MSc Program
Renewable Energy Systems

# Flexibility Products and their Future Opportunities for the Austrian Electricity Market

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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# Affidavit

I, **MARIIA RASKOPINA, MA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "FLEXIBILITY PRODUCTS AND THEIR FUTURE OPPORTUNITIES FOR THE AUSTRIAN ELECTRICITY MARKET", 70 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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# ABSTRACT

The integration and development of green energy sources for electricity production is essential for further decarbonization, which became even more vital in the light of the 2020 pandemic. In the current climate, the most important characteristics of an energy system is its reliability, security and quality of power. To provide a stable load in an electricity distribution grid with a high share of renewables, TSOs and DSOs require flexibility opportunities to adapt to the varying levels of demand. Over the last couple of years, the phenomenon of flexibility in the energy sector has received great attention. A number of European countries have begun to piloting marketplaces for trading flexibility and have been testing their concepts of flexibility projects, among them the UK's "Piclo Flex", Germany with "Wi NODE", the Netherlands with "GOPACS" and Austria with "Flex Hub". The objective of this research was to identify and study these energy flexibility projects and determine which of these approaches would be most beneficial for the Austrian market. This encompassed identifying more than 20 different parameters for the analysis of these projects. We c identify the criteria for successful execution, such as: clear participation and bidding rules; user-friendly interfaces; clear and achievable and non-discriminatory technical requirements; clear definition of congestion points; identification of selection and activation periods and the activation mode; well established communication scheme, transparent trading etc. W comparing the design of the project and products we could establish the main trends, that included third party management of the platform, product standardization and pre-qualifi tion, TSO-DSO cooperation establishment etc. We also analyzed the existing legal framework regulating the Austrian electricity market within the framework of energy flexibility, in order to see the possibilities and restrictions that will affect the future of flexibility development in the country. Some of the projects are still at their execution stage, and there is to enough data to conclude which one of the projects is best fitted for the Austrian energy market. However, it can be said that the Austrian flexibility project Flex-Hub is taking into account all the requirements needed to create a reliable and well performing flexibility platform. At this stage, the technological development is in advance of the legal framework, which in many ways is merely reactive. The EAG was only passed in 2019, and therefore in order for the energy market to further develop and to ensure the active participation of all the actors involved more research and studies into its effects are required.

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# 1. INTRODUCTION

## 1.1. Introduction and Motivation

The COVID-19 pandemic and the unprecedented measures being implemented to combat it are putting the global economy on hold, and with it the energy transition. At the same time, a widespread decrease in CO2 emissions is being observed. It is, however, difficult to predict its further growth or decline after the normalization of the epidemiological situation. Nevertheless, the goals set out within the framework of the Paris agreements are not currently being revised and the environmental agenda remains, regardless of the economic downturn, of fundamental importance.

According to the prognoses of the analytics, by 2020 the global energy is predicted to suffer from lower demand (Arboleya et al., IEA, 2020) and reduction in investments - a record of 10% for the last indicator, however it is different when considering the sectors; for fossil fuels, the reduction is predicted to be more than 25% , but for renewables only 10% (IEA, 2020c). The International Renewable Energy Agency (IRENA, 2020: 12) has issued its new report on post-pandemic recovery. According to IRENA forecasts, with proper political and regulatory support in implementing the global economic recovery in 2021–2023, “clean” energy will be able to attract up to $ 5.9 trillion in investments in three years. The World Bank is among the proponents of a green path to economic recovery, indicated in a new report that investments in a low-carbon economy can generate four times the return on investment (Mukhi et al., 2020: 5).

The "Renewable Energy Systems" program allowed students of the Technical University Vienna to understand in detail the principles and technical aspects of this area of energy. Having participated in this program, the importance of the future of modern power systems and electricity markets has become only further underlined to me. We visited various enterprises producing energy from renewable energy sources and received an in-depth understanding of how the Austrian electricity market functions. It is necessary to trace how local markets will develop in the future, what promising tendencies can be observed now, and to determine if there are possibilities to adopt existing models, and if it is possible to learn from the experiences of other countries.

### 1.2. Problem Definition and Relevance

During the past ten years, Europe has seen an increase in the share of renewables in electricity generation. At the same time, a certain level of unpredictability of solar and wind resources poses serious threats to the balance of the power system (IEA, 2020b). To provide a stable load in an electricity distribution grid with a high share of renewables, Transmission System Operators (TSOs) and Distribution System Operators (DSOs) need flexibility opportunities to adapt to the varying levels of demand (Kemfert et al., 2019: 179). Flexibility, according to the European Commission Smart Grid Task Force (2015), is “the ability of a power system to modify the production and consumption patterns in reaction to an external signal”. This can be flexibility in supply, flexibility in demand, and flexibility in production.

Over the last couple of years, a number of research centers and consulting agencies have turned their attention to the phenomenon of flexibility in the energy sector. Scientists advocating the transition to carbon-free energy, which has become especially evident in the framework of the pandemic, prioritize issues of flexibility as a guarantor of the stable functioning of the system.

For example, Wood Mackenzie calls (Parnell, 2020a) the future of energy “nothing less than the new era of flexible grid, or the era of energy flexibility”. In a new report, Wood Mackenzie identifies three major stages in the development of power systems with distributed energy sources, each successively replacing each other with a growing share of renewables in the energy balance. The stage of "smart grids" is characterized by a centralized response of power systems and electric grids to the challenge of distributed energy and renewable energy sources due to new - digital - technologies. The “grid edge” stage, which is just ending at the turn of 2020, is characterized by the active integration of distributed energy into the network, building local ecosystems of active consumers, giving them the opportunity to contribute to the management of energy systems, and testing new regulatory models. Finally, the stage of "flexible grids", with the reformatted energy markets and the emergence of national or even regional markets of flexibility, where distributed energy resources will begin to have a beneficial effect on energy systems as a whole, and become full participants in the management of these power systems.

In a number of European countries (primarily in the United Kingdom [UK]) a transition has begun to piloting marketplaces for trading flexibility (Radecke et al., 2019: 1). But none of these countries, not even the leaders of the energy transition, have yet introduced a nationwide model of a *flexibility market*, even in experimental mode. Therefore, it is especially interesting to trace how this transformation could take place in Austria, from several different vantage points: legal, technical and economic.

### 1.3. Research Objectives

The objective of my research is to identify and study current energy flexibility projects and from this determine which of these will be most beneficial for the Austrian market.

For this purpose, I will first adapt the metric proposed by Heilmann, Klempp and Wetzela (Heilmann, et al. 2020: 10) – to better correspond with the parameters presented on the Austrian market. Secondly, I will identify ongoing projects within the European Union (EU) and in Austria and will collect data and conduct the interviews with people involved in these projects. Finally, I will apply the metric and identify the most profitable projects and products. In order to reach the research objective, the following research questions should be answered:

- Which flexibility projects are ongoing in Austria and in the EU and what kind of products do they offer?
- What are the criteria for the successful execution of an energy flexibility project?

- Which flexibility products would provide the optimum benefits for the Austrian electricity market?

The expected outcome of this thesis is an improved methodology for the evaluation of flexibility products on the Austrian energy market, that may facilitate the further research of fellow scholars. The framework will be developed on the basis of expert interviews and an adapted version the metric proposed by Heilmann, Klempp and Wetzela.

The expected outcome is to be reached in several steps, as follows:

In the first step the existing background information and the state of the art of flexible energy systems and products, their types and specifications is analyzed in order to determine the active vocabulary, underline potential drawbacks and inconsistencies.

The second step includes the transformation of the metric, proposed in “Market Design of Regional Flexibility Markets: A Classification Metric for Flexibility Products and its Application to German Prototypical Flexibility Markets” by Erik Heilmann, Nikolai Klempp and Heike Wetzela. This metric, which will be adapted to the Austrian case, encompasses more than 20 parameters for the analysis of ongoing flexibility projects. By applying this metric I expect to be able to demonstrate the projects’ usability and, in turn, compare the products proposed within.

In the next step the existing legal framework, regulating the Austrian electricity market within the framework of energy flexibility will be assessed in order to see the possibilities and restrictions, and tailor the metric to better fit the local market.

In the next step ongoing flexibility projects in Austria will be assessed, using open source expert interviews. Due to the fact that some of these projects are not yet completed there can be an absence of final data. By applying the metric, I hope to find the product that will provide the optimum benefits among the projects running within the country, and possibly the project that can be adapted to the Austrian energy market that is being tested within the EU.

Finally, In the last step, the results of the previous steps are interpreted and evaluated according to adopted improved methodology.

### 1.4. Methodology

The general approach to the research is reflected in expert interviews, followed by a quantitative analysis using a tailor-made metric. Such an observational study provides deeper understanding of the phenomena under study and their interrelations. This approach allows, to a certain extent, to evaluate the shortcomings and perspectives of chosen projects.

• Requirements Elicitation

– Literature review. State of the art should be summarized to outline the background of the related topics: energy flexibility, smart grids, flexible grids, flexibility products, etc.

• Realization

– This paper will be based on Semi-Structured, Guideline-Based Expert Interviews, followed by a qualitative analysis, using the metric developed on the basis of German Federal Ministry for Economic Affairs through the smart energy showcases (SINTEG) program.

Semi-structured interviews offer an appropriate middle ground between structured and unstructured interviews. The interviewer thereby asks a set of questions (often with several sub-questions) based on an interview guideline containing most questions in a pre-defined order. The information collected will be later analyzed according to the metric proposed by Heilmann, Klempp and Wetzela, that "provided a novel metric for the design of flexibility products, consisting of more than 20 product parameters in four stages of different abstraction levels" (Heilmann, et al. 2020: 6).

• Evaluation

– Qualitative data collection. In this paper I will use open source data and data collected via interviews.

– Analysis of collected data. Applying the metric according to the proposed criteria.

– Interpretation of the results and hypothesis confirmation. Summarizing the research results and answering the research questions.

### 1.5. Structure of the Thesis

My thesis will consist of six chapters. In the first one I will explain my motivation, outline the main research question. In the second chapter I will provide background information and the state of the art of flexible energy systems and products, their types and specifications. In the third chapter I will explain the methodology chosen, which in this case will be based on a metric, which will be adapted to the Austrian case, that encompasses more than 20 parameters for the analysis of ongoing flexibility projects. By applying this metric I hope to demonstrate the projects' usability and, in turn, compare the products proposed within the projects. In the fourth chapter I will consider ongoing projects in Austria and in Europe and apply the metric to find the product that will provide the optimum benefits among the projects running within the country, and possibly the project that can be adapted to the Austrian energy market that is being tested within the EU. In chapter five I will take a closer look on the existing legal framework, regulating the Austrian electricity market within the framework of energy flexibility. Finally, in the last chapter I will draw conclusions, where I hope I can provide an adapted improved methodology for the evaluation of flexibility products, find opportunities for future development of flexibility products and projects in the Austrian energy market and facilitate the further research of fellow scholars.

# 2. STATE OF THE ART

## 2.1. Theory and Literature Review

The macro trends, that directly effect the modern energy systems, can be characterized under the abbreviature DDDII, which stands for Decarbonization, Decentralization, Digitalization, Integration and Inclusion (Hillberg, et al. 2019: 9). This new energy era is characterized by an urgent need to lower energy production's impact on the ecosystem while simultaneously keeping up with the growing energy demand. At the same time, it demonstrates a shift from large power plants to local energy units. Interdependent, heavily linked energy grids have become more sophisticated and automated, and are emerging against the backbone of growing electrification.

With the increase in the share of renewables in the global energy balance, the principles of energy balancing are being transformed, and its structure is changing (Kessels et al., 2019: 22 ). There are a number of major factors that create a background for systems in need of energy flexibility (Villar et al., 2018: 329-30), among them:

1. Conventional energy sources still dominate on the market, and enable the necessary stability and security of the system, however decreasing variable costs of renewables and spot-auctions, allowing the operators to reduce the hours or shut down the plant, which makes the switching back more costly.
2. Renewables attracting more investment and playing a key role in the short and long term development scheme, at the same time this trend is accompanied by an increasing need of Energy Storage Systems (ESS), that will allow more effective, resilient and stable power generation, and more favorable cost of electricity
3. Market with heavily integrated renewables still requires additional support, from conventional power utilities and inflect more pressure on stakeholders to balance the grid.
4. The end consumers begin to be more involved in the current energy affairs and take on proactive roles, by acting as prosumers, via private charging sta-

tions, domestic energy installations of different kind, storages etc. Active participation in the future wholesale market privately and as a group is also expected. Piloting projects like Prosumers and Energy communities expand their knowledge of the mechanism and call for active participation in a green electricity production and nature preservation.

5. As a consequence Distributed Generation (DG) is a more complicated framework to operate in, keep the balance and frequency in case of transmission operation (TSO) and reverse power flows, face congestion and voltages issues for distribution operators (DSO).

6. Technical innovations, such as Smart Meters, Smart Grids and Flexibility platforms and Aggregators will become the basis for the further development of the energy sector, however require an easy and well established communication and regulation scheme for all the parties involved.

The characteristics of the power system mentioned above require special and sensitive calibration. Integration and development of green energy sources for electricity production is essential for further decarbonization, which became even more vital in the light of the 2020 pandemic. In the current climate, the most important characteristic of an energy system is its reliability, security and quality of power. Current systems often mainly rely on fossil fuels for electricity production, since they provide the required reserve capacity. In the nearest future, due to the uncertainty of Renewable Energy Systems (RES), their effective integration in the power mix will require additional storage and reserve capacity. To reach the low carbon goals, there are a number of actions that need to be implemented on many levels: national, local and regional. Within the framework of decarbonization (in order to satisfy the demand of the consumers, minimize losses and maximize the profit and most importantly to mitigate against the climate change) the energy system requires flexibility (IEA, ISGAN 2020: 1,2).

There are a number of definitions given for the term ‘flexibility’. In many cases it relates to the ability of a system to rapidly adapt to changes, though there is no uniform term to describe it (Hillberg et al., 2019: 10). "In harnessing variable renewables - a guide to the balancing challenge," identifies flexibility as: “the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to maintain reliable supply in the face of rapid and large imbalances, whatever the cause” (IEA, 2011, cited by Hillberg, 2019). Flexibility is described as a novel non-standard product or concept, introduced or supplied by different energy markets located at the transmission or at distribution grids (Kouzelis et al., 2015: 1-5). In other words it is “the capability of a power system to cope with the variability and uncertainty that Variable Renewable Energy (VRE) generation introduces into the system in different time scales, from the very short to the long term, avoiding curtailment of VRE and reliably supplying all the demanded energy to customers” (IRENA, 2018: 23).

As we can see, flexibility is a universal tool, applicable to all aspects in the power system. Based on the definitions we can say that flexibility allows for:

▪ Effective and easy integration of renewables into the energy/electricity mix, thus stimulating less use or more rapid decommissioning of fossil based utilities. Flexibility may enable all stakeholders (TSOs,DSOs, etc) to balance their supply and demand more efficiently, minimize network congestion.

▪ Greater grid reliability and security against imbalances and disruptions. With space to maneuver within the grid, the operators can better calibrate the systems to avert outages in case of system fatigue or equipment malfunctioning, or due to external natural events.

▪ Lower general cost. By being able to quickly and more economically reply to the growing demand, flexibility allows for a better use of local available energy resources and gives, simultaneously lowering the electricity prices and providing more opportunities for local producers (Villar. 2018: 329).

▪ More rapid and more effective decarbonization and subsequent economic benefits, related to CO2 taxes.

The existing academic papers, when addressing the subject of flexibility, focus on the following aspects: organizational, technical papers, and economic. Other focus on the implementation possibilities or provide the general analysis of existing projects.

Schittekatte et al (2020: 9) address organizational aspects in the form of a Question and Answer session, where they analyze four pioneering projects implementing flexibility markets and concluded that "all of the considered flexibility markets are operated by a third party". All projects also communicate with different DSOs to in turn become a platform provider. Differences are found in the integration of those projects, the payment schemes, cooperation scenarios between the parties, the vision and project maturity (Schittekatte et al. 2020: 9). Olivella-Rosell et al (2018) analyzed different local electricity market designs, paying special attention to the role of aggregators.

More technically oriented papers include, for example, Cruz at al (2020), focused on the demand side, network side, supply side and other flexibility options, including storages.

A more economic focussed approach was demonstrated by Michaelis et al. (2017) They examined and compared four aspects of ongoing flexibility projects - increasing the residual load, decreasing the residual load and shifting the electricity demand / supply temporally or spatially.

Specific research of the Austrian market from a regulatory point of view has been conducted in 2016 by Poplavskaya (2016) showing that the existing regulatory framework at the time was not sufficient with respect of Distributed Energy Resources (DERs).

The majority of the papers mentioned indicate a connection between the concrete issues to resolve and offer a befitting flexibility solution. Based on the literary review presented in this paper it is safe to conclude that there is extensive research being conducted in the field of flexibility, but it is mainly concept and technology oriented.

A number of papers provide tailored analysis of economic and technical aspects of flexibility products, that can be applied to a specific country, however there is little research that takes into account the legal aspect and the existing regulatory tools. Finally, we can say that there is a need for a specific tailor-made analytical framework for a regional (in our case Austrian) flexibility market.

## 2.2. Types of flexibility and main stakeholders

The majority of researchers share the opinion that there are four main stakeholders in the flexibility market. They are:

• Transmission System Operators

• Distribution System Operators

• Electricity suppliers and retailers

• Aggregators

In this section we are going to talk about flexibility, first in a more general sense, ie. not within the framework of the supply/demand side, but from a management and planning perspective.

By understanding the concept of flexibility needs, it is easier to tailor the flexibility product in harmony with the existing resource base, technical restrictions and legal regulations.

In the discussion paper the International Smart Grid Action Network (ISGAN) provides the following characteristics of the three main flexibility needs (ISGAN 2019: 13-19):

- **Power flexibility** is characterized by need to sustain power supply/demand balance, in order to maintain frequency stability and the ability to be activated within the time of less of a second up to sixty minutes. This mainly relies to the dependency of renewables on the weather conditions (i.e. solar and wind) and their share in the generation mix.
- **Energy flexibility is a** medium to long term energy supply and demand balance, characterized by a limited number of conventional fossil fuel produc-

tion units with storages in the generation mix. This option involves long term planning and a longer activation period, up to years, with seasonal variation loads altering demand behavior.

- **Voltage flexibility** as the ability to keep the voltages within the certain limits, in accordance with local and regional requirements, increasing distributed generation is making balancing power flows quite challenging to the DSOs, thus in order to guarantee ramping and keep the voltages at the preferred levels there is a need for such flexibility with the activation time of between seconds and ten minutes (ISGAN 2019: 13-19).

Based on the above discussed characteristics of the energy systems, we can assume that energy flexibility has the following traits:

- Power alternation
- Energy in MWh
- Response time in s or h or y
- Delivery speed in MW/s
- Duration
- Recovery period
- Location
- Function

In light of the flexibility needs discussed earlier, we can talk of flexibility options or flexibility products that are aimed at providing the flexibility whenever it may be needed. The modern literature accounts for hundreds of different products and product-related concepts for electricity markets. Definitions of products and the spectrum of solutions, services and market and legal mechanisms is different for every particular situation, market and country. For instance, Nolan et al. (2019) distinguish more than a hundred various types of products on the current market, and define a product to be an option that is traded, delivered and remunerated when called upon. The other literature distinguishes two approaches – demand/supply side and network flexibility products or flexibility products for transmission and distribution grids.

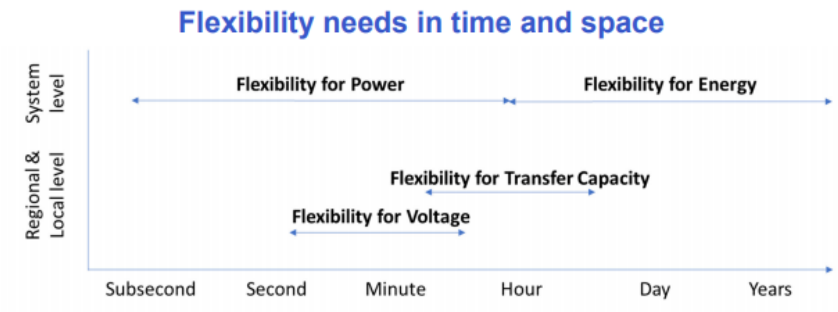


**Figure 1. Flexibility needs in time and space (*Source: ISGAN, 2020)***

Flexibility options can be provided to TSOs for system flexibility (Nolan et al. 2019: 49) (balancing of power, frequency control etc.), and to DSOs for local purposes: balancing voltages and to deal with congestions at the network level. Villar et al. (2018) distinguish the following options -

- **Transmission grid flexibility options** include intraday and reserve options provided by traditional suppliers together with new products aimed at optimization of dispatching of capacities.

Flexibility products in this category are usually directly traded in wholesale markets, examples of such products can be seen mostly in Northern America, where there is an existing framework for such a participation. The American electricity market is a day-ahead energy market with a 1 hour interval, operated by Midcontinent Independent System Operator and California Independent System Operator and other system operators, and a real-time energy market for dispatching to satisfy the load needs on a 5 minute basis. Between those markets flexibility can be provided by ramp capability products, ancillary services, that help the grid operator to keep the balance, such as “spinning and non-spinning reserves” (Navid et al., 2013: 3). Where spinning reserves is understood as “the generation and responsive load that is on-line, begins responding immediately, and is fully responsive within ten minutes; and non-spinning reserve is the generation and responsive load that is off-line but can be fully responsive within 30 minutes"(NREL, 2020). The ramp capability product (Khajeh et al. 2019: 5) is designed to balance the net load in even shorter period of time: five minutes. There are also products to manage the actual load every four seconds.

- **Distribution grid flexibility services** are aimed to meet the local needs of voltage balancing, congestion management and reduction of energy losses, here TSO–DSO coordination is of vital importance, and new technical and regulatory requirements are needed. An interesting example of such a products can be found in Electric Vehicles (EVs) and their charging infrastructure, that can bring not only energy benefits, but economic ones as well.

According to an open letter from Kaluza, Octopus Energy, Centrica, E.On and Moixa to the Office of Gas and Electricity Markets (Ofgem), if all UK EV charging stations were to provide flexibility services, the UK would save £133,000,000 this summer by reducing trading volume in the balancing market (Grundy, 2020b). Some of the flexibility potential of the charging infrastructure is already being exploited. The British company Ev.energy, which owns 25 MW of charging stations, became one of the winners of the UK Power Networks flexibility auction (Parnell, 2020b). Even more possibilities, according to the estimates of the network company Western Power Distribution (WPD), have Vehicle to Grid (V2G) charging. Therefore, WPD, in cooperation with Crowd Charge, is launching a pilot project in March 2021 that will install V2G charging stations free of charge to Nissan electric car owners living in Midlands, South West England in South Wales, and will also pay the project participants £ 120 for the fact that their cars will be connected to these stations at certain times. Upon completion of the project, participants will be able to redeem the charges for £ 250 at a market price of £ 5500. The power utilization of V2G stations already connected to Kaluza's Flexibility Management System has doubled since the start of the British quarantine in March (Grundy, 2020a). In the long term, by 2050, according to Catapult Energy System analysts, V2G technologies will provide the

UK power system with access to 50 GWh of storage capacity of car batteries (Catapult, 2020).

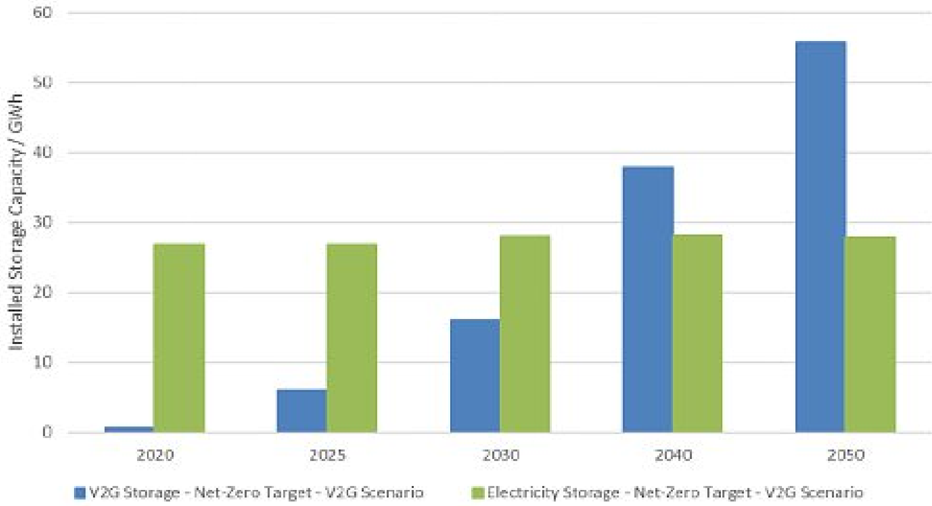


**Figure 2. Cumulative capacity (GWh) of electric vehicles connected to V2G stations and stationary storage** ***(Source : Energy System Catapult, 2020)***

Cumulative capacity (GWh) of electric vehicles connected to V2G stations and stationary storage devices. Source: Energy System Catapult

Wood Mackenzie estimates that by 2030, around 40% of newly manufactured vehicles will be EVs (Parnell, 2020a). This growing infrastructure, coupled with EVs, can provide new flexibility options. For example, the Power Plant Development Center has calculated that British companies in 2020–2025 could receive additional £ 25 billion in revenue from participating in the country's transition to electric vehicles (APC UK, 2020).

### 2.3. Demand side flexibility

It is actively discussed that demand side can offer a wide spectrum of flexibility options. These options can be reflected in consumer behavior, as a reaction to different kinds of price related stimuli and also in non-financial (behavioral) stimuli. This can relate to technical aspects, such as energy efficiency, financial/demand-response practices and to other behavioral aspects, such as distributed consumption, i.e. switching to non-peak hours.

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**Demand response**

Demand Response (DR) a flexibility solution at the consumers end, that enables consumption to adapt to rapidly changing energy prices. Flexibility products offered in this area allow the demand to become more flexible – allowing for shifts or consumption reduction or both. Demand response, according to Cruz at al. can be incentive-based or price-based. The first option is reflected in such flexibility programs as "direct load control, curtailable load services, demand bidding" (Cruz et al., 2018, 339) etc. "Price-based option includes time-of-use (ToU), critical peak pricing (CPP), peak time rebate (PTR) and real-time pricing (RTP) programs" (Cruz et al.: 2018: 339).

Flexibility products can also be found in the form of different aggregators, blockchain technologies implemented solutions and other IT-solutions, such as forecasting tools, etc. Undoubtedly, such innovations require a legal basis. One of the leading countries actively developing this area is the UK, which is trying to allow sources of flexibility, such as storage and demand management, to the markets for capacity and system services. For example, in May, Ofgem removed the barriers to participation in the UK market for storage capacity and demand management aggregators, in particular reducing the entry threshold to 1 MW (Lempriere, 2020).

Generally, among the strong sides of the DR it is possible to name an overall cost and consumption reduction and a more effective ramping rate due to quick adjustment. The main barriers include the fact that the majority of markets are centralized and cannot offer demand flexibility, non-transparent regulatory and tariff schemes, unpredictable consumer behavior, privacy and data security issues, energy security and need for a large investment (Cruz et al., 2018: 341).

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**Energy efficiency**

Demand Side Management (DSM) is “the demand side mechanism to influence the use of electricity by changing the pattern and demand volumes, such flexibility options include - peak clipping, load shifting, valley filling, strategic conservation etc.” (Cruz et al., 2018: 341). For many cases this strategy implies cold or heat storage utilities.

This option is related to the behavioral aspects of consumption and implies voluntary reduction in consumption, energy savings, installation of more efficient equipment, and so on. The incentive schemes have proved to be very effective, such as contracts that offer lower cost in night time and maximum cost during high peak hours. Part of experimenting with market design is developing new tariff types for consumers. For example, the British Parliament is listening to a draft law on local energy exchange, which allows for the payment for electricity produced and consumed within one local community, not according to general rules and tariffs,  but based on the local special prices and tariffs for this community (Local Electricity Bill, 2021, 1-2).

The arguments for such products include: balancing opportunities; large response time variations; overall cost reduction and system expansion reduction costs; and minimization of losses (Lund et al., 2015: 791). The main barriers, as in case of demand response include the need for financial and regulatory incentives, and active participation from stakeholders.

Another untapped flexibility solution presents itself in the form of smart thermostats. The United States of America (US) are actively implementing this technology throughout the country (Gerdes , 2020).  A subsidiary of the IT giant, Google Nest, equipped more than a hundred thousand households with free remote-controlled thermostats, which reduced the average electricity bill for the summer months by 20% and provided around 13 MW of flexible assets (John, 2020). A study by EnergyHub, Rheem, and United Illuminated shows that heat pumps and water heaters can also be used as sources of flexibility (John, 2020).

Pilot projects to use heating to balance the power system are under way in the UK. National Grid ESO and the Grid Company of Scotland and the South (SSEN) have launched the 4D Heat project, in which they are investigating the possibility of 380,000 households in Scotland using electric heating to balance the production of wind turbines located in the North Sea (Lempierre, 2020). An interesting and comprehensive Smart Local Power System (SLES) project has kicked off in West Sussex. The project is forming a virtual power plant from residential and municipal flexibility sources, comprising 350 rooftop solar panels with MOIXA storage, 12 MW of networked municipal storage from Connected Energy, 250 heat pumps from PassivSystems and five clusters of charging stations for electric vehicles, in addition to using a hydrogen refueling station with an electrolyzer from ITM Power and an intelligent electric heating system for houses from ICAX (Lempierre, 2020).

## 2.4. Flexibility of supply

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### Fossil fuels generation

In order to provide stable energy supply a system needs to be balanced at all times. The demand should always be satisfied, and in many cases this meant that electricity production mainly relied on fossil fuels. Depending on the demand there are three categories of power plants - baseload, peaking and load following regimes (Hillberg et al., 2019: 21). Coal and nuclear power plants fall in the first category and operate at all times, almost without an opportunity of shutting down or restarting, i.e. they have no or very little flexibility. The second category are easier to manipulate and they come into play during peak hours, and the last category include gas and hydropower plants, that have the fastest response time. But this situation needs changing, due to the increasing demand for flexibility. Combined technology power plants can be a solution to this issue, to a certain extent, so is an implementation of heat pumps, storages etc. However, the cost of fuel, the CO2 tax associated with it and the ecological consequences will eventually become a serious barrier for the use of conventional power plants. There is a great need of RES integration and the development of the technology, storage in particular.

### 2.5. Renewable Energy Sources

Renewable energy, such as wind and solar energy, are very dependent on the weather conditions, and the availability of resources in general, and in the absence of reliable storage it can lead to highly intermittent energy generation (IEA, 2020b). Solar and wind power resources are inherently dependent on weather conditions and cannot guarantee uninterrupted electricity generation. It is important to notice, that solar energy is produced during the daylight, which coincides with the highest demand. The arguments against solar generation include the fact that clouds can lower the efficiency of solar panel, and that the distribution of solar resources around the world is a-priori uneven. Some regions get very high direct normal irradiance and some do not, but engineers, together with scientists, are trying to find a solution to this issue. In the case of wind (onshore and offshore), it is fair to say, that the power generation is more reliable, since the wind blows at night as well as during the day, but at the same time, it can change rapidly within minutes or can stay constant for days. Brunner et al. (2020) considered three separate combinations of fluctuating renewable energy sources for energy generation, with the share of renewables of around 80%. They came to the conclusion that an option with increased offshore wind or Photovoltaic (PV)+offshore wind "have almost the same effect on the residual load, and an increased offshore wind minimizes the range of the residual load, while PV+offshore minimizes the surplus energy" (Brunner et al., 2020: 1315). According to the paper "high PV shares, the daily pattern of electricity generation minimizes the surplus time but strongly increases the hourly gradients as well as the quantity of surplus energy. This further hampers the utilization of the surplus energy in other sectors, e.g. via power-to-heat or power-to-gas, mainly due to the reduced full-load hours for such technologies" (Brunner et al., 2020: 1315).

## 2.6. Grid flexibility

This section is dedicated to flexibility options that can be implemented on a grid level. These include, for example, smart-grids, micro grids, dynamic switching and application of platform technologies for network management.

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### Smart-grids

Brunner et al. give the following definition for a smart grid: "a smart grid is an electricity network that can cost efficiently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" (Union I, 2014: 2). It is vital to stress, that such technologies employ IT-technologies and algorithms and to a certain degree can be autonomous. On the demand end, in turn, it can be reflected in the form of smart meters and related technologies, that make the communication with network operators and aggregators more efficient, as it can analyze patterns and later predict consumer behavior. Consumers employing smart appliances can promptly react to price changes and save energy or significantly reduce it during peak-hours, or shift consumption to follow the Renewable Energy System (RES) energy production at lower cost (Batalla-Bejerano, 2020: 7). The strength of the smart grid lies in an opportunity to balance any disruptions by an active demand response (Batalla-Bejerano, 2020: 7).

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### Microgrids

Microgrids are decentralized local grids, that allow small-scale participants, i.e. consumers and prosumers to trade energy within their community. Microgrids can have energy storage, can integrate renewable energy sources and be connected to the main grid (IRENA, 2014: 5). However, if needed it can be isolated using special islanding systems. In the event of outages, disruptions etc., they can be disconnected from the main grid and continue local operation. With an integration of distributed generation systems, microgrids can balance themselves and avoid power outages within the microgrid. Thus facilitating a sustainable, resilient balance of generation of the local and main grids. Blockchain application technologies for microgrids are one of the most interesting and controversial flexibility products on the market to this date. These applications (Goranović et al., 2017: 2) will help end-users to personally choose their suppliers and source of energy. Blockchain technology use smart contracts - transaction protocols that automatically execute, control and register any activity, following contract or an agreement - which help to avoid any fraudulent manipulations with the absence of centralized supervision (Fries et al., 2019: 3). Personal data is encrypted, thus these application satisfy the need for private information security (Goranović et al., 2017: 5). At the same time, this technology is not universally accepted, requires additional testing and a special regulatory framework.

Nevertheless, blockchain technology for congestion management can be beneficial in the future (Amenta et al: 2021: 4).

## 2.7. Energy Storage

**Energy storage systems**

Energy storage is a system that allows for the storage of a “surplus of energy in one form or another and/or meet the energy deficit by acting as a generator and discharge electricity” (Cruz et al., 2018: 346). Energy Storage Systems (ESSs) can offer an array of technical and economic benefits, can be integrated at any part of the energy system and provide additional security to the system in general, by providing grid support and fulfil the balance needs during the peak hours in particular, due to fast response feature (Cruz et al., 2018: 345). They also allow for more RES penetration and to some extend neutralizes the problem of their variability, uncertainty and dependence on the weather conditions. Economic benefits can be reflected in the flexible charging and discharging capacity, these operations can be carried at the best suitable price (Cruz et al., 2018: 347).

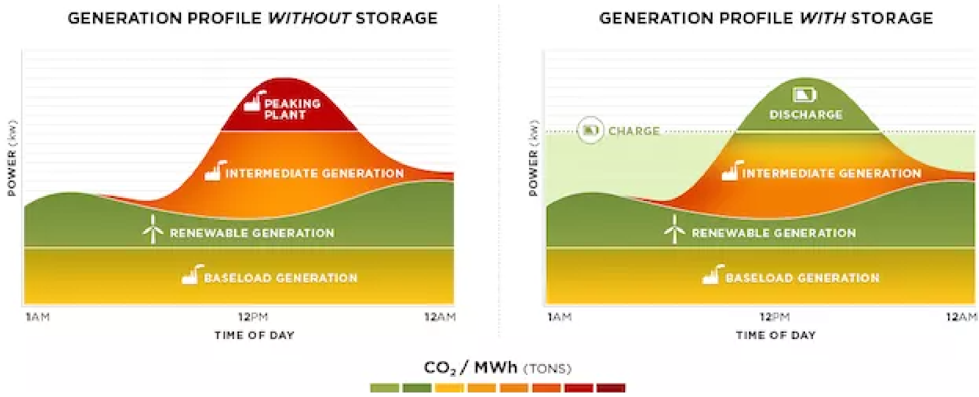


**Figure 3. Energy generation systems with and without storage (*Source: University of Copenhagen, 2019)***

There are a large number of different types of storages. For RES technologies in particular, there are 6 main types: biological, electrical (sometimes known as electrostatic), electrochemical, chemical, thermal and mechanical, sometimes also known as physical.

**Table 1. Renewable and Advanced Energy Storage Methods** ***(Source – U.S. Department of energy, Energy Storage Association, 2018)***

| Renewable/Advanced Energy Storage Methods | |
|---|---|
| **Biological** | **Electrical** |
| • Starch<br>• Glykogen<br>• and other | • Capacitor<br>• Supercapacitor<br>• Superconducting Magnetic<br>• Energy Storage and other |
| **Electrochemical** | **Chemical** |
| • Batteries<br>• Fuel Cells<br>• Ultra Batteries<br>• Flow Batteries<br>• Rechargable Batteries<br>• and other | • Synthetic Fuels<br>• Syn Gas<br>• Biofuel<br>• Hydrogen<br>• Oxyhydrogen<br>• Liquid Nitrogen<br>• Hydrogen Peroxyde<br>• and other |
| **Thermal** | **Mechanical** |
| • Ice Storage<br>• Solar Pond<br>• Molten Salt<br>• Eutetic System<br>• Stream Accumulator<br>• Fireless Locomotive<br>• Seasonal Thermal Store<br>• Cryogenic Liquid Air or Nitrogen<br>• Innovative Construction Materials<br>• and other | • Spring<br>• Hydraulic Accumulator<br>• Flywheel Energy Storage<br>• Hydroelectric Energy Storage<br>• Compressed Air Energy Storage<br>• Gravitational Potential Energy (Device)<br>• Pumped-Storage<br>• Hydroelectricity<br>• and other |

The most frequently mentioned characteristics of the main energy storage systems are power capacity, reflected in MW, storage duration measured in hours, cycling or lifetime in years, and efficiency in %. Each system has both a number of important advantages and disadvantages. For example, Pumped Storage is one of the leaders in storage capacity, energy storage time, and service life, however, it has a relatively low energy density. On the other hand, lithium-ion batteries have a maximum energy density, excellent efficiency, but are so far inferior to most other systems in terms of power and durability. Thus, it is possible to choose the system, depending on the specifications of the project.

A detailed analysis of the advantages and disadvantages of energy storage technologies was carried out by IRENA (2017). It was noted in the document, that pumped storage stations in almost 90% of cases is associated with Electric Energy Time Shift. Electro-chemical storage systems are best suited for frequency regulation. Electro-mechanical - for local On-Site Power etc. High efficiency, long cycling and fast response storage can help balance voltage and frequency in the grid (IRENA, 2017: 4).

**Table 2. Technical Characteristics of the main energy storage systems** ***(Source: Electricity Storage/ SBC Energy Institute/ September, 2013)***

| Name | Power rating (MW) | Storage duration | Cycling or lifetime | Energy density (W/l) | Efficiency |
|---|---|---|---|---|---|
| Pumped hydro storage | 100 - 1 000 | 4 - 12 hours | 30 - 60 years | 0.1 -0.2 | 70 - 80% |
| Compressed air energy storage | 10 - 1 000 | 2 - 30 | 20 - 40 years | 0.2 0.6 | 40 - 75% |
| Flywheels | 0,001 - 1 | Sec - hours | 20000 - 100000 | 5000 | 70 - 95% |
| NaS battery | 10 - 100 | 1min - 8 hours | 2500 - 4500 | 120 - 160 | 70 - 90% |
| Li-ion battery | 0,1 - 20 | 1min - 8 hours | 1000 - 10000 | 1300 - 10000 | 85 - 98% |
| Flow battery | 0,1 - 100 | 1 - 0h | 12000 - 14000 | 0.5 - 2 | 80 - 85% |
| Molten salt | 1 - 150 | hours | 30 years | n/a | 80 - 90% |
| Hydrogen | 0,01 - 1000 | min - weeks | 5 - 30 years | 0.2 - 20 | 25 - 45% |

The advantages and disadvantages of various types of rechargeable batteries, including lithium-ion, as well as their price characteristics, are discussed in detail in the

Handbook on Battery Energy Storage Systems by Asian Development Bank (2018). The advantages are: long cycle and extended shelf-life; maintenance-free; high capacity; low internal resistance; simple charge algorithm; and reasonably short charge times. The disadvantages are: the need for protective circuits against possible thermal overloads; degradation at high temperature and when stored at high voltage; the inability to quickly charge at relatively low temperatures - less than 0°C; and special rules for transporting batteries in large quantities.

More detailed analysis of storage system integration in the distribution grid is provided by Farrokhifar et al., and perspectives on the further development of the technology is featured in Global Energy Transformation by IRENA (2018).

### 2.8. Renewable Energy Auctions

Auctions, according to IRENA, refer to "competitive bidding procurement processes for electricity from renewable energy or where renewable energy technologies are eligible. The auctioned product can be either capacity (MW) or energy (MWh). An auction is a mechanism (institution) through which one or several goods are allocated and priced on the basis of submitted bids, where auctions are regarded as an efficient market mechanism for renewable energy sources; they provide a higher degree of cost control and offer a lower support level and better efficiency compared to feed-in-tariffs (IRENA and CEM, 2015: 15).

Auctions are flexible by design, they can be tailored depending on the objectives and circumstances. Thus, "one of the mechanism's strengths is its ability to cater to different jurisdictions reflecting their economic situation, the structure of their energy sector, the maturity of their power market and their level of renewable energy deployment" (IRENA and CEM, 2015: 15). Auctions also help determine the "optimal" supplier. The need for auctions arises in the systems where supply exceeds demand, competitive prices are lacking, and communication between auctioneer and bidders is somewhat disrupted (IRENA and CEM, 2015: 37).

**Auction**

There is a set of requirements that the participants need to meet in order to take part in the auctions : 1) reputation; 2) technology; 3) securing grid access; and 4) instruments to promote local socio-economic development (IRENA and CEM, 2015: 17).The table below illustrates all the criteria mentioned in detail.

**Table 3. Different types of qualification requirement according to IRENA and CEM** ***(Source - IRENA and CEM, 2015)***

| *Reputation* | *Technology* | *Grid access* | *Socio-economic aspect* |
|---|---|---|---|
| • *Legal framework*<br>• *Financial proof*<br>• *Previous record and experience* | • *Energy generation source*<br>• *Equipment*<br>• *Other technological constrains (size etc.)* | • *Necessity to ensure the successful grid access*<br>• *Compatibility* | • *Measures taken to educate, employ, include and promote local communal forces* |

At an auction there is a minimum competition requirement and a ceiling price mechanism, that prevent dominant providers from creating monopolies during the auctions, and give an opportunity to participate to multiple competing bidders. The process of an auction includes the bidding procedure, which in case of renewable energy auctions includes processing the information on the price at which the bidders would offer their generation capacity. There are three main approaches –

1. Sealed bid process – is the process where the bidders give the price directly to the auctioneer.
2. Iterative process is characterized by the bidders sharing the information on the price during the course of an auction.
3. Hybrid approach combines the characteristics of the other two.

**Winner Selection Process**

The winner selection process results in awarding providers with a contract.

If the aim of the auctioneers is to get the lowest price the most simple and transparent procedure would be *minimum-price criteria*. On the other hand, it should be borne in mind, that other factors may be included, such as socio-economic, environmental impact, the origin and experience of the provider etc. If taking these criteria into account, we face a more complex selection scheme.

When various products are being selected during the auction it is common to apply *adjusted minimum-price scheme* which includes a "correction factor" that gives a possibility to compare different products, such as wind energy and solar for example.

**Payment aspects**

In the modern practice there are three main ways to award winners with payments:

1) pay-as-bid pricing

2) marginal pricing schemes

3) nonstandard pricing schemes

**Pay-as-bid**

Pay-as-bid mechanisms are very widespread in the modern auction processes. This scheme is complicated by the fact that "bidders do not seek simply to win the auction, but rather to win while submitting the highest possible bid" (IRENA and CEM. 2015: 26). In this process predicting the competitors bids can be an essential part. Moreover, there is a danger of bidding too low in an attempt to get a contract, which may result in not fulfilling the obligations at all.

**Marginal pricing schemes**

These schemes are more preferable at auctions, as opposed to pay as bid, due to the fact, that "by making project developers' remuneration independent from their price bid, bidders are encouraged to disclose their actual costs" (IRENA and CEM, 2015:

38). There is a practice of a uniform pricing, where each of the winner is later paid according to the highest bid accepted.

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**Nonstandard pricing schemes**

These type of pricing schemes includes any scheme that cannot be described by the approaches above. In some cases it involves negotiations with the winner, after the auction has been completed. On the one hand it can result in a better price, on the other hand that kind of processes strip the auctions of their transparency and trust-worthiness.

# 3. FLEXIBILITY METRICS

## 3.1. Flexibility Metrics

In order to assess the system's ability to fulfil flexibility needs and in order to compare different flexibility options, special metrics are used.  There are a great number of different metrics that exist, but all the compilers unite in the understanding that flexibility cannot be measured with a single or even short list of indicators .

**Table 4. Types of flexibility products metrics** ***(Source - Heggarty et al., 2019)***

| Type | Role | Metric | Comment |
|---|---|---|---|
| Evaluating a resource's ability to provide flexibility | Compare different flexibility resources, commonly used as input parameters in dispatch models | Ramp rate<br>Minimum up/down time<br>Start-up time<br>Response time<br>Minimum power output | Characterise flexible generation, flexible load or storage |
| | | Energy capacity | Characterises storage |
| Evaluating a system's ability to provide flexibility | Analyse long-term power system data or the outputs of dispatch models, allowing a straightforward comparison of complex systems | Loss Of Load Probability<br>Loss Of Load Duration<br>Expected Unserved Energy | Standard adequacy metrics giving probability, duration and volume of loss of load |
| Evaluating a system's need for flexibility | Analyse net load curves to evaluate implications of energy policy decisions and improve the understanding of potential challenges | One or multiple hour ramp | Derivative of net load over time, expressed in MW or as a percentage |
| | | Ramp acceleration | Double derivative of net load over time |
| | | Volatility | Sum of ramp accelerations over a certain time period |

In general, they can be divided into three groups, based on their point of focus – resources, the system itself, and energy needs. Table 4 , based on the findings from Heggarty at al. (2018) depicts some of those metrics.

As can be seen from the table above, there is no universal metric that would be applicable to any market or product. When it comes to the flexibility options assessment, the literature is even less numerous and the approaches are less unified. For example, Lynch et al. characterized flexibility options in three dimensions, such as “the energy, the power and the ramp rate the unit is able to provide” (Lynch et al., 2012: 27). The compilers came up with a metric to evaluate any facility that provides, consumes or stores energy. The flexibility in this case is calculated as a sum of all the parameters, and following the same pattern, multiple facilities can be compared within a system.

### 3.2. Flexibility products metrics

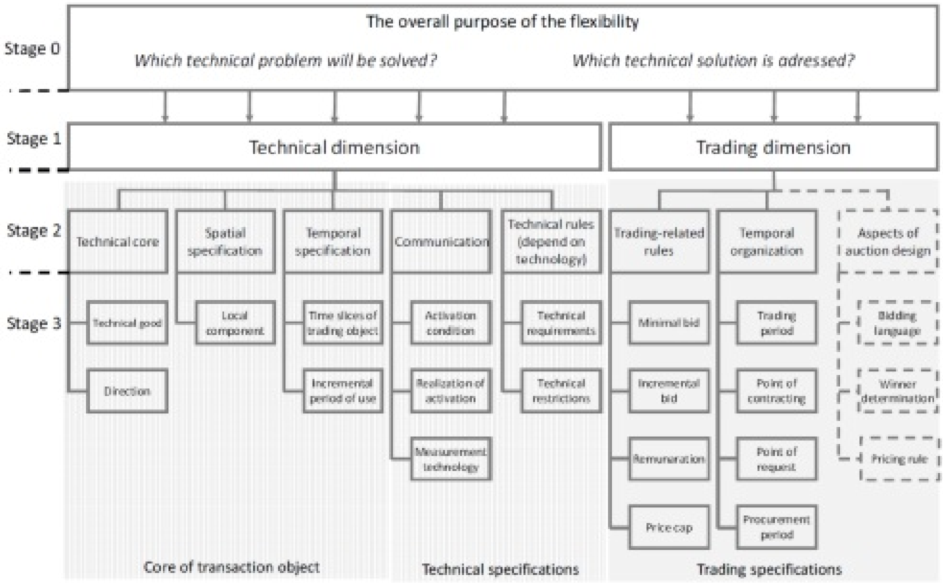
To date, there is no unified metric, that allows for different flexibility products to be compared, especially regard to flexibility. The best example of a flexibility metric design to date, that helps assess flexibility products was given by Heilmann et al (2020). in their discussion paper, where they developed a metric for a German market. In their work they relied on findings and scientific papers, including such works by Villar et al., 2018; Dauer, 2016; European Distribution System Operators for Smart Grids, 2018; Ding et al., 2013; Zhang et al., 2013; Heussen et al., 2013 etc.

Table below presents the metric developed.

Heilmann et al. argue, “that for the majority of cases in the existing scientific literature the products are being investigated from a consumer’s point of view” (Flath et al., 2015: 2).

The current level of technical advancement allows for a better understanding of consumer desires and behavioral aspects through smart metering, which allows for a tailor-made design of product, aimed at a particular consumer. In this regard, the starting point in assessing and comparing different products on the market is to identify its end user.

**Table 5. Summarized metric approach of the design of flexibility products** ***(Source : Heimann et al., 2020)***




The metric proposed has 4 stages.

Stage 0 poses the question on the aim of the flexibility by asking “Which technical problem can be solved?” and “Which technical solution is addressed?”.

Stage 1 identifies and distinguishes the product’s technical and a trading aspects.

Stage 2 describes in detail technical parameters, special organization, temporal specifications, the means of communication between the actors and technical requirements. This stage also describes in detail the trading rules and the aspects of auction design.

Stage 3 gives more detail description of the proposed product. Technical component, location, duration, activation time etc.

**Flexibility needs**

Earlier we discussed the flexibility need and what kind of problem can be solved using this or another product, and at what level. As discussed in Chapters 1 and 2, one of the main goals of flexibility at a national level is to ensure the network's successful operation by balancing the network, conducting congestion management, voltage control or the mixture of these parameters. In this context, before comparing the existing products on the market, it is important to define: what is the issue that will be addressed and what is the solution proposed? This identification cannot be done without addressing technical specifications of the product.

**Technical specifications**

The aspect of technical specifications is of vital importance both to the network operator and the theoretical supplier, and of course the consumer. The first needs the information to see how this product can provide the flexibility needed, for the second, it is possible to identify whether he can participate and how this participation can be carried out. Transparency for the consumer is important not only in terms of establishing trust, but also to ensure the honest actions of the providers.

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**Technical core product**

This important parameter is the "good" itself, that can be reflected in a physical value, such as electrical power for example. We assume that, for the purpose of this paper, all the products compared will have electrical power as their *core product*. There are two ways this product can be used, in order to ensure flexibility – negative and positive – i.e. the electrical power can be both produced and consumed.

**Local component**

The engagement of a local community is one of the important factors of regional flexibility products by definition. We talk in detail about flexibility solutions for local network in chapter 2, where we established that on a local level well-balanced production/consumption schemes are very feasible, due to the volumes, easier management schemes and the possibility of de-attachment in case of technical difficulties.

**Time frame**

The temporal framework of a flexibility product is represented by two different time indicators, the first indicator shows the period of time when the product can be traded, the latter, when it can be used and when flexibility can be delivered.

**Communication**

The communication process is a complex procedure that has many steps. The first step is the activation, which can be "a direct request with a defined value of the technical good, or indirectly as a limit value or quota for a technical behavior" (Ecofys et al., 2017: 153-161). This underlines the fact that a number of small units, if needed to be activated separately, decreases the reliability of the product. The activation, traditionally is carried out by a direct order of the network operator, or by the supplier, after receiving the activation request (Heilmann, et al., 2020: 6).

**Technical rules**

Technical requirements of the network operator can be reflected as, for example, a "reaction period that defines the time between the activation signal of the DSO and the beginning of the adaption of the technical good, and a ramping period that describes the time needed to achieve the nominal value of the technical good" (Heilmann, et al., 2020: 12). Another example of a technical restriction is the limited number of activation sessions within a defined time span, such a restriction is explained by the need for recovery of the system.

### 3.4. Trading dimension

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**Trading rules**

In the section dedicated to energy auctions we talked about specific trading rules. These rules regulate the process or trade and payment. Trading rules, such as technical rules can be very specific, depending on the product provided. The payment process can be carried out within the framework discussed above, but it is necessary to add that, in case of flexibility products, the remuneration can be reflected in the payment for power itself, the number of activations etc.

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**Temporal organization**

The trading period is the time slot within which bidders can place an offer. It can be 1 day-ahead of the auction, a longer period of time, or it can be a continuous trading period, minutes before the delivery etc.

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**Request point**

This is the process discussed above, when the DSO issues an activation signal by himself or sends it to the supplier, which can happen simultaneously at the point of contact, or sometime before the delivery.

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**Auction design**

This issue was discussed in the previous part of this paper. However, in addition to the aspects mentioned in the discussion paper, it is important to talk about such aspects as price per activation, which may help to compare the economic dimension.

Second, it is important to evaluate risk issues that may directly affect the functioning of the project. Such risks, for example, include failure in supply due to faulted communications or control systems between the aggregator and the DSO.

Third, in some cases it can be beneficial to compare the penalty for failed supply, and the conditions of the termination of the contract, if they have been established.

# 4. COMPARISON OF FLEXIBILITY PRODUCTS

## 4.1. Comparison of flexibility products designs

In this section, the aforementioned metric will be applied to 5 different European flexibility projects. These projects include 4 different products. These projects originate from different countries, but this metric will show their main similarities and differences.

The findings presented in the table below are based on interviews with project coordinators or found in open sources. It is important to note that some of the projects are not yet completed, and some of them are not even yet implemented, so some key pieces of information could be missing and some of the conclusions remain hypothetical.

**Table 6. Comparison of different European Flexibility Products (Part 1)** ***(Own table)***

| Project Name | | | WindNODE | WindNODE | GOPACS | Piclo Flex | Flex-HUB |
|---|---|---|---|---|---|---|---|
| Core Characteristics | Traded Product | | Day ahead flexibility | Intraday flexibility | Intraday via the ETPA market platform | Months ahead flexibility | Intraday Flexibility |
| | Flexibility Asset Type | | Controllable flexible asset | | Flexible assests connected to GOPACS | Controlled flexible assets connected within a predefined geographic area | Flexible assets connected to Equity Platform |
| | Project Duration | | Trial project (finished) | | Ongoing project | Ongoing project | Ongoing project (Proof of concept finished) |
| | Size (Power and Energy) | | | | 10-100 MWh per trade | 18 MW contracted and 95 MW on demand | TBA |
| Technical Aspects | Direction | | Positive and Negative | | Positive and Negative | Positive | Positive and Negative |
| | Product Location | | Network Node | | No static zones, dynamic dependent on congestion needs | 28 constraint geographical areas | Austrian network node |
| | Duration per Activation | | 15 minutes | | Continuous product | 30 minutes to 2 hours | 15 minutes |
| | Communication | Activation Condition | Direct | | Via Platform | Via Platform | Direct |
| | | Activation Mechanism | Activation by supplier | | Activation by supplier | Activation by supplier | Activation by supplier |
| | | Measurement | 13.9 SAIDI minutes | | Supplier dependant | Supplier dependant | Supplier dependant |
| | Technical Rules | Technical Requirements | Not yet defined (NABEG) | | 110 kV or higher, 50 kV or lower, agreement with ETPA, Every order has to include location data for GOPACS to be able to use it. | 11 kV or lower | The providers are compliant to the same rules as the other market participants. |
| | | Technical Restrictions | Option for offered power division (NABEG) | | Only flexible assets connected to the transmission grid, DSO connection is planned | Restricted geographical location | TBA |

**Table 7. Comparison of different European Flexibility Products (Part 2a)** ***(Own table)***

| Project Name | | | WindNODE | | GOPACS | Piclo Flex | Flex-HUB |
|---|---|---|---|---|---|---|---|
| Product Name | | | Day ahead flexibility | Intraday Flexibility | Intraday flexibility via the ETPA market platform | Month ahead flexibility | Intraday Flexibility |
| Trading Aspects | Trading Rules | Minimal Bid | From 100 kW (NABEG) | | 100 kW | 50 kW | 100 kW |
| | | Incremental Bid | 100 kW (NABEG) | | 100 kW | 50 kW | 100 kW |
| | | Price Cap | no | | no | no | no |
| | | Renumeration | Euro per MWh | | Euro per MWh | Euro per MWh | Euro per kWh |
| | Temporal Organisation | Trading Period | Bids can be placed by 16.00 day ahead | 2 h before delivery | Continious product | Bids can be placed by 12.00 in March 2019, 4 days ahead | All day |
| | | Contract Establishment | By 22. 00 day ahead | 1 h before delivery | After GOPACS approval | By 12. 00, 4 days later | 25 minutes ahead of real time |
| | | Request Period | At the time of contracting | | at the time and location of the EAN code corresponding to the orders | Later in 2021 | Market dependant |
| | | Procurement Period | Next day | 1 h of current day | Up to 1 h of current day | 4 days (trial auction) | Optional (Market dependent) |
| | Market Design | Pricing Rule | Pay as bid | | Pay as bid, In the event of a price difference between the buy order and a sell order, the grid operators pay the price difference. | Pay as bid | Pay as bid |
| | | Bidding Rules | Existing bidding rules | Existing bidding rules | Participating parties trade electricity by placing buy orders and sell orders on the ETPA market platform. GOPACS calculates if the order solves and not aggravates the congestion. | Existing bidding rules | Existing bidding rules |

**Table 8. Comparison of different European Flexibility Products (Part 2b)** ***(Own table)***

| Project Name | | | WindNODE | GOPACS | Piclo Flex | Flex-HUB |
|---|---|---|---|---|---|---|
| Trading Aspects | | Winner Determination | Interactive oprimisational process, that begins with the lowest DSOs to the TSOs | Economical optimisation depending on the geographical proximity | Merit order | Merit order |
| | Price per Activation | | Not available | Not available | Not available | Not available |
| | Risk Issues | | Failure in supply due to faulted communications or control systems between supplier and the DSO | Failure in supply due to faulted communications or control systems between supplier and the platform | Not available | TBA |
| | Penalty for Failed Supply | | Not identified | Not identified | Not identified | End of the year |

### 4.2 WindNODE

About the Project (WindNODE 2017-2020)

The WindNODE flexibility platform has been developed within the framework of SINTEG and run in cooperation with a number of electricity providers, including 50Herz and Strommnetz Berlin. The platform connects grid operators with flexible power producers and consumers. In case of grid congestion the platform ensures that the renewable energy can be either successfully used or stored. The grid operators forecast the load for the upcoming hours, while the flexibility providers check if their power requirements can be delayed, if they need batteries to be charged, or if they require additional cooling capacities. On the platform they indicate the volume needed and the providers indicate the price bid they would like to receive for their services. There are day ahead and intraday trading options. Monitoring the grid is essential, and, if the offer can cause additional congestion, the grid operator can block one offer and choose another in order to avoid bottlenecks in the grid (WindNODE, 2017-2020: 17-18).

The functioning of such platform can only be economically feasible if the flexibility options provided are considerably cheaper than existing ones and support renewable energy providers. The distribution of flexibility consumers is uneven and the volumes and frequency of flexibility consumption vary depending on the location. This project has had a successful trial run, however, in view of regulatory framework changes of the Netzausbaubeschleunigungsgesetz Übertragungsnetz (NABEG), a big share of flexibility will be part of the regulated redispatch assets. This may create additional stress to the grid and brings the cooperation of DSO-TSO and flexibility providers to the forefront of the issue.  The untapped resource, which is not included in the NABEG regulation, is solely represented by flexible loads. However this process is hindered by strategic bidding. Flexibility providers can artificially create a bottleneck, then using their own resources balance it back, and gain money from it. The way to regulate this issue is a mandatory integration of these providers in the grid balancing apparatus (WindNODE 2017-2020: 44).

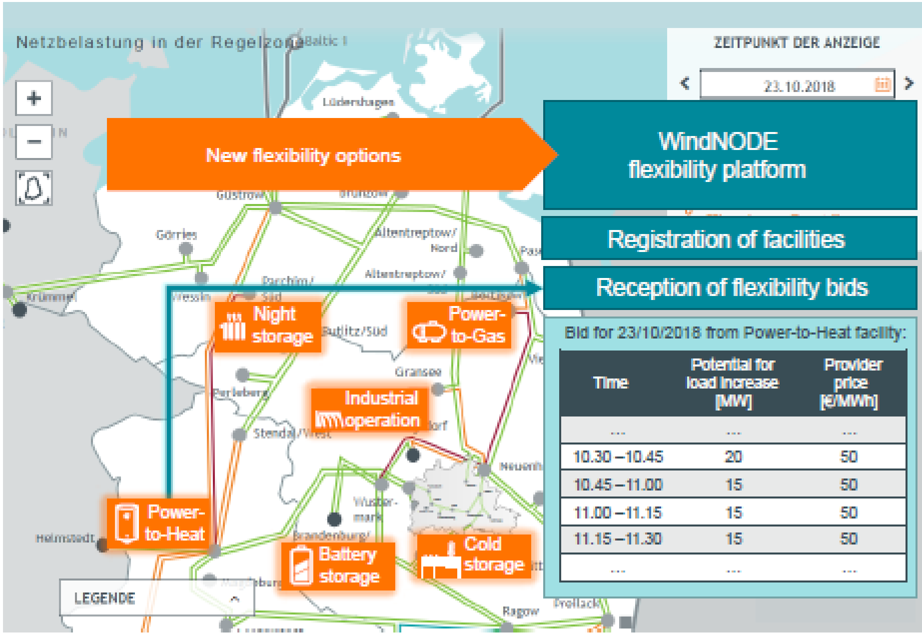


**Figure 4. Example of WindNODE platform interface *(Source: WindNODE, 2020)***

### 4.3. GOPACS

**About the Project** (GOPACS 2020)

GOPACS, as opposed to WindNODE, is not platform, but a facilitating app. It runs with cooperation with the intraday Energy Trading Platform Amsterdam (ETPA) and will be connected to other platforms in the future (EpexSpot, Nord Pool) (GOPACS 2020).

The grid operators determine the future congestion point, which are later entered into GOPACS, and the facilitator signals the market. Suppliers in the congestion point can indicate an order on a market platform, but not on GOPACs directly. Intra-day congestion spreads (IDCONS) - is a “combination of two orders (buy order and sell order)” (GOPACS 2020). Every order has to include location data for GOPACS and the lower amount of electricity in the congestion area is combined with an opposite order from a market party outside of the congestion area. “Market parties indicate in their orders whether it can be used for IDCONS (in addition to participating in regular continuous trade)”(GOPACS IDCONS Special Report, 2020: 4-5). GOPACS is responsible for identifying that the order does not threat the grid balance elsewhere. In the event of a price difference between the buy order and a sell order, the grid operators pay the price difference. A unique advantage of this tool, is that a match made by GOPACS is unlikely to have taken place otherwise, because the grid operator has to pay the "spread" price, however the match is only made if the congestion balance of electricity grid is cost-efficient. "In such a way orders with the lowest difference ('spread') between the buy and sell price not necessarily will be called first, if they have don't meet the necessary transport restrictions" ( GOPACS, 2020).

### 4.4. Piclo Flex

**About the project**

Piclo Flex (Piclo Flex, 2020: 3) is a second generation energy application that started its pilot process in 2018, and entered commercial operation in 2019. Contracts have now been signed with AMP Clean Energy, Limejump, Powervault and Moixa to deliver 18.1 MW of flexibility.

Piclo's platform oversees a heat-map of network congestion and connects the flexibility providers using demand-side-response technology, employing batteries and other flexibility utilities. The providers indicate on the platform the information about their assets and the platform connects them with the consumers. Such an approach is especially beneficial for suppliers with multiple production units, saving their time and effort to find potential clients, thus making it more affordable for the end-consumer.

It is interesting to see the share of the flexibility players participating at Piclo Flex platform. In their report they notice that "larger batteries (1MW+) contributed significantly more to the overall capacity at 842MW or 19%. Generators contributed the most, with 3429 MW or 77% of the total capacity. Only 141MW of demand-response systems (on commercial and industrial sites) have been registered on Piclo to date. This is only 14% of the 1GW of industrial DSR currently in the UK" (Piclo Flex, 2020: 4).

**Table 9. Main characteristics of the Piclo Flex platform** ***(Source : Piclo Flex, 2020)***

| Feature | Included in trial | Description |
|---|---|---|
| Announcement of needs | ✓ | DSOs can publish intent to procure flexibility in specific areas |
| Starting procurement | ✓ | DSOs can launch new tenders by inputting their requirements |
| Response | ✓ | DERs can provide information on their assets and respond to bids |
| Matching | ✓ | Automatic allocation of capacity by the marketplace algorithms |
| Dispatch | X | Automatic dispatch signals from DSO via marketplace API |
| Settlement | X | Automatic settlement using the specified baselining method |
| Multiple buyer types | X | Multiple flexibility buyer types can competitively bid for flexibility |

The compilers of the report also note that there is a great untapped potential for flexibility providers when investigating the number of unmatched assets to adverts. “Out of around 4,500 MW of assets uploaded, only 116 MW qualified for active competitions during the trial. At the same time on the transaction side more than 300 MW of advertised flexibility need remained unmatched” (Piclo Flex, 2020).

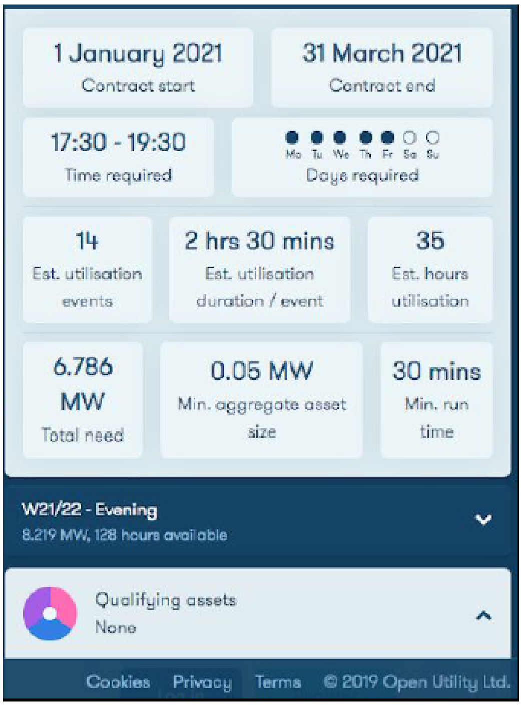


**Figure 5. Example of Piclo Flex platform interface** ***(Source : Piclo Flex, 2020)***

Piclo Flex managers see great potential in mobile assets, such as mobile generators and transport assets including electric vehicles. According to the report (Piclo Flex, 2020: 18) 'Vehicle to grid' (V2G) technology combined with smart-charging technology encourages the owner to charge their cars during peak hours of renewable energy generation and gain economic benefits from it.

The same applies for household's battery systems. Enterprises that engage such batteries on behalf of households have a great potential in the foreseeable future. Small scale storage systems can benefit from feeding the grid during low solar activity periods.

## 4.5. Flex-Hub

About the Project (based on an expert interview with Markus Riegler: Team management TSO Markets Austrian Power Grid)

Flex-Hub is a project, led by Austrian Power Grid AG (APG) and the Energy Web Foundation (EWF) which is focused on harvesting short term flexibility and bringing it into existing market mechanisms. This is a multi-market management platform with a single point of entry to the electricity market for small-scale players. The central component of the Flex-Hub is the Equity Platform which is also called crowd-balancing platform. The Platform is already used by 5 TSOs in 5 countries: Switzerland, Italy, Germany, the Netherlands, Austria and will be connecting more countries in the near future. In February 2021 the first phase of the project, the concept phase, was finished and the next phase will take place from 2025 onwards. In the future the aggregator will be in charge of collecting flexibility from prosumers, formulate flexibility bids and put them on the crowd-balancing platform (Riegler, 2021).

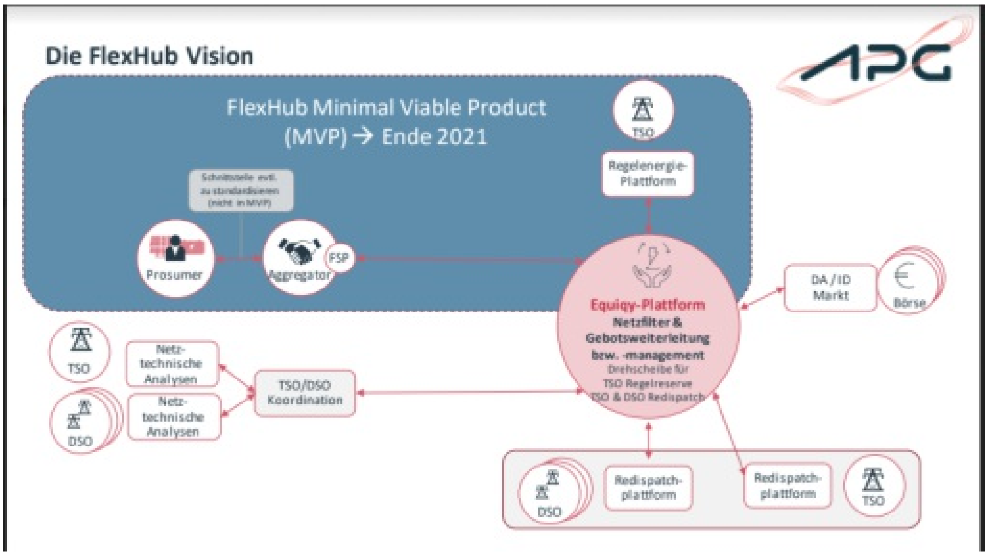


**Figure 6. The vision of FlexHub** ***(Source - APG [provided by Riegler, M.])***

Simultaneously there will be a TSO DSO coordination platform established, that will perform the grid calculation, and the grid operators will be able to set restrictions for third parties to use flexibility in their grid. The operators will decide whether they need to relieve congestion in their own grid. TSO and DSO redispatch can also be formulated as a demand on the platform. The functionality of the platform lies in filtering bids according to the merit order. If some bids or their sum is higher than the limits of the grid restriction, then the most expensive bids would be cut off the merit order list and communicated back to the aggregator as non-feasible. Thus the grid filter (Netzfilter) and bid management are the main component and functions of the platform (Riegler, 2021).

The platform then will forward the grid compliant bids to existing market platforms. The idea behind the project is not to create a separate flexibility market as such, but to enable flexibility to take part in already existing market processes. The bids will be forwarded to the balancing market platforms and to the day ahead / intraday markets. The same flexibility can be also used for redispatch. One of the main aims of the project is to avoid the fragmentation of liquidity. There are a lot of platforms emerging on the market, but there is not enough liquidity to satisfy all of their needs. Flex-Hub is targeted at bringing those flexibility potentials together into one system with a single entry point. The flexibility management schemes are still under development. One way is strictly sequential management, which is the easiest one to achieve. The flexibility is being offered along the gate-closure time of the different markets - in the redispatch market - several hours ahead of real time, and when this gate is closed then the remained flexibility can participate in the x-bit and the intraday market, where the gate closure time is one hour ahead of real time. The rest which is not used can go into the balancing time frame, where the gate closure time is 25 minutes ahead of real time. The other option is a more sophisticated system where everything is done in parallel. Here, bids simultaneously appear on several markets and then once it has been awarded on one market the platform automatically signals to the other markets that this bid is no longer available. This approach will require a sophisticated technical solution because the timeframe in this approach will be fractions of seconds. This approach also demands solving the issue of simultaneous demands and simultaneous awardee of bids. It also requires a set of rules to be set. In other words in the future this will be a multi-market management platform with a single point of entry to the electricity market for small-scale players. The first stage of the project, which will be carried out through the year 2021 will only include the "blue" part (Riegler, 2021).

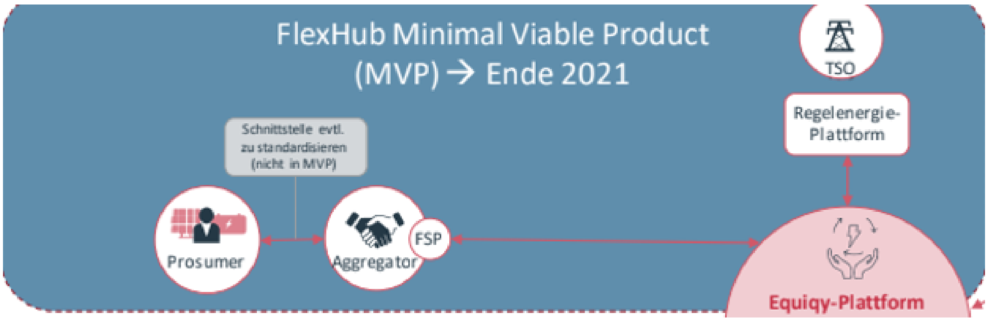


**Figure 7. First stage of the project.** ***(Source - APG [provided by Riegler, M.])***

At this stage, the aggregator will be able to participate on the balancing market via the crowd balancing platform. Implementation of restrictions and the multi market management part will come later. Nevertheless, the current flexibility providers are compliant with the balancing market.

Once the aggregator places the bid on the platform and then it is subjected to the grid filter. The most expensive bids are filtered out if they are not within the restriction of the grid. The compliant bids are forwarded to the target markets. Then the selection of bids is carried out according to the rules of the target market. There is no implicit bid selection on the flexibility market as such. This is a core idea of the whole concept, because it is designed as a system operation platform for increased TSOs and DSOs cooperation (Riegler, 2021).

# 5. LEGAL FRAMEWORK

**5. Legal framework for flexibility**

On June 5th 2019 the European Parliament and the Council for the European Union enacted Directive 2019/944 (the Directive) on common rules for the internal market for electricity) (EU Journal, 2019: 125). Among the many provisions set out in the directive, two of them - Articles 16 and 36 - have particular relevance to the development of flexibility markets and will be discussed in detail below.

EU Directives are binding on member states, although they allow countries freedom as to how they are implemented at the national level (EU Journal, 2012, C 326/1). As such, while Austria has options in terms of the technical and legislative implementation of the directive, it must ensure that it follows the aims of the directive.

With specific regard to the renewable energy provisions in the Directive, on September 16th 2020 the Austrian parliament enacted the Renewable Expansion Law (EAG) ( Erneuerbaren-Ausbau-Gesetz – EAG; Erneuerbaren-Ausbau-Gesetzespaket – EAG-Paket, 2020). The main goals of this legislation are to: increase annual electricity generation from renewable sources by the year 2030 by 27 TWh; to ensure the integration of the country's energy system; to ensure the security of the energy system; and to increase the renewable share in district heating (Erneuerbaren-Ausbau-Gesetz – EAG; Erneuerbaren-Ausbau-Gesetzespaket – EAG-Paket, 2020: 1). These aims are in line with the Directive 2019//944 and Directive 2019/943, but also address the issues of Citizen Energy Communities and energy storage facilities contained in Articles 16 and 36 of the Directive, setting out a legislative and regulatory framework for both suppliers and consumers.

Article 16 of the Directive sets out four provisions for the implementation of citizen energy communities in member states; two obligatory and two optional (EU Journal, 2019:152). The first obligatory provision, Article 16.1, states that members "shall

provide an enabling regulatory framework for citizen energy communities.” In doing so they must ensure that: a) participation is open and voluntary; b) members or shareholders are entitled to leave the community (subject to the provisions in Article 12); c) members or shareholders of a citizen energy community do not lose their rights and obligations as household customers or active customers; d) distribution system operators cooperate with citizen energy communities to facilitate electricity transfers within citizen energy communities; and e) citizen energy communities are subject to non-discriminatory, fair, proportionate and transparent procedures and charges, including with respect to registration and licensing, and to transparent, non-discriminatory and cost-reflective network charges in accordance (EU) 2019/944, 2019:152).
The legislation to achieve these aims in Austria are set out in ss. 74-77 of the EAG (EAG, 2020: 32-34). Section 74(2) states that participation in an energy market must be open and voluntary. To achieve Article 16.1.b, the Austrian EAG s 76(2)(a) states that the terms of termination must be set out in the founding document. In principle, the contractual agreements between the actors will be based on the Austrian law. For example, section 9 of the Directive states that one of its aims is to ensure the creation of a market framework that rewards flexibility and innovation in order to encourage the uptake of renewable energy, allowing existing national law to determine contract rules promotes legal certainty. Austrian contract law operates on the basis of freedom of contract (Lando et al., 2000: 142) where the parties are free to determine any terms they wish provided they do not “fall foul of statutory laws” (Austrian Government, 2021) and competition laws. Businesses operating in Austria will be familiar with this legal environment, that aims to promote certainty while allowing for flexibility.

Article 16.1.(c) is reflected in the EAG s 74(1) (EAG, 2020: 32) which says that “network user’s right’s and obligation’s remain unaffected by their participation in an energy community”. Therefore an individual’s rights and obligations will remain the same under national law. The advantage this offers to consumers is clear: their rights and obligations are established, however, businesses also benefit from having a clear regulatory framework in which to operate. Without a clear framework businesses may lack the certainty needed to make investments, particularly relevant in emerging sectors (Kroes, 2013: 2), and competition can be stifled, as new companies may be reluctant to enter the market. By introducing the legal framework for energy communities in a directive, the means to achieve them will be set out in national law, but most importantly much will be governed by, or adapted from, existing national law; as such businesses (or their legal representatives) investing in energy communities and storage facilities will have the legal certainty required to effectively operate.

Article 36 of the directive concerns the ownership of energy storage facilities by DSOs (Directive (EU) 2019/944, 2019: 162). Section 1 sets out the general principle that distribution system operators shall not "own, develop, manage or operate energy storage facilities", while section 2 provides a list of ways in which Member States may derogate from this general principle. There are two ways in which this can be done. Either a Member State may allow a distribution system operator to own, develop etc. a storage facility if the operator is a "fully integrated network component and the relevant regulatory authority has granted its approval" or if the operator meets all three of the following conditions: one, following an open and transparent tendering procedure that is subject to review by a regulatory authority, no other party has either been awarded the right to own or operate a storage facility, or would be unable to do so in a cost-effective and timely manner; two, a storage facility is necessary for the operator to fulfil the directive's objectives and the facilities are not used to buy or sell electricity in the electricity markets; third, the regulatory authority has decided derogation from Article 36(1) is necessary and has assessed the tendering procedure. Again, all three conditions must be met to allow an operator to own or operate a storage facility via this route. Article 36(3) establishes the duties required from the regulatory authority and 36(4) provides for a list of exceptions to 36(3).

Article 36 is illustrative of the approach taken by EU law (and by extension Austrian law) with regard to discouraging monopolies. Article 102 of the Treaty on the Functioning of the European Union (TFEU) (EU Journal, 2008: 89) outlines the general principle that allowing a business to abuse a dominant position is incompatible with the principles of the internal market. By discouraging monopolies, small scale flexibility providers are given space to enter the market and competition amongst manufacturers is encouraged.

# 6. CONCLUSIONS

**6. Conclusions**

The objective of this research was to identify and study current energy flexibility projects and from this determine which of these will be most beneficial for the Austrian market. Doing so involved a comparative analysis of four different ongoing flexibility projects. This analysis involved a combination of applying a metric and answering the three following questions:

- Which flexibility projects are ongoing in Austria and in the EU and what kind of products do they offer?
- What are the criteria for the successful execution of an energy flexibility project?
- Which flexibility products would provide the optimum benefits for the Austrian electricity market?

The execution of this research involved a number of steps. The existing background information and the state of the art of flexible energy systems and products, their types and specifications was analysed in order to determine the active vocabulary, underline potential drawbacks and inconsistencies.

The second step included the transformation of the metric, proposed in “Market Design of Regional Flexibility Markets: A Classification Metric for Flexibility Products and its Application to German Prototypical Flexibility Markets” by Erik Heilmann, Nikolai Klempp and Heike Wetzela. This final metric encompassed more than 20 different parameters for the analysis of ongoing flexibility projects. By applying this metric it was possible to some extent compare the products proposed within the projects.

Four ongoing flexibility projects were assessed, namely GOPACS, WindNODE, Piclo Flex and Flex-Hub, using open source expert interviews. Some of these projects are not yet finished and not all the data could be collected.  All of these projects in one way or another offer a flexibility platform. The criteria for the successful execution of an energy flexibility project: clear participation and bidding rules; user-friendly interfaces; clear and achievable and non-desctiminatory technical requirements; clear definition of congestion points; identification of selection and activation periods and the activation mode; well established communication scheme, transparent trading etc.

When analysing the similarities and differences of the aforementioned projects, a number of trends can be traced from the design of those projects. First of all, apart from the WindNode, all the projects are based on the third-party software, which manages the flexibility platform itself. Schittekatte et al (2020), when conducting a similar analysis point out, that having a third party managing the platform can be beneficial in terms of saving the cost and time of the development of the software, moreover third-party platform operator can act with greater impartiality then the actors and make the process more transparent, additionally the creation of a monopoly would be the inevitable consequence of allowing network operators to manage the platform.
The second trend is that all the products - to some extent - follow a set standard. When considering the question of product standardisation, the “TSO – DSO REPORT”, published by the European Network of Transmission System Operators for Electricity (ENTSO-E) states that, according to the European Commission through the Clean Energy Package (Art. 32 (1) of the Electricity Market Directive) such products require standardization in order to “enable bids by market participants” and that this should be implemented at the national level. At the same time, these projects need to have a room for further harmonisation in order to be implemented on the cross-border level.

The next trend is that there is no specified technology that can participate in delivering flexibility for the platform, even for WindNODE, despite its name. At the time of the writing of this paper, Flex-Hub used predominantly lithium-ion batteries at household level, but there are no restrictions in place regarding the type of the technology used.

The fourth trend is that there are preliminary procedures for all flexibility providers for all four platforms.  Product pre-qualification is also a very important aspect and along with the grid-prequalification, is the needed procedure for all the flexibility providers to participate in all four projects. In the case of Flex-Hub it takes place via the aggregator. There is one major benefit of such a process: due to the fact that it is helps to incorporate small-scale and technically less advanced providers (ENTSO-E 2019).
The fifth trend is the possibility to deliver flexibility in both directions (positive and negative). Such aspect is characteristic to three flexibility projects chosen. According to the ENTSO-E report, such "possibility of aggregation is essential for providers and requesters of the flexibility services and will most likely increase the liquidity of the market… a bid could potentially be used for multiple purposes, like for example for both congestion management and balancing".

The next trend is that three projects out of four are aimed at establishing a better TSO-DSO cooperation. Only the Piclo Flex is a platform for the distribution system operators, the rest of the projects are intended as TSO-DSO cooperation platforms. This approach may be supported by the idea, that in case of separate multiple platforms there is not enough liquidity to satisfy all the needs (Riegler 2021). At the same time single entry point for both TSOs and DSOs and all the other market players can ensure easier, more efficient and timely cooperation, gives a clear separation of balancing and congestion management and their cost and can help avoid conflicting activations and even perform synergetic activations in the future (Schittekatte et al 2020, ENTSO-E 2019).  On top of that, all the platforms are engaged in establishing closer DSO cooperation, which leads to an easier entry for small flexibility providers. All the platforms are establishing clear trading rules. In the case of WindNode the winner determination is done via an interactive optimisation process from lowest DSOs to TSOs, in the case of GOPACS it is dependent on the geographics and the rest of the platforms determine the winner using the economic merit order. As discussed earlier the WindNODE platform is facing the risk of gaming, so it is evident that establishing clear non-discriminatory rules, that would make the processes of trading transparent for all the participants is essential at this point. The penalty for non-delivery is also to be established. It is important to note that one of the major bottlenecks is the timely communication between all the actors. Flex-Hub employs blockchain technology, which can become very promising in case of the parallel flexibility trade, when bids will simultaneously appear on several markets and the whole process will happen within fractions of seconds. This requires solving the issue of simultaneous demands and simultaneous awarding of bids. It also requires new of rules to be set. At this point, and with not enough data to perform a deeper analysis while these projects are at their earlier stages, it is difficult to say whether one project is superior to the others. However, it can be said that the Austrian flexibility project Flex-Hub is taking into account all the requirements needed to create a reliable and well performing flexibility platform.

The existing legal framework, regulating the Austrian electricity market within the framework of energy flexibility was assessed in order to see the possibilities and restrictions that will affect the future of flexibility development in the country.

The European Parliament and the Council for the European Union's Directive 2019/944 (the Directive) together with the Austrian Renewable Expansion Law (EAG) provide a legal framework for the functioning of flexibility markets. Two articles are of particular interest because they deal with energy communities and storage systems. The directive and the Austrian EAG state that one of its aims is to ensure the creation of a market framework that rewards flexibility and innovation in order to encourage the uptake of renewable energy.

An example of how it is achieved is by allowing existing national law to determine contract rules and therefore promoting legal certainty. Businesses operating in Austria will be familiar with this legal environment, that aims to promote certainty while allowing for flexibility.

These legal documents ensure that "network user's right's and obligation's remain unaffected by their participation in an energy community". Therefore an individual's rights and obligations will remain the same under national law. The advantage this offers to consumers is clear: their rights and obligations are established, however, businesses also benefit from having a clear regulatory framework in which to operate. Without a clear framework businesses may lack the certainty needed to make investments, particularly relevant in emerging sectors, and competition can be stifled, as new companies may be reluctant to enter the market. By introducing the legal framework for energy communities in a directive, the means to achieve them will be set out in national law, but most importantly much will be governed by, or adapted from, existing national law; as such businesses (or their legal representatives) investing in energy communities and storage facilities will have the legal certainty required to effectively operate.

Article 36 of the directive concerns the ownership of energy storage facilities and sets out the general principle that distribution system operators shall not “own, develop, manage or operate energy storage facilities” discouraging monopolies. Article 102 of the TFEU outlines the general principle that allowing a business to abuse a dominant position is incompatible with the principles of the internal market. By discouraging monopolies, small scale flexibility providers are given space to enter the market and competition amongst manufacturers is encouraged.

At this stage the technological development is in advance of the legal framework, which in many ways is merely responding. The EAG was only passed in 2019, and therefore in order for the energy market to further develop and to ensure the active participation of all the actors involved more research and studies into its effects are required.

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# LIST OF ABBREVIATIONS

APG - Austrian Power Grid AG

CEM – Clean Energy Ministerial

CO2 – Carbon Dioxide

COVID-19 - COronaVIrus Disease 2019

DDDII - Decarbonization, Decentralization, Digitalization, Integration and Inclusion

DER – Distributed Energy Resources

DG - Distributed Generation

DSO - Distribution System Operators

EAG - Erneuerbaren-Ausbau-Gesetz

ENTSO-E - European Network of Transmission System Operators for Electricity

ESS - Energy Storage Systems

EU – European Union

EV – Electric Vehicles

IEA – International Energy Agency

IRENA – International Renewable Energy Agency

ISGAN - International Smart Grid Action Network

IT – Information Technology

MWh – Megawatt/hour

NABEG - Netzausbaubeschleunigungsgesetz Übertragungsnetz

PV - Photovoltaic

RES - Renewable Energy Systems

SINTEG - Schaufenster für intelligente Energie: Forschung für das Stromnetz der Zukunft

SLES - Smart Local Power System

SSEN - Grid Company of Scotland and the South

TFEU - Treaty on the Functioning of the European Union

TSO - Transmission System Operators

UK – United Kingdom

US – United States

V2G – Vehicle to Grid

VRE - Variable Renewable Energy

WPD - Western Power Distribution

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