with the role of aggregator. Based on functions listed in (ISGAN, 2024).

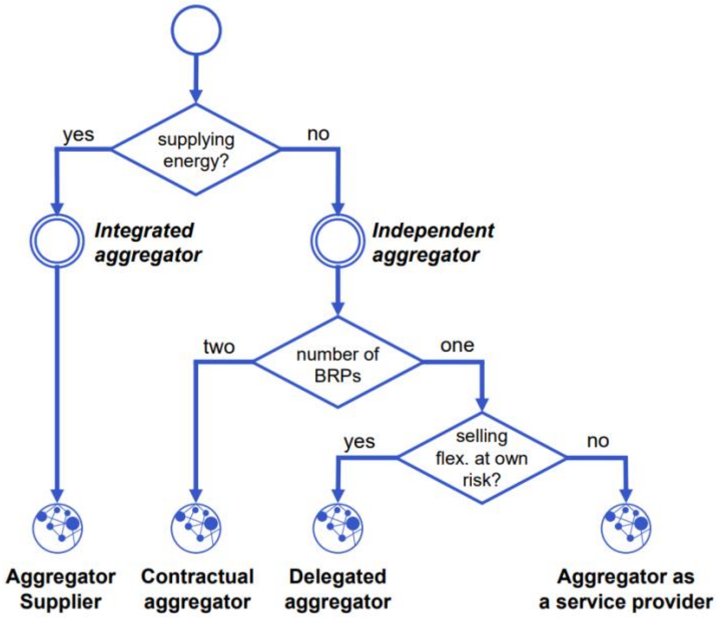
Functions	Role of aggregators
Bundling flexibility	Can consolidate the flexibility from multiple small- and medium sized DER (such as residential and commercial consumers) into a larger, more manageable resource pool.
Market participation	By pooling resources, aggregators enable the consumers to make their flexibility available on the energy markets and makes the transaction easier both for them and the flexibility buyers.
Automation	Can manage the setup and control of automated demand response, which allows for more efficient and stable flexibility from small DERs.
Risk management	Although the role is not clearly defined, the aggregator can help or take responsibility for managing the risks associated with balancing.

3.1.2 Types of aggregators

In a report by ISGAN, the authors distinguish between two types of aggregators, integrated and independent (ISGAN, 2024). These two overall types can be subdivided based on whether and how they take on the role as BRP.

The report includes a decision tree that is used to determine the type of aggregator, which is presented below.

Figure 1: Decision tree to determine the aggregator type. Taken from (ISGAN, 2024).



An integrated aggregator is a company that both supplies energy to a customer and bundles the customers DER to be sold as flexibility services. Such an aggregator is in a good position to access collect and utilize its customers flexibility resources, however, in a report by the JRC the authors argue that this type of aggregator might keep the customers from realising the value of their flexibility and limit them to participate in indirect demand response (a definition of indirect and explicit demand response can be found in the beginning of the paper in the section named Definitions) (JRC, 2022). Instead, they recommend the use of independent aggregators as these are described as empowering small users to understand the value of their flexibility better.

If an aggregator does not supply energy but is taking on the responsibility of BRP together with another actor, it can be labelled a contractual aggregator. If it takes on the responsibility alone it can be labelled a delegated aggregator, and if it does not take on the responsibility of BRP it can be labelled an aggregator as a service provider.

3.2 Communications protocols

A communication protocol is a set of rules that set standards for how information is transferred between systems. They define things such as the data format and the transmission methods, to ensure efficient and reliable communication. While communication protocols such as Wi-Fi and IP can provide the basic connectivity and transport of data, more application specific communication protocols are also needed in flexibility trading to align and structure the communication, so as to ensure that stakeholders and devices can communicate effectively and reliably.

A flexibility platform or aggregator must use the same communication protocol as the distributed energy resource to adjust its energy use and activate a flexibility service. However, cloud solutions exist which are able to translate information between different communications protocols, thus allowing the sender and receiver to use different communication protocols. A flexibility service can also be activated by communicating the need for the service to the owner of the DER, who can then manually adjust the energy consumption accordingly. However, to effectively utilize the demand response flexibility of households and the commercial sector, automation is needed. As these distributed energy resources are small, they need to be aggregated to form bundles of a size tradeable on the flexibility market. To be able to ensure that the distributed energy resources can deliver the committed flexibility, the aggregator or flexibility platform must have the permission and ability to adjust the energy use of the distributed energy resource remotely.

Multiple studies highlight OpenADR and IEEE 2030.5-2023 as the most widely implemented and most applicable communication protocols for demand response management (smartEn, 2023) (EPRI, 2021) (QualityLogic, 2020) (FlexTalk , 2024). The New Zealand based flexibility project FlexTalk identifies the OpenADR communications protocol as the most suitable to act as a common communication protocol for all actors on the flexibility market in New Zealand. As for IEEE 2030.5-2023 it has become the default protocol in California's Rule 21, which requires smart inverters to be managed by utilities or operators/aggregators of distributed energy resources (DER) to maintain grid reliability (EPRI, 2021).

Another communications protocol standard that should be highlighted is the S2 Standard, which has been developed by a consortium consisting of the FlexiblePower Alliance Network, ECOS, TNO and KNX (S2, 2023). The standard defines how communication should be conducted between smart devices and energy management systems. It is stated in the standard's white paper that the S2 standard allows the devices to react directly to signals from the DSO. The S2 is published as an official European standard, EN 50491-12-2.

Table 2: Descriptions of the selected communications protocols.

Communications protocol	Description	Services / functions provided
OpenADR 2.0[1]	Specifies the signalling data models between a virtual top node (VTN, which publishes information to automated clients) and a virtual end node (VEN, which subscribe to that information)	• Registration of actors to roles of VENs or VTNs. • Enrolment of resources for participation in flexibility/demand response programs • Market contexts. It is used to discover rules or standard reports, i.e., information that does not change frequently and appended to every message. • Event. Used to instruct the required behaviour given a transaction (e.g., committing a resource to provide demand response under some conditions). • Quote or dynamic prices. For distributing complex dynamic prices (e.g., block or tier tariffs). • Reporting or feedback, to set the state of a resource • Availability. Constraints on the availability of a device. • Opt or override. Enables short notice changes to availability of a VEN
IEEE 2030.5[1]	Facilitates the integration of smart home devices into the grid via two main functionalities	• Give information to the consumers about energy prices • Enable consumers to receive orders for device control (e.g. control of

		heat pumps, EV charging, PV control, storage control).
The S2 Standard	Facilitates communication between smart devices and an energy management system	• Defines communication between a Customer Energy Manager (CEM), e.g. a smart home energy management system, and a Resource Manager (RM), which is build into the individual device and can send device information to the CEM (S2, 2023).

[1]*The information on OpenADR 2.0 and IEEE 2030.5 is taken from* (EU-SysFlex, 2021).

The project done by FlexTalk named *'The Demand Flexibility Common Communication Protocols Project'* concludes that standardized functionalities for communication and data exchange is a necessity to effectively utilize demand-side flexibility (eea, 2024). The functionalities the standardized communications protocols should have are:

- Interoperability
- Real-time data exchange
- Scalability, flexibility
- Maintainability
- Platform independence
- Backward and forward compatibility
- Non-proprietary attributes

The project concludes that both the OpenADR 2.0 and IEEE 2030.5 fulfil all these functionalities. Based on the information available in the S2 white paper, it is assessed that the S2 standard also fulfils these functionalities.

3.3 Residential and commercial demand side flexibility

In the paper '*Aggregated demand-side energy flexibility: A comprehensive review on characterization, forecasting and market prospects'* the authors describe demand side flexibility through three identified classifications and six characteristics (Plaum et al., 2022). These will be described in the sections below.

3.3.1 Flexibility classification

The authors classify flexibility based on whether the energy load is 1) storable 2) shiftable or 3) curtailable (Plaum et al., 2022). The classification is founded in the works of (Mancini et al., 2019) and (He et al., 2013). Here storable energy loads are the most flexible and curtailable loads the least. Identifying which category an energy load falls within; one should assess the flexibility starting from the top.

- **Storable loads***:* This category covers loads than can be stored and used at a different time than when it was produced (Plaum et al., 2022). Examples of this type of load are batteries and electrical heating/cooling and domestic hot water appliances that store energy in a thermal mass. However, these types of storage also differ: a battery can deliver electricity again, whereas a hot water storage can't. If the energy load is non-storable one should move on to assess if it is shiftable or non-shiftable.

- **Shiftable loads**: This category covers loads that can be shifted to run at a different time, either earlier or later than originally planned (Plaum et al., 2022). These loads need to be scheduled in advance, as they usually operate on a set cycle that cannot be paused once started. Examples include appliances like washing machines, dryers, and dishwashers. If the energy load is non-shiftable one should move on to assess if it is curtailable or non-curtailable.

- **Curtailable loads**: This category covers loads that cannot be shifted, either due to consumer comfort requirements or because shifting is unnecessary, such as room lighting (Plaum et al., 2022). However, curtailable loads can be temporarily interrupted if consumers are provided with sufficient incentives. If the energy load is non-curtailable then it can be considered inflexible.

3.3.2 Flexibility characteristics

The authors further characterize energy loads based on six characteristics, whether they are capacity or energy type, by their response direction (unidirectionally upwards or downwards, or bidirectional), response speed, response duration, availability, and predictability (Plaum et al., 2022). These characteristics can be used to determine how they can be used in flexibility services. The authors base their characterisation on the work of (Eid et al., 2016).

- **Type (capacity or energy):** Indicates the energy-to-power ratio of the flexible load. Loads with a low ratio can deliver high power but only for short durations, making them suitable for short-term flexibility services like frequency containment reserve (FCR) and fast frequency reserve (FFR) services. These are considered capacity-type loads. Conversely, loads with a high ratio can sustain power for extended periods, and can thus be considers as energy-type loads that are better suited for longer applications, such as peak shaving.

- **Response direction**: Specifies the direction of the load's power flow. Some loads are unidirectional, meaning they either function solely as a load or solely as a producer, but not both. Bidirectional flexibility sources, on the other hand, can act as prosumers, providing upwards flexibility (decreasing consumption or increasing generation) at times and providing downwards flexibility (increasing consumption or decreasing generation) at other times

- **Response speed**: It is the time between when a signal is sent to the flexible resource and when the resource adjusts its consumption or production. For residential flexible resources, the response time is typically quick, ranging from seconds to minutes.

- **Response duration:** Is the amount of time the flexible resource can sustain the service it is providing. An example is a battery with a maximum capacity of 50 kWh and a charging speed of 10 kW. Such a battery would have a response duration of 5 hours, as it can take up the 10 kW of power for 5 hours, before the battery is entirely full. The response duration is both technology specific and dependent on consumer behaviour.

- **Availability:** Determines when and how often the flexible resource can be called upon. Examples of this are electric vehicles that are available when plugged in, typically during the evenings and over the night. Or dishwashers and washing machines, which might be activated at varying hours during the day, either when it fits the user to activate it or within a timespan defined by the user.

- **Predictability:** This characteristic has to do with how accurately the availability of the resource can be estimated. A battery system is an example of a predictable resource, whereas the washing machine and dishwasher are more unpredictable.

3.4 Relevant regulations, standards & labels

3.4.1 EU Code of Conduct for Energy Smart Appliances

The Code of Conduct (CoC) is created by DG ENER and the Joint Research Center (JRC) and was launched in Q2 of 2024. The CoC sets out basic principles for data sharing and interoperability requirements to be followed by all who participate in producing and developing Energy Smart Appliances

(ESA) to be put on the European market. The aim of this is to remove barriers that delay the realisation of the full demand flexibility potential of EASs in Europe. Signing the CoC is voluntary, but if signed the company agrees to make all reasonable efforts to meet seven commitments, outlined in the CoC and listed below:

a) Ensure that at least one model of ESA available in the Union market implements the applicable use cases for the specific ESA as of one year after the official launch of the first version of the Code of Conduct.
b) Ensure the implementation of interoperability profiles based on standardised open Application Programming Interface / open communication protocol to enable the information exchange for the applicable use cases (see point a).
c) Apply state of the art and open security mechanisms for the open communication protocol used (see point b) to: (1) secure the communication, (2) support the installation, administration and configuration (including the assignment of the system roles), (3) ensure proper authorisation for accessing the ESA, and (4) provide the control over the usage of private data, in accordance with the relevant EU legislation in force.
d) Ensure that all relevant information elements used in the implemented use cases (see point a) as well as in the open protocol (see point b) have a corresponding SAREF representation, fully compliant with the SAREF framework of ontologies according to the technical specification ETSI TS 103 264 (SAREF core) and ETSI TS 103 410 series (SAREF extensions)
e) Provide end-users with information on the use cases, including the conditions needed to use them, how to activate them and the benefits.
f) Cooperate with the European Commission and Member States authorities in an annual review of the Code of Conduct.
g) Indicate the compliance with the Code of Conduct when registering new ESA models in the EPREL database.

3.4.2 Regulation (EU) 2017/2195, Regulation (EU) 2019/943 & Directive (EU) 2019/944

The EU 2017/2195 regulation establishes a guideline on electricity balancing on the European electricity market (EU, 2017). The regulation sets seven objectives, one of them being:

- “Facilitating the participation of demand response including aggregation facilities and energy storage while ensuring they compete with other balancing services at a level playing field and, where necessary, act independently when serving a single demand facility”

Regulation (EU) 2019/943 aims to set the basis for achieving the objectives of the EU climate and energy framework for 2030, by enabling market signals to be delivered in order to increase, among other things, flexibility. Directive (EU) 2019/944, on common rules for the internal market for electricity, gives the aggregator a new central role in the electricity market, and states that the participation of demand response through aggregation should be fostered and be allowed to participate in the electricity market in a non-discriminatory manner (EU, 2019). It lists the following elements, which must be contained in the member states regulatory framework:

- the right for each market participant engaged in aggregation, including independent aggregators, to enter electricity markets without the consent of other market participants.
- non-discriminatory and transparent rules that clearly assign roles and responsibilities to all electricity undertakings and customers.
- non-discriminatory and transparent rules and procedures for the exchange of data between market participants engaged in aggregation and other electricity undertakings that ensure easy access to data on equal and non-discriminatory terms while fully protecting commercially sensitive information and customers' personal data.
- an obligation on market participants engaged in aggregation to be financially responsible for the imbalances that they cause in the electricity system; to that extent they shall be balance

- responsible parties or shall delegate their balancing responsibility in accordance with Article 5 of Regulation (EU) 2019/943.
- provision for final customers who have a contract with independent aggregators not to be subject to undue payments, penalties or other undue contractual restrictions by their suppliers.
- a conflict resolution mechanism between market participants engaged in aggregation and other market participants, including responsibility for imbalances.

3.4.3 Market model 3.0 (DK)

The Market Model 3.0 is developed by the Danish Energy Agency with the objective of creating a flexible electricity market that can support the transition towards a climate-neutral society (Danish Energy Agency, 2021).

It has been deemed necessary to separate the selling of electricity from trading with flexibility, to establish a market actor with a primary focus on utilizing flexibility from small-scale consumers. This new market actor is thus an independent aggregator.

To do this the following regulation has been adopted in Danish law in 2020 (The Danish Ministry of Climate, Energy and Utilities, 2020):

- Aggregators have the freedom to develop business models, including those for independent aggregators who do not supply electricity.
- They must have non-discriminatory access to all electricity markets.
- Aggregators are required to fully inform consumers about contract terms and conditions.
- Electricity suppliers must not discriminate against customers who have contracts with aggregators.
- Activation of flexibility by aggregators should not distort the electricity market.

However, the Market Model 3.0 emphasizes that rules for aggregators need further development to prevent market distortions. Currently, the market rules do not support the implementation of independent aggregators. This could lead to market distortions resulting in some market participants gaining advantages at the expense of others, and a need for electricity suppliers to be compensated for the lost revenue from electricity sales.

Based on Market Model 3.0 developed for increasing flexibility in Denmark, it is proposed that there should be efforts towards harmonizing conditions across the Nordic region to enhance competition in the flexibility market and create a larger market for flexibility services.

3.4.4 Proposal for a Network Code on Demand Response (EU)

In June 2022, ACER was mandated by the European Commission to draft a framework guideline on demand response (ACER, 2024). The European Commission cleared ACER's framework guideline in March 2023, and asked the DSO Entity and ENTSO-E to draft the proposal for the new binding EU rules. Among other things the proposed regulation requires that a list of standards for data exchange between actors related to the electricity system be made available and maintained (EU DSO Entity & ENTSO-E, 2024). The European standardisation organizations ETSI, CEN and CENELEC are charged with this task, and it is stated that the standards for data exchange should be based on existing ETSI-CEN-CENELEC standards.

3.4.5 §14a of the Energy Industry Act (EnWG) (GE)

The EnWG is a German regulation that has been in place since 2005 (EnWG, 2005). Section 14a was introduced in 2011, but only came into force in the beginning of 2024 (gridX, 2024). Section 14a obligates DSOs to conclude agreement with suppliers, end consumers and subscribers on the DSO's permission to control consumption devices to avoid system congestion, and in return reduce the network fee of the supplier of the flexibility. The consumption devices in this context are heat pumps, non-publicly accessible charging points for electric vehicles, installations for the generation of cooling or for the storage of electrical energy and night-time electricity storage heaters. The DSO is allowed to reduce the consumption to a minimum of 4.2 kW

3.4.6 PAS 1879:2021 (UK)

The PAS 1879:2021 standard is a UK standard, with the purpose of enabling standardized control of energy smart appliances (ESAs), to benefit stakeholders participating in the consumer energy supply chain (BSI, 2021).

The standard describes four overall aims that the standardized control of ESAs should help achieve:

- match the short-term availability of intermittent renewable energy generation sources such as wind and solar;
- decrease the peak load on the electrical transmission and distribution networks to alleviate the need for network upgrades to handle new domestic appliance types, such as electric vehicle (EV) chargepoints and electric heating, ventilation and air conditioning (HVAC) systems;
- allow control of electricity network characteristics such as line frequency, system inertia and network voltage, and help prevent network and generation outages; and
- allow the offset of short-term market imbalances by controlling flexible load on the network. These aims are achieved by shifting (in time) and/or modulating (increasing or decreasing) the collective electricity consumption or production of domestic appliances, in line with consumer preferences and agreement, in response to signals from grid-side actors.

The standard also presents four principles for consumer DSR, 1) Interoperability, 2) Data privacy, 3) Grid stability, and Cyber security. One of the practises that the standard describes as necessary to adopt to ensure interoperability, is the avoidance of vendor lock-in. It states the following:

"This principle [Interoperability] aims to maintain consumer choice, so that the consumer has freedom to change service providers and avoid lock-in due to use of ***proprietary protocols or system interfaces****"*

Here it is stated that a smart appliance that follows this standard, should use non-proprietary communications protocols.

4 Status of flexibility platforms

4.1 Selected case studies

To assess the status of flexibility platforms, literature research has been combined with case studies on four selected flexibility platforms. The case studies are based on interviews with key employees from the selected companies. The case studies chosen for this study are: Flex platform, GOPACS, CyberGrid and NODES.

4.2 What stages of development are they at, globally?

The research conducted as part of this study found only a handful of flexibility platforms currently operating on the market and concentrated in Europe. Flexibility can be managed in different ways, and one interviewee speculated that the reason flexibility platforms were mainly seen in the EU was that other countries such as the USA, was taking another approach to addressing the issues. Demand side flexibility management can be addressed in many ways and e.g. be managed more decentralised, be incorporated into existing electricity wholesale market or handled directly by a vertically integrated utility.

Besides the identified flexibility platforms there are multiple flexibility platform projects, focused on pilot projects and research, and some flexibility platforms that are not targeting DER.

The energy regulator of Great Britain, Ofgem, described in a study from 2019 the stage of flexibility platform development as a mix of trials, pilots and early-stage functioning flexibility platforms (Ofgem, 2019). However, one of the interviewees stated that the platforms on the market today have moved past the start-up phase and are now in the scaling-up phase.

Below is a list of the identified flexibility platforms, and some identified flexibility projects and aggregators.

Table 3: Identified flexibility platforms, projects and aggregators.

Name	Country
Platforms that work with household and commercial demand side flexibility	
Flex Platform	Denmark
Piclo Flex	United Kingdom
CyberGrid	Austria
GoPacs	Netherlands
Nodes	Norway
Tiko	Switzerland
KrakenFlex	United Kingdom
FlexTools	Norway
Electron Connect	United Kingdom
Markedroid	Estonia
Projects	
Flextalk	New Zealand
EcoGrid EU	Pan-European
INTERRFACE	Pan-European
eSIOS-CECRE-CoordiNet	Spain
FLEXITRANSTORE	Pan-European
Other platforms	
DA/RE	Germany
Equigy	Pan-European
Aggregators	
Octopus Energy	United Kingdom (Pan-European)
Flexcity	Pan-European
Leap	United States of America
Voltus	United States of America
Sympower	Netherlands
gridXE	Germany
Amalo Grid	Denmark

4.3 How can they be characterised?

This section provides a characterisation of the interviewed flexibility platforms. The characterisation is divided into an overview of some of the general aspects of the platform and a list of the functions they provide. The overview covers whether they are proprietary, what type of flexible platform they can be defined as, what services they provide, how they handle aggregation, and which communications protocols they use and can handle. The platforms were chosen based on their market participation, geographical spread, relevance to the domestic and commercial demand-side flexibility, and their willingness to participate.

Table 4: Overview of general flexibility platform aspects.

Area	Flex Platform	GOPACS	Cybergrid	NODES
Ownership	Proprietary	Non-proprietary	Proprietary	Proprietary
Software	Both open and proprietary	Proprietary	Proprietary	Proprietary
Access	Open	Open	Open	Open
Type	Market intermediary	Self-contained marketplace	Market intermediary	Self-contained marketplace for DSOs Market intermediary for TSOs
Engagement with assets	Works with flexibility from both households and commercial assets	Does not currently work with flexibility from households and commercial assets, but are planning to do so	Works with flexibility from commercial assets, whereas flexibility from households is currently only on a research stage	Works with flexibility from both households and commercial assets
Services	FCR, aFRR & mFRR	Congestion management	FCR, aFRR, mFRR, RR, (Congestion management)	Congestion management
Aggregation	The platform acts as an independent technical aggregator, with the role of commercial aggregator handled externally	No work with aggregators at the moment, but expecting to start working with external aggregators in the near future	The platform acts in Austria as an independent aggregator, but also licenses the software to third parties to do aggregation in other markets	The platform does not aggregate but works with external aggregators. The platform is neutral in the sense that they organize market participation but do not participate themselves.
Communications protocols	Supports all open communications protocols, and can work with most proprietary protocols	Communication is API based, and is between power exchangers and system operators	Rely on open communications protocols but can work with proprietary protocols as well	-

The table above shows that most of the platforms interviewed are owned by private companies. The exception is GOPACS, which is owned by the Dutch system operators. Generally, the software used on the platforms are proprietary and developed by and for the platform. However, it was mentioned by multiple interviewees that their software might be made open to be used in other countries, when the concept was proven on the markets they were active on.

The platforms are either market intermediaries, meaning that they act as a gateway for their users to participate on an external market, or they are self-contained marketplaces, meaning that they handle the trade on their own platform.

Two of the platforms are already managing flexibility from household and commercial assets, one provides system balancing services and the other congestion management. The other two are working on being able to handle flexibility from this group. The flexibility platforms have a primary focus on either system balancing or congestion management services.

Two of the platforms take on the role of aggregator themselves to manage flexibility from households and commercial assets. Flex Platform takes on the role of technical aggregator by managing the technical bundling of assets, but leaves the commercial part of aggregation to an external aggregator.

Cybergrid is acting as an aggregator in Austria, but is licensing their software to other aggregators in other markets. NODES does not do aggregation themselves but acts solely as a flexibility marketplace, and does not participate in the market themselves. The two flexibility platforms that also acts as aggregators both states that they support all open communications protocols, but that they are also able to integrate most proprietary protocols using cloud-based solutions.

Flexibility platforms can provide a variety of functions that facilitate the trading, dispatch and settlement of flexibility services. The functions that the platforms provide are listed in the table below.

Table 5: Functions that the interviewed flexibility platforms provide. An X indicates provision.

Function	Flex Platform	GOPACS	Cybergrid	Nodes
Asset registration and prequalification	We have an advanced asset register for all assets on the platform and perform pre-qualification and Audits towards the TSO in accordance with Ancillary Services requirements.	Asset registration but not prequalification	Asset prequalification is a week long process including the TSO. This is provided by CyberGrid but at some points outside of the Platform CyberNoc	Yes – NODES support both registration and prequalification. Both processes can be done via a web-based portal or via NODES API.
Notification of flexibility requirements	X	X	For TSOs flexibility is needed all the time. Notifications are sent if the offered flexibility is accepted from the market (TSO) and if the need of providing arises.	There are three ways System Operators may notify the market about flexibility requirements: 1) System operators may express their coming constraints and resulting needs on a map. But without publishing contracts. 2) System operators can publish long term or short term flexibility requests which FSP can respond to. 3) System operators can publish market messages with information about requests/needs.
Submission of offers	Submission of offers and receival of reservations and/or activations. FCR-D (BR Service); FCR DK1 (Regelleisting); Bid/Reservation/Activation API's for integration with energy retailer trading systems	X	X	Yes, both FSP and system operator
Coordinated grid impact assessment and priority of access	-	X	X	Support provided. Each SO may limit activation by other SOs where relevant. Priority of access is market based.
Matching	-	X	X	X
Price formation	Price data obtained from ENTSO-E and Energinets Dataservice	X	X	X
Issuing dispatching instructions and activation	Dispatching and activations are fully automated, and can be prioritized and disaggregated according to the flex agreement on asset level and across	Partially, actual activation is handled outside of the platform	X	Yes, configurable for each portfolio.

Function	Flex Platform	GOPACS	Cybergrid	Nodes
	geographical and organizational hierarchies.			
Validation and settlement	The validation and settlement reports are automated. They can be sliced and diced according to the date intervals, point of delivery, organizational portfolios, asset types, geo tags, flexibility markets.	Partially, we are working on centralising the settlement process	X	X
Other (include explanation)	AI virtual sub-metering, so we only need to install 20% submeters for the asset that we are operating. AI flexibility forecasting and baselining. We do 48 hours rolling forecasts on asset level for production, consumption and available flex capacity, that are modelled according to impact of weather as well as storage and loss of power, process temperature, pressure gain and loss, lumen etc. Asset monitoring. We ensure that the operation and uptime of individual plants are monitored and controlled. This is done continuously and automatically to ensure that the assets are available and can deliver the agreed flexibility. AI to predict how much flexibility can be made available to the market. Our models are based on asset load, activation time and speed, and how much they can be made available. The AI models are continuously calibrated with production schedules and temperature fluctuations. This ensures that our forecasts are as accurate as possible. Flex Contracts Register on asset level, which is agreement between the for how much we can use the asset for flexibility , which markets and at what minimum price levels.		Participating with one asset/flexibility on different markets for revenue optimisation	May be integrated with DSO tools for grid optimisation. Cascading of bids to mFRR markets implemented (currently not active).

4.4 Summary of interviews

4.4.1 Flex Platform

It supports all open communications protocols and can also work with most proprietary protocols, PLCs and control systems. The preferred communication protocol is MQTT, as it is both fast and secure. The interviewee emphasised that although proprietary communications protocols had been an issue in the past, it was no longer one of the primary market barriers. The interviewee knew of the OpenADR standard but stated that it was not widely used in Denmark.

The interviewee explained that when they started developing the platform the household sector was less mature and thus their focus in the beginning was on the industrial sector. Now, however, with more and more household appliances being smart and thus able to communicate and be remotely controlled, the household sector is mature enough to participate in the flexibility market.

The company has, from the outset, had the ambition to create an open platform that can integrate into existing ecosystems and has thus made it accessible to third parties.

The Flex Platform operates by connecting to installations, create flexibility profiles and offer the flexibility to the electricity market through a commercial aggregator. The management of flexibility services is fully automated to ensure effective utilisation.

The interviewee distinguishes between technical aggregators and commercial aggregators, with the Flex Platform being a technical aggregator. The commercial aggregator could e.g. be an electricity supplier and would be the one having the commercial interaction with the flexibility provider, such as providing electricity bill discounts or direct payments for their services.

Two findings from the EcoGrid project were mentioned as an inspiration for the design of the platform. The two main findings were stated as being, that having to set up hardware to utilize flexibility form households is too expensive, and that there was a lack of trust in the value chain for delivering flexibility in the market. Here it was said that Flex Platform has solved the first issue by making software integration with already existing hardware, and the second issue by having developed a virtual meter for the delivered flexibility.

It was stated that the ancillary services market for demand-side flexibility started to open up in 2017, and the commercial incentives for small-scale flexibility providers started to appear:

- Democratise the ancillary services market by adjusting bid sizes to increase access and competition
- Create a single marketplace for both TSOs and DSOs where the highest bidding DSO gets the priority.
- Create a certificate to be used for ESG reporting in companies who provisions flexibility.

In terms of customer feed-back on having their heat pumps and EVs controlled, the interviewee said that they did not receive any complaints regarding comfort or practicality.

One of the biggest barriers to unlock flexibility from households and the commercial sector for the ancillary services market is a lack of focus and knowledge, both from the consumers and from the energy suppliers. It is only seen as a small part of product that an energy supplier delivers, and it is a very complex topic for a salesperson to fully understand and be able to explain to the customer. This is one of the reasons, why the interviewee believes there is a need for more independent aggregators, who can have this topic as their main focus.

4.4.2 GOPACS

The platform is owned by the system operators in the Netherlands and is open and market-neutral. This means that all market parties can connect and participate on the platform, avoiding vendor lock-ins. The software they use is currently proprietary, as they are aiming to make the platform work perfectly in the Dutch market.

In terms of implementing the same solution in other countries, it is an issue that both legislation and grid layout might vary greatly between countries. The grid layout is difficult to change, but it is the experience of GOPACS that at least the Dutch regulator is becoming more proactive in trying to shape the market to allow for solutions such as theirs.

The GOPACS platform is API based and at the moment only connects with power exchangers and system operators. The API used is generic, in order to make it easier to quickly integrate with new initiatives. The platform only connects with two power exchangers now, but allows for an unlimited amount of power exchangers, aggregators and other platforms to participate on their platform. The platform is currently B2B and focused on high- and medium-voltage grids, but they expect to expand towards low-voltage grids soon, as congestion and reactive power issues are becoming more common on that level. The GOPACS platform solely functions as a marketplace and does not have contact to the end consumers.

Thus, the economic incentives for consumers to participate is set and handled externally. The service they provide is congestion management, with a focus on solving the issue of system operators optimizing their part of the system, without accounting for the effect that changes in their system has on other systems. They both have a planned day-ahead and an intraday product. The planned day-ahead product is for planned and expected congestion due to e.g. maintenance, whereas the intraday product is for congestion that happens suddenly over the course of the day. Here they use redispatch to make sure that the curtailment in one area is balanced with increased generation in another place, to avoid imbalance in the system.

When they move to low voltage customers it would need to be through aggregators. They see the market as consisting both of established players and newcomers but is unsure if it is growing fast enough to meet the flexibility needs that arises in time. As a technical barrier the inability of electrical vehicles to provide bi-directional charging is highlighted. As a market barrier the low liquidity of the current market is highlighted, but they hope to see this improve in 2025 and onwards. The company sees the market as maturing. Most players have moved past the initial start-up phase and is now trying to scale-up. The interviewees stated that GOPACS was seen as a frontrunner in using flexibility for congestion management, but they expected that system operators in other countries would soon catch-up.

4.4.3 CyberGrid

The platform only uses open communications protocols. The most widely used is the MQTT protocol, and another commonly used is IEC 104. The interviewee highlighted that even with open standards the integration needed to be thoroughly tested, as manufacturers might interpret the protocols in different ways or deliberately make adaptations. The platform can also interact with proprietary communications protocols through a cloud-based solution.

The interviewee stated that the TSO market for flexibility was more mature than the DSO, and that there were still regulatory barriers to flexibility procurement on DSO level in countries such as Austria. Here the regulatory framework was seen by the interviewee as underdeveloped, making flexibility trading at this level more complicated. The platform primarily offers services for TSOs, with services such as curtailment management for DSOs being more on a research and development level. The interviewee expressed that he did not see household appliances as being reliable enough to provide flexibility services to TSOs and further stated that any need for additional hardware would make the solution economically unviable.

The largest barriers were seen as being legislation and lack of knowledge. Flexibility services is a difficult topic to convey to consumers. The economic incentives for the consumers are furthermore low, and similarly are the earnings per household for the aggregator. Thus, the integration of the household appliances and the operation must be smooth to be economical. This might be easier if the aggregator is allowed to connect to the appliances back-end system and thus avoid consumer involvement to the extent possible.

The interviewee saw the flexibility platform market as mature in the sense that they provide reliable services and are financially sustainable. He saw more and more flexibility platforms entering the market but was not yet sure to what extend the market was able to grow.

4.4.4 NODES

The NODES platform is owned by NODES, who acts as a neutral market operator, and do not participate on the market themselves. For flexibility from households and the commercial sector NODES work with external aggregators who access and use their platform. Bigger providers, including commercial, public and industrial ones, are actively selling their flexibility on the platform without an aggregator.

It was stated that timing was important for a DER to be seen as having high potential for providing flexibility services. The example brought up was electric vehicles (EVs), which is a highly flexible asset, but their availability to provide flexibility is limited because they are typically set to charge at night when demand for flexibility services is low. This is in particular the case where they receive incentives through dynamic supply contracts based on spot price (implicit flexibility). Other potential assets like heating systems are being explored but have not yet contributed large volumes on the NODES aggregator

Generally, heat pumps, water heaters and batteries were mentioned as the most relevant appliances for flexibility in households. In the commercial sector the potential was higher, and it was seen as easier to manage. Things like cooling facilities, heating and ventilation systems and swimming pools were brought up as high flexibility assets in the commercial sector.

The interviewees stated that the market is still developing and currently most of the volumes of flexibility come from individual assets like industrial boilers, and not smaller aggregated sources. The potential for growth in utilising flexibility from smaller aggregated sources was, however, highlighted. Especially the integration of smart appliances was seen as enabling the integration of household flexibility.

Varying regulation between markets was highlighted as a barrier to flexibility platform development. In some regions, DSOs (Distribution System Operators) are free to experiment with flexibility, while in others, regulatory gaps limit progress. Platforms like Nodes are also able to provide access to balancing markets, but regulatory harmonization will be crucial for future growth. Without the cooperation of the TSO(s) that organises the balancing market, the coordination of local flexibility markets with balancing markets remains impossible in practice. Hence, a regulatory push is needed to enable flexibility service providers to maximise the revenue from their assets by being active in several markets simultaneously.

One of the key benefits from using a market approach to meet flexibility needs, was seen by the interviewee as being the markets' ability to direct investments to the areas of the grid that needs it most, by transparently sharing volumes and prices. The market makes it visible where there is the largest need for flexibility services, which can be used by companies investing in new flexible technologies to prioritize where to put their investments. Also, contrary to implicit mechanisms like dynamic or differentiated tariffs (where the availability and price sensitivity of providers at a given moment are not shared with the system operator), markets offer the possibility of a direct and dynamic communication between flexibility buyers (system operators) and providers through the offered prices and through the price curve for each moment.

It was lastly stated that the success of using flexibility from households and the commercial/ industrial/ public sector will depend on building trust between DSOs and aggregators or other providers, as well as generating sufficient volumes to make the market commercially viable.

5 Identified barriers and solutions to utilizing demand-side flexibility from household and commercial assets

Several barriers were identified through literature and interviews. Smart appliances are a key enabler to access flexibility from the household and commercial sector. To effectively utilize the flexibility the appliances must be able to smoothly integrate with aggregator software and their participation in delivering services be allowed to be handled automatically. This can be improved by manufacturers adopting a limit variety of standardized open communications protocols.

It is a general finding that customers lack awareness about the possibility of delivering flexibility services, and that the economic incentives for participation are low. Thus, communication initiatives should be extended and the participation made as seamless and simple as possible.

On the aggregator side, the profit margin per household is slim, and so to make a viable business the integration and management of households needs to be efficient, and there needs to be enough volume. The system operators are found to be cautious about using flexibility from this group, due to a lack of trust in its reliability. A trust that needs to be established through proof of concept and legislative support.

Regulation is brought up as posing a general barrier due to things such as variation between markets, unclear definitions of roles, and regulation that that limits the possibility of trading flexibility from DER. These issues are described in more detail below.

5.1 Communications protocols

The use of proprietary communications protocols is often highlighted in literature as one of the main barriers to utilization of household flexibility. This was also a stated in a study by smartEN, who found that the majority of their members rely on bespoke and device-specific REST APIs to access Distributed Energy Resource (DER) data, complicating seamless integration with flexibility aggregators and hinders easy switching between them (smartEn, 2023).

In a study by OECD it was argued, that the reason for why businesses might opt for a proprietary solution is that it can allow for quicker market entry and ensure a high-quality products, however, they also concluded that these systems can lead to monopolistic lock-in of consumer data and limit the emergence of new market actors that could drive energy efficiency innovations (OECD, 2022).

In our interviews with flexibility platforms, two of which also acted as aggregators, the use of proprietary communications protocols was not highlighted as a major obstacle. Both aggregators explained that they were able to integrate with proprietary protocols by using cloud-based solutions. This is in line with findings from EPRI, that many devices that support only proprietary protocols might be able to utilize cloud-based ecosystems to translate messages from open standards into their specific formats for better interoperability (EPRI, 2021). Although the interviewed flexibility platforms did not see proprietary communications protocols as a necessity for integrating household devices, it was stated that it would allow for easier and smoother integration, if manufacturers only applied a limited number of standardised open communications protocols. Both of the interviewed aggregating flexibility platforms stated that the MQTT protocol was the one they used most often.

As one of the barriers to utilizing flexibility from households is the low revenue the aggregator can get per household, it is important in order to overcome this barrier that the cost of integrating with the household assets is as low as possible.

5.2 Regulation

As innovative flexibility marketplaces develop across Europe, aligning market arrangements and product specifications is critical to facilitate smoother integration of DERs (ENTSO-E, 2021). This was a topic brought up by all interviewees as a necessity to more easily integrate solutions between markets. Regulation might also set barriers that directly hinder DSOs from accessing flexibility resources at end customer premises (ISGAN, 2023). This was experienced by one of the flexibility platforms interviewed.

These and other barriers are addressed in the EU regulation 2019/943 and directive 2019/944. The regulation and directive are seen as setting the right legislative framework to eliminate the barriers to demand-side flexibility (smartEN, 2022). However, in a market monitor by LCPDelta and smartEN published in 2024 looking into the maturity of the demand-side flexibility market in Europe, the executive director of smartEN, Michael Villa, concludes that:

"[…] the EU Market Monitor for DSF reflects a stagnant situation. While more and more DERs are being deployed, their flexible use is still lagging in many European countries. This is not due to low market interest, but by barriers on the "rules of the game" - (LCPDelta & smartEn, 2024)

SmartEN have monitored the implementation of the EU regulation 2019/943 and directive 2019/944 in the European member states in 2022 (smartEN, 2022). Here it is concluded that *"there is still only limited progress towards the transposition of key provisions into national legislation."*

Thus, although actions have been taken to solve the regulatory barriers to utilizing demand-side flexibility on EU level, it has still to be fully adopted into national legislation. ACER have made a market monitor report on the current barriers in the legislative framework in the member states, which includes a detailed list of recommendations on how to remove the barriers (ACER, 2023).

5.3 Knowledge and awareness

It was brought up by the interviewees that a major barrier is the lack of knowledge and awareness on flexibility services both on the supply and demand side. This is in line with the findings of a study by ISGAN, who also found that system operators consider customer awareness and willingness to participate as a large bottleneck (ISGAN, 2023). There is a need for customer education and good incentive schemes to increase consumers' willingness to participate.

Consumers do not know of the option to sell flexibility services unless they are informed about it by e.g. their electricity supplier or an independent aggregator. One interviewee mentioned that electricity suppliers that also acts as aggregators, might not prioritize the flexibility product as it constitutes a smaller part of their revenue. The concept of flexibility can also be difficult for sales personnel to fully grasp and convey and similarly hard to understand and trust as a costumer. The organization UsersTCP have made a guidebook to unlock residential demand flexibility (UsersTCP, 2024). Here they also state that barriers to get more participation is that people find it hard to understand, difficult to sign up, do not see it as user-friendly, and that they might hold the misconception that their personal data is being collected.

To address these barriers, one step is to ensure that independent aggregators are ensured non-discriminatory access to participate in the market, as they have flexibility services as their core product and thus a strong focus on promoting and developing it. In addition, customer awareness and knowledge could be improved through targeted information campaigns, which could be guided by e.g. the UsersTCP guidebook.

5.4 Economic incentives

Although the use of a market-based approach to utilizing demand side flexibility promotes fair customer compensation for their flexibility services, the lack of sufficient economic incentives for consumers to participate in the flexibility market is often brought up as a barrier (ENTSO-E, 2021). This was also brought up in the interviews. To mitigate the issue the need for smooth integration and low consumer participation was brought up. It is also important that the consumer trusts that they will not experience any reduction in comfort or convenience if they agree to have their appliances offer flexibility services. As the economic benefit for the consumer is low, it can be expected that the tolerance for issues will be likewise.

To ensure that the consumers receive the right compensating it is important that the economic savings for the DSO and TSO in using the flexibility services are reflected in the compensation to the flexibility service providers.

5.5 Revenue per asset, and the need for smart appliances

Small-scale distributed resources, such as household and commercial assets, can only participate if aggregated (ISGAN, 2023)**.** As the revenue an aggregator can achieve per asset is low, it is important that integration of new assets is as cost efficient as possible and that it is possible to bundle enough assets to make the business economically sustainable. In order to achieve this for households, it is necessary that the household have a sufficient flexibility potential, that the appliances do not need additional hardware installed, that the software integration can be done smoothly, and that the activation of flexibility can be handled automatically. This can only be achieved with smart appliances.

5.6 Trust in the product

TSOs and DSOs may view contracting with DERs as riskier compared to utility-scale assets (ENTSO-E, 2021). This was mentioned as a one of the key challenges that one of the interviewed flexibility platforms aimed to solve. As the use of DER from households and the commercial sector is a relatively new concept, trust in the product needs to be established. This is a task partly undertaken by the aggregators, flexibility platforms and system operators, who are taking part in developing the flexibility market. However, it can be facilitated by removing any regulatory obstacles that complicates or hinders the selling or procurement of aggregated flexibility services.

6 Lessons learned

6.1 Lessons for residential and commercial demand-side flexibility

- Household and commercial consumers need better knowledge on the benefits of providing flexibility, both for them and the system.
- The economic gain for the costumer exists but is limited. It is important that the economic benefit on system level (e.g. reduced investment, avoided curtailment) from using households flexibility is reflected in the economic compensation or other benefit to the customer.
- Alternatively, other business models may be developed that can result in better attraction to the customers.
- Independent aggregators allow for decoupling flexibility from other services/products.
- Smart appliances are a necessity for utilizing the flexibility of households. If additional hardware needs to be installed to deliver the flexibility service, it becomes economically unviable.
- If appliances can be purely software integrated with the aggregator platform, it is possible to easily bundle a large number of consumers and make it easy for consumers to switch between aggregators.

6.2 Lessons for policy makers

- Open standardized communication protocols in appliances eases the integration with flexibility platforms. However, it is possible to connect without it. In order to make integration with household DER as cost-efficient as possible, it is recommendable to adopt a limited amount of open communication protocols to be used in heat pumps, batteries, electrical cars and HVAC systems.
- Independent aggregators only have flexibility services as a product and might be more focused on developing the product compared to an integrated aggregator. Thus, it is important that independent aggregators are allowed to participate in the market in a non-discriminatory manner.
- Clear legislation is needed, which allows for non-discriminatory access of aggregated flexibility on the flexibility marked.
- Legislation should be aligned as broadly as possible, so that flexibility solutions can be easily scaled up and shared. This would entail that proven solutions in one country can be expanded to other countries.
- Legislation should be aligned, as to permit flexibility to be utilised between neighbouring countries.
- The use of flexibility services from aggregated flexible resources should be assessed in terms of security and reliability, and consequently promoted.
- Mature market solutions exist already, and the flexibility platforms are in their growth phase.
- A lack of clear legislation and large variability between how markets are set up in different countries, poses a barrier for the market to grow.
- A lack of knowledge about the possibility of providing demand-side flexibility on the consumer side, and a lack of trust from the system operators in flexibility services from this segment, is another barrier to growth.

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Annex A: Alignment with EDNA's product policy framework

In this annex the main elements of EDNAs product policy framework are compared with the findings of the desk and case studies. The three main elements of the framework are:

- The device
- The communication architecture
- The use cases

These three elements together with the interoperability issues identified in the framework, will be addressed separately below.

The device

Device delivery capability

The framework states that the power, duration and response time of the unit, should be used to determine the device's capability to participate in demand-side flexibility. It further suggests that recovery time should be added as a capability parameter for some devices.

This is in line with parameters identified through literature as relevant for devices to participate in demand-side flexibility. It also matches the parameters used to determine the flexibility profile of an asset, according to material shared by one of the flexibility platforms interviewed.

However, as recovery time is a parameter relevant for most assets such as batteries, EVs, heat pumps, hot water tanks, HVAC and commercial cooling facilities, it is recommended that the parameter is included in the framework as a general parameter alongside power, duration and response time.

The material shared by the interviewed flexibility platform also gives the response times needed for an asset to deliver different flexibility services on their platform. For an asset to deliver FCR services, it needs to be able to respond within 30 seconds, for aFRR between 30 seconds and 5 minutes, and for mFRR between 5 and 15 minutes. These response time intervals could be used to decide on the intervals used in the framework.

Device ancillary functionality

The framework requires that the device can communicate with e.g. an aggregator, that it is able to measure energy and synchronize with time, that it is secure in terms of cyber security, and that it is programmable.

- **Communication**: For the device to deliver flexibility services through a flexibility platform, the communication has to be two-way, so that the aggregator software can obtain the necessary information to determine the delivery capability of the device. It could be added here, that in order to ensure interoperability and seamless integration with aggregator software, the device should apply standardized open communications protocols. Preferably the manufacturer should be able to choose from a predefined list of communications protocols. The list could look to the standards chosen as part of the upcoming EU Network Code on Demand Response, see Section 3.4.4, the open standards described in Section 3.2, and the MQTT standard highlighted by the case studies. Creating the list, would require a dedicated study on communication protocols. The EU code of conduct for Energy Smart Appliances also states that the communication protocols used should be standardized and open, and that they should be fully compliant with the SAREF framework of ontologies, see Section 3.4.1.

- **Measurement and synchronization**: The device must be able to measure all the relevant parameters needed for the aggregator software to determine the delivery capability of the device. For a heat pump this would also include the temperature in the house, as this is needed to determine if the load can be reduced or increased. The device must also be able to match all measurement with accurate time data, and ensure that the time is synchronized with the aggregator software.

- **Cybersecurity**: Although this study does not look at the cybersecurity aspect of smart appliances and flexibility platforms, it is recommended that the framework aims to be compliant with the upcoming EU Cyber Resilience Act, which is currently in the proposal phase (EU, 2022). Currently no standards have been identified which meet all security and vulnerability handling requirements of the proposed EU Cyber Resilience Act, but the ETSI EN 303 645 V2.1.1 (2020-06) standard has been identified as one of the most relevant to meet product-related security requirements (JRC & ENISA, 20224).

- **Programmability**: This function could be relevant for the device to deliver flexibility services for planned events, such as infrastructure maintenance that requires congestion management.

Communication architecture

In order for a device to deliver flexibility services through a flexibility platform, the control signals have to be direct. As the flexibility platform solution is market based, the flexibility service has to be in the form of a product that can be bought and sold.

Use cases

Additions to the list of use case presented in the framework are included in the table below in red.

Table 6: Examples of use cases from the EDNA product policy. Recommendation for additions added in green and for deletions in red.

User of flexibility	Use cases		
	Electricity cost/CO_2 management	**Network capacity management**	**Network and system balancing**
Device owner	Shift consumption and generation (across time) to reduce electricity costs or CO_2 emissions	Shift consumption and generation to reduce network charges. Optimize connection size to reduce connection costs. Receive payment or other benefit for providing flexibility services.	Receive payment or other benefit for providing flexibility services.
Energy retailer	Shift consumption across time to lower generation or transportation costs. Reduce peak capacity		
DSO		Defer/avoid augmentation to shifting discretionary consumption or generation to lower use periods. Avoid curtailment of renewable generation. Postpone or avoid new infrastructure investments.	~~Manage security and reliability to enable greater integration of variable generation~~
TSO			Ancillary services and reserves from DF devices enable greater integration of variable generation. Reduce the need for fossil based reserves.
BRP			Optimize the portfolio to make it easier to match consumption and generation

Interoperability issues

Direct versus indirect control signals

As the concept of flexibility platforms relies on flexibility that is able to be traded on a marketplace, the control signals have to be direct in order to ensure that the sold product is activated when needed.

Need of an energy manager

This study does not look specifically at the effect of having an energy manager. However, it can be concluded from literature and interviews that an energy manager is not a necessity for an asset to provide flexibility. If an energy manager is used, it must be able to provide the same information to the aggregator as the flexible asset. To avoid conflict between systems the activation of flexible assets, when an energy manager is used, should be done through the energy manager.

The role of cloud solutions

This study does not look at the role of cloud solutions for energy management systems.

Semantics related to direct and indirect control signals

To utilize flexibility from DER the flexible resource must support two-way communication. This allows the resource to send information to the aggregator regarding timing and available flexibility (e.g. room temperature or battery power level)

Relation to functions such as comfort and safety

As the provision of flexibility is associated with only modest economic benefits for the consumers, it is important that participation is easy, automated and results in no negative implications, to ensure consumer willingness to participate. This can be addressed through agreed upon rules on how the resource can participate. This could be, for example, a heat pump where the consumer allows the aggregator to adjust the consumption, as long as the room temperature stays within a specified range.