edgeFLEX

D6.1

Comparative analysis of potential business impact

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Abstract
This document introduces the edgeFLEX approach to combine technological approaches with organizational structures in order to provide more flexibility in the European electrical network, at a moment when the need to mitigate fluctuation in power generation due to the increasing share of intermittent energies in the electrical mix in Europe becomes crucial.

On the one hand are described the various technological solutions and sources of flexibility that can be relied on: they consist in central local flexible assets or distributed small flexible assets. On the other hand, are explored organizational structures can be used to foster the harvesting of flexibility; they may be DSO centered, aggregation-service-provider centered or happen thanks to local energy communities.

Keyword list
Flexibility – local energy communities – aggregation service providers – distributed assets

Disclaimer
All information provided reflects the status of the edgeFLEX project at the time of writing and may be subject to change.

Executive Summary

This deliverable exposes the edgeFLEX proposal in terms of the origin of flexibility and organization of its aggregation. Two further versions of this deliverable are planned as part of the project's future activities.

Technological solutions to mitigate fluctuations in intermittent power generation can rely on central local flexible assets or distributed small flexible assets. The former is more traditional while the latter is developing, and requires aggregation work to be taken over. This aggregation can be proposed in a number of organizational structures: either Distribution System Operator (DSO) centred, with the introduction of a pure player such as an aggregator, or being built on local energy communities' structures that emerge more and more.

edgeFLEX suggests a panel of exploratory paths for incentivising flexible assets to increasingly help in the system: risk separation solution, ancillary service provision, energy communities, flexibility trading, virtual power plant shall all allow to take in charge better the burden of intermittence of production or mitigate it.

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1. Introduction

1.1 Philosophy of edgeFLEX

The inception of intermittent energy sources such as wind and solar and their significant penetration in the European electricity mix, triggered by heavy subvention of their development, is transforming the power generation landscape.

In particular, the random character of their production puts a lot of stress on grid balancing. As a consequence, in order to accommodate these intermittent "renewable" energy sources (RES) in the most efficient way, it is mandatory for the electricity system to find suitable flexible resources to rely on.

The assumptions in edgeFLEX are that:

- Artificial tariffs that had been enforced by governments in Europe, at a very high cost for public finances, are coming to an end. It is expected that RES assets are not going to benefit from subsidies in the future.
- Efficient, transparent markets shall be relied upon to enable the best available solution to emerge and be rolled out across Europe and possibly across the globe.

Therefore, in edgeFLEX we engage in trying to improve the economic attractiveness of the ownership and operation of intermittent Distributed Energy Resources (DERs), as they are going to compete with alternative sources of energy. edgeFLEX strongly believes that only if intermittent energies can prove that they are more competitive than other solutions can they find their appropriate place in the energy mix.

edgeFLEX aims at suggesting innovative methods to bring flexibility in the system, since increased flexibility available shall help intermittent energies being integrated more easily, hence removing some hurdle to their extended deployment.

In order to tackle this, we will adopt the following framework: we will first discuss the various potential origins of flexibility (large scale or distributed) in chapter 2, then we will explore the different possible organizations of flexibility aggregation (Aggregators, DSOs or Energy Communities) in chapter 3, and finally, in chapter 4, we will outline the edgeFLEX approach.

Note that this is the preliminary revision of the deliverable. A revised version of it will be compiled upon completion of several workshops that are part of Task 6.2 and will result in deliverable *D6.2 - Comparative analysis of potential business impact, V2*, which will be submitted in month 36 of the project.

1.2 Types of flexibilities

Talking of flexibility can have very diverse meanings and challenges depending on the time horizon considered.

Grid balancing obviously requires that the same power is delivered and consumed at every single instant, and the grid operator is responsible for the equilibrium to be maintained at all times. This is done in a different way depending on the reaction timeframe considered. Here-after we give a classification of flexibility types.

Flexibility can be categorized in the following manner:

- **Primary**: reaction time is below 1 second - this is also referred to frequency control. A sudden imbalance between load and generation poses an additional mechanical burden on the alternators coupled to the rotating turbines of large power plants, resulting in a system frequency variation. Primary reserve is used to limit such frequency variation and recover from it.

- **Secondary**: activation time is in the range of few minutes. Its purpose is to return the frequency to the nominal value after a disturbance. When frequency is managed appropriately, but that frequency reserves are exhausting, secondary reserve is called in, to provide more substantial shift; in particular, it ensures that the voltage of the network is kept at a nominal level.
- **Tertiary**: reaction time is below 1 quarter hour, to balance even more significant power level than Secondary balancing, according to the same logic.
- **Intraday**: duration time is over several hours, concerned by the issue of adapting to daily intermittent production fluctuations and to deterministic demand. Here we are not any more concerned by the grid balancing, but are taking rather a market approach, when there is a need to, typically, supply a maximum of electricity at 19:00 to the average household, while production of intermittent energies is in general not aligned at this very moment.
- **Inter-season**: provision horizon is over the year, addressing electricity needs that are not the same in winter, spring, summer, autumn as well as the long term (e.g. weekly) intermittent production fluctuations. The situation in mid-season in Europe with no heating and no air conditioning and decent wind/solar output is a good situation that differs much from a calm early January week situation with minimal wind and solar output, but maximal consumption request: being able to store energy interseasonaly is a huge – and crucial – challenge.
- **Long term trend** – this is the evolution of demand and corresponding means of production over the course of years and decades.

Flexibility can be categorised primarily in relation to the reaction speed of the asset providing the flexibility. Each system needs flexibility with various speeds of reaction in order to ensure stability. This being said, not all sources of energy can provide flexibility in the same fashion: for instance, batteries can provide short term flexibilities with a fast activation but usually are small and cannot help much in tertiary balancing.

As far as the edgeFLEX exercise is concerned, the Virtual Power Plants optimizations of slow dynamic trial tackles intraday flexibility; otherwise, the focus is on fast dynamics and the concern to provide flexibility in the sense of primary and secondary control. As a consequence, the rest of the present document is concerned about primary and secondary flexibility provision.

1.3 Outline of the report

This report is divided into 5 chapters. In the following chapter, chapter 2, the technical solutions used for primary and secondary flexibility provision, using either a centralised approach or a decentralised approach, will be described. As the traditional approach to providing flexibility using a centralised strategy is well developed and well know, in Chapters 3 and 4, we focus on the provision of flexibility using decentralised approaches, which offers new possibilities as the proportion of volatile RES in the power generation mix increases. Chapter 3 focuses on the description of the different organizational structures that can support the decentralized flexibility provision and management, while chapter 4 describes how edgeFLEX approach allows enhancing and fostering the introduction of sources of flexibility in the context of a continuing increase in the use of decentralized energy production deployments.

Finally, chapter 5 presents the conclusions of the report and the plans for future work to be carried out in the second phase of the project.

1.4 How to read this document

This report can be read as a standalone document. However, other deliverables can be helpful to get a better view of the concepts advanced in the edgeFLEX project and to have more details on the edgeFLEX platform.

Specifically, for a better understanding of the work plan and in general of the D6.1 content, the following deliverables are relevant to be consulted in this context:

- D6.5 - A new financing model for RES, to simplify investments in RES beyond subsidy schemes [1]
- D6.3 - Engaging with policy makers, with organizations and experts in regulation and standardization – v1 [2]

2. Technological solutions and sources of flexibility to mitigate fluctuation in power generation

Sources of primary and secondary flexibility can be roughly split into centralised and distributed sources.

Both centralized and decentralised approaches can be used to provide both primary and secondary reactions and, while centralized structures can be considered the traditional approach, decentralised flexibility provision solutions are now becoming possible and are increasingly being used.

In 2.1 and 2.2, we describe these two approaches, highlighting the differences between them.

2.1 Centralised local flexible assets

The traditional approach to managing fluctuation in power generation and demand is by the use of large flexible assets.

Typically, grid operators (such as TSOs) can contract flexibility from rotating, but adjustable, assets such as hydropower turbines and gas turbines. This allows the grid operator to adjust production as needed with automatic or manual control signals to those assets. By having a few large assets, critical mass is easily reached and the process of managing these assets can be done in a relatively manual manner.

The grid operator has a series of assets available and triggers them manually or semi-manually if and when required.

The nature of those contracts can vary. It can take the form of an obligation of system relevant plants, i.e. plants larger than a certain threshold to provide flexibility, such as in Italy, or a market where interested assets participate in an auction to make their flexibility available, such as in Switzerland and Germany.

The contracted assets, despite the focus on generating assets, can also be consumption assets. An example of this is the "Interoperabilità" (interoperability) system in Italy, where large energy consumers receive an incentive for being available for power consumption reduction if required. Another example is the TRL system in Switzerland and Germany.

Additionally, in recent years, with the reduction in prices of battery-storage, thanks to pilot projects by grid operators, such systems have increasingly been used to provide flexibility.

2.2 Distributed small flexible assets

While the traditional approach has kept our energy systems stable for the last 100 years, recent decades have seen unprecedented growth in intermittent generation which calls for provision of more flexible assets being made available for the system operator. While this could be dealt with through large central storage solutions, additional storage or flexibility would come at a higher price, i.e. due to the move up the merit order curve.

At the same time, technology in communication, optimization and interfaces has improved and become more cost effective. Therefore, system operators and policy makers have increasingly been looking towards smaller, distributed systems to provide the required flexibility. These can be:

- Smaller generation assets too small for individual manual operation from system operator,
- Smaller consumption assets, such as boilers, AC systems, where opportunity cost is low for provision of flexibility.
- Distributed storage systems with a different primary use-case such as peak-shaving, price arbitrage or uptime guarantee.

These have been gaining traction and become an important component of the system stability over the last decades, to a different extent in different countries though. Spain and Italy have just started piloting this approach while Switzerland and Germany have been using it successfully for a decade or so.

The typical case that one can think about when thinking of distributed small flexible assets is the case of car batteries. Obviously, electric vehicles' share of the total circulating fleet is expected to grow dramatically in the next years, so there is going to exist a pool of batteries available out there, that could be used to absorb surplus of production when needed, and deliver back to the grid when the consumption peaks arrive, while charging during the night from cheap capacities so that their owners can drive to work in the morning. How to capture this available flexibility is one of the biggest challenges to be tackled in the near future.

3. Organizational structures fostering the harvesting of decentralized flexibility

With the growing share of intermittent and “renewable” energy sources in the electricity system, new ways of providing flexibility to the electricity system should be considered.

A lot of flexibility is already available in the system [3] but still need to be made accessible and usable for grid stability measures within the time range of minutes and seconds or even below as well as for longer timeframes of hours or months. This is a relevant challenge on technical, organisational and market level. In the following, three approaches for organizational structures to support the increasing use of decentralized flexibility are discussed.

3.1.1 DSO centred

When thinking about how to collect flexibility from distributed assets, one of the possibly most obvious steps would be to enable the responsible DSO to collect these flexibilities from the resources.

DSOs themselves also need flexibility to manage their system, e.g., to keep the voltage in a given range or provide operational reserve to the grid. Also, for congestions management and to even avoid additional investment in grid reinforcements, flexibility of a wider time frame is relevant for DSOs. Such flexibility can be provided by various assets in the grid, including PV systems on rooftops, demand-response functionalities and, in the future, more and more distributed storages.

In the DSO centered approach, the DSO would be the party responsible of “collecting” the flexibility from the assets within the grid he is operating. For this, a local flexibility management and market system, as developed in the edgeFLEX project, is needed, together with a responsible party for managing system. In the DSO centered scenario, such role would fall under the DSO’s responsibilities, together with the hosting and management of the platforms and tools that enable the harvesting of the distributed flexibility.

He then can either use the flexibility for his grid management or be a “technical aggregator” who aggregates the flexibility to provide it to the relevant TSO. Whenever he needs flexibility to stabilize his own grid section, he can either directly activate and remunerate the flexibility provided by participating assets. Alternatively, he could buy it from the local flexibility market he is also the operator of. When not using the flexibility himself, the DSO could, in the case of fast flexibility, provide it to the TSO. How this can be realized differs in EU countries and might need a change of EU or national regulations.

3.1.2 Aggregation service provider centred

Another approach to the collection of distributed flexibility is the introduction of aggregation service providers, or “aggregators”. This role has already gained some traction in different markets such as Italy, Germany and Switzerland.

The aggregators identify market opportunities for flexibility – such as participation in intraday, primary, secondary or tertiary control and contract distributed flexible assets. They contact the asset operators, agree on a service fee (for example revenue share) and then market the flexibility in an optimized way based on market signals.

In exchange for the service fee the aggregator handles the connectivity, approval works needed, marketing of flexibility and the communication with the respective flexibility buyer.

The main difference to the DSO approach mentioned above is that the aggregator is entirely market driven, i.e. does not have understanding or the right to deploy the required flexibility in the realm of the DSO or TSO. He would entirely operate based on market and operation signals from those parties.

It is up to the system operators to define the requirements and market incentives such that the aggregators make the right type of flexibility available.

3.1.3 Local energy community

The third option is a local energy community (LEC) which wants to harvest the flexibility its members can offer.

Energy communities in this sense are either *"renewable" energy communities* (REC) as defined in Article 22, EU directive 2018/2001 "on the promotion of the use of energy from "renewable" sources" [4] or *citizen energy communities* (CEC) as defined in Article 16, EU directive 2019/944 "on common rules for the internal market for electricity" [5]. One of the aims of these energy communities is to provide environmental, economic or social community benefits for their members or the local area by empowering citizens. It is therefore a tool to increase public acceptance of new projects as well as to mobilise private capital for wind and solar energy and to increase flexibility in markets. These two types of energy communities differ in some aspects. The main differences are shown in the following figure. Apart from differences with regards to memberships, the geographic dimension of REC is limited to the proximity of the generation asset whereas in the case of CEC there is no geographical limitation stated. The energy sources in REC need to be 100 % "renewable" but can be all kind of energy carriers. In the case of CEC any technology is allowed as long as it is electricity.

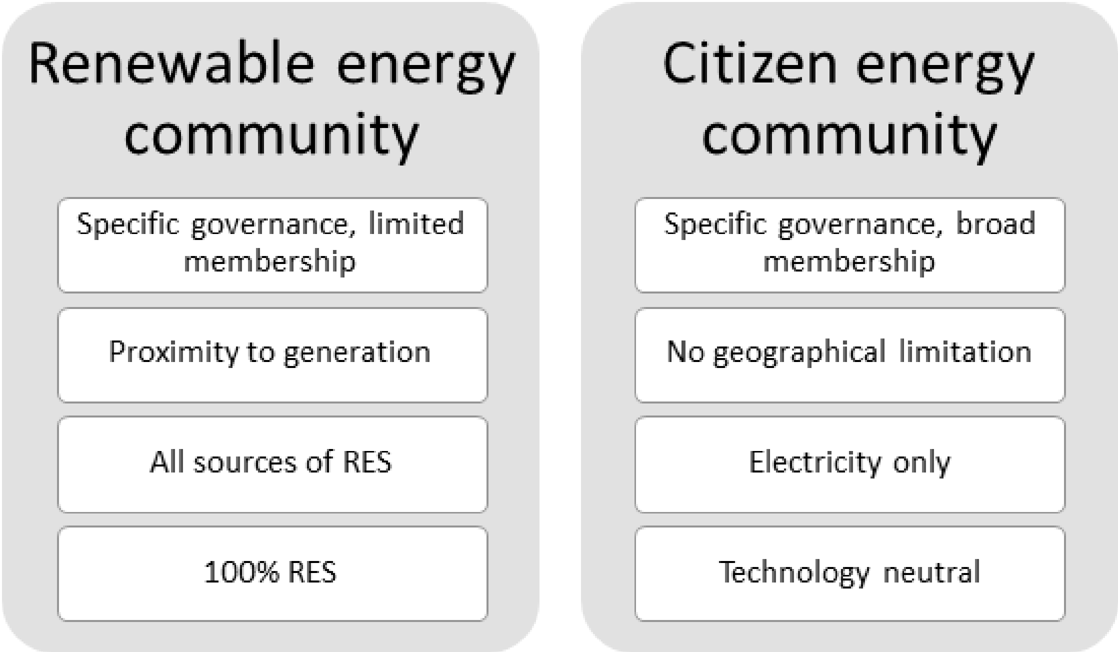

Figure 1 – "Renewable" energy community vs Citizen energy community

Both types of energy communities can play a role when it comes to flexibility and its harvesting. In the context of edgeFLEX, suitable electrical "renewable" sources need to participate in a REC. Also, in the case of CEC its geographical extent best be limited.

When it comes to harvesting flexibility, as role such as the energy community responsible (ECR) or a contracted third party is the manager of all relevant services and platforms. He or she can also be the market operator of the local market if it is not delegated to a contracted third party.

The LEC could – depending on the fastness – offer their flexibility to the responsible DSO either directly remunerated or by letting the DSO participate in the market. The flexibility can as well be offered to an aggregator or the balancing market of TSOs. Also, the LEC could potentially be nested within a VPP and be seen and handles as one asset of many within the virtual power system.

4. edgeFLEX approaches to combining technological approaches with organizational structures

Generally speaking, edgeFLEX's aim is to explore how to find, enhance or foster the introduction of sources of flexibility (in the first place the distributed ones that are increasingly deployed) in the European electrical power system.

In succeeding to do so at a satisfactory scale, the intermittence of wind and solar energy would be prevented from impairing their profitability - and it would then result in (at least marginally) more investment into wind and solar energy.

Several ideas are advanced in edgeFLEX. Here after are exposed these various edgeFLEX approaches and how they articulate with the mapping of technological approaches and organizational structures described here-above.

For each of the approaches, in the following we will highlight how they combine the flexibility type and the organizational set-up to provide it.

4.1 Approaches

4.1.1 VPP optimization

The approach of the VPP optimization effort of edgeFLEX is to manage jointly various types of assets, both flexible and intermittent. These assets are integrated together as a Virtual Power Plant (VPP).

Then the owner or operator of the VPP should be able to optimize the relative dynamic production and consumption of each of the assets in his portfolio throughout a period of time in order to maximise his financial outcome.

edgeFLEX aims at demonstrating that the economic outcome for the VPP as a whole is better than the sum of the outcome of the individual assets optimized independently from each other. Then thanks to aggregators, the size of the VPP may scale up, so it can rely and encompass plants of all sizes, from larger asset farms to private households on the production side, and from large industrial plants to individuals on the consumption side.

Upon success of the VPP optimization to improve the economic output of its owner, additional flexibility is in effect brought into the system for each additional VPP that gets constituted. Indeed, the market shall push flexibility owners to couple their assets with intermittent ones, and intermittent asset owners have no choice but to invest into storage/flexible means in order to increase the profitability of their existing randomly-producing assets.

In terms of technology, VPP optimization may rely on all kind of flexible assets, depending on the size of the intermittent assets concerned. One of the great interest of VPPs is that they can be declined in all sizes and mobilize either centralized assets or distributed ones.

The VPP constitution and optimization approach can be considered an open one regarding the organizational structure: indeed, it can be imagined that VPPs can be created and managed either by local energy communities, or pure players, or industrial players, etc.

4.1.2 Risk separation in Power Purchase Agreement

Another suggestion of edgeFLEX is to decouple the various kind of risks that have to be born when owning an intermittent asset. In separating the various risks associated with the ownership, operation and commercialization of wind or solar assets, so that each of them can be managed more cost-efficiently one by one, by specialized actors.

This will in turn reduce the risk cost of the owner of intermittent assets.

Strictly speaking, we are not providing flexibility here, rather reducing the burden of intermittence, which is the primary concern in fact. However, according to the mapping provided in the previous chapters of this document, we are dealing from the point of view of an aggregation service provider, typically.

4.1.3 Ancillary service provision

This proposal is about increasing the value of flexible assets by positioning them on the primary or secondary control market.

Ancillary services can be best proposed either by aggregation service providers, but also by centrally organized players.

4.1.4 Energy communities

Primarily, the aim of a local energy community is to guarantee energy supply for its members by taking their possible additional criteria into consideration e.g., only use “renewable” energy sources or only use local sources for the energy supply. Naturally, various types of generation – depending on the type of LEC either only from “renewable” resources or not - and demand can be joined in an energy community which by themselves and in combination, as a Virtual Power System (VPS), can provide flexibility.

The energy community could also enhance its self-consumption as well as flexibility as a whole by jointly investing into a storage system. The energy community itself or its participants would be able to provide flexibility to whomever needs it or can make use of it.

The remuneration for this flexibility provisioning would mean an additional incentive to install in “renewable” and / or storage assets which can also be beneficial in terms of flexibility provisioning.

By definition, the organizational set-up here is the specific one of energy communities; and they are dealing with small, highly distributed assets, that is typically solar panels and a few batteries spread out within a neighbourhood. Nonetheless, theoretically, CECs could also own wind power plants located somewhere far away in a better suited wind location.

4.1.5 Flexibility trading

Flexibility trading in the course of the edgeFLEX approach would primarily mean trading within a distribution system to benefit grid management and with that optionally save investment in grid infrastructure which otherwise the DSO would have needed to make.

This could be also part of the realization of the energy community to bring generation and demand together. Flexibility is traded 15 minutes ahead of physical realization and can help the DSO to manage his grid in terms of voltage control or help the energy community optimize their self-supply.

Hence this approach is deployed at the level of the DSO and is mainly concerned of the distributed assets that are scattered within its responsibility. Nevertheless, an aggregation service provider could also be interested in this approach.

4.2 Aspects of the approaches to evaluate

4.2.1 Technological options benchmark

There is a need to examine which decarbonized flexible assets are best suited, best placed for each of the approaches.

In particular, the following questions are examples of issues that should be investigated:

- Which sources of energy should the "typical" VPP be composed of?
- Which assets are best placed to benefit from risk separation in a PPA contract?
- Which intermittent assets are the most suitable and which are not for ancillary services provisioning?
- Which configuration of which storage devices should be retained for flexibility trading business?

4.2.2 Organizational options benchmark

For each of the edgeFLEX approaches, the various possible organizational set-ups should be reviewed in order to find out the strengths and weaknesses for each, and recommend the most suitable organizational configuration that edgeFLEX should push forward.

Therefore, the following questions, among others, need to be assessed:

- What organizational structures are predestined for realization of what edgeFLEX approaches?
- By what organizational structure is the ancillary service provisioning approach best realized?
- Which of the edgeFLEX approaches can be implemented (for a DSO) in the DSO centred approach? Under current regulations and future ones?

4.2.3 Value creation

The basic goal of edgeFLEX is to help wind and solar energies to be more valuable from a grid management point of view and with that more profitable from an investor's point of view. As we have seen extensively in the previous paragraphs, this is intimately linked to our capacity to introduce flexibility at all levels of the system. Hence, it is of prime importance to assess the change in rate of return on the profitability of intermittent assets from an investment in the various edgeFLEX approaches.

For memory, edgeFLEX can create value in the following typical ways:

- By giving access to previously un-accessible flexibility, whose marginal cost is lower than alternatives or negligible.
- By utilizing flexibility that already exists on new markets such as DSO or other local markets.

5. Conclusion

5.1 Summary of progress

This first revision of the deliverable exposes the edgeFLEX proposal in terms of the origin of flexibility and organization of its aggregation.

Technological solutions to mitigate fluctuations in intermittent power generation can rely on central local flexible assets or distributed small flexible assets. The former is more traditional while the latter is developing, and require aggregation work to be taken over. This aggregation can be proposed in a number of organizational structures: either DSO centred, or with the introduction of a pure player, or being built on local energy communities' structures that emerge more and more.

edgeFLEX suggests a panel of exploratory paths for incentivising flexible assets to increasingly help in the system: risk separation solution, ancillary service provision, energy communities, flexibility trading, virtual power plant shall all allow to take in charge better the burden of intermittence of production or mitigate it.

5.2 Plans for future work

The second and final revision of this deliverable will assess the interest of these solutions for stakeholders, find out which organizational scheme might be preferred for each, and provide an evaluation of the expected gain compared to current organizations.

The plan for further work as part of Task 6.2 of edgeFLEX is as follows:

- Identification of stakeholders to invite to workshops, from various and representative segments of the value-chain.
- Preparation of workshops, including elaboration of questions and organization of workshops.
- Performance of workshops
- Exploitation and analysis of the inputs gathered from the various stakeholders regarding the various theoretical approaches and appreciation of the edgeFLEX proposals.

6. List of Figures

7. References

[1] H2020 edgeFLEX, „D6.5: A new financing model for RES, to simplify investments in RES beyond subsidy schemes,“ https://www.edgeflex-h2020.eu/progress/work-packages.html.

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[4] *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources,* 2018.

[5] *Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU,* 2019.

8. List of Abbreviations

CEC	Citizen Energy Community
DSO	Distributed System Operator
ECR	Energy Community Responsible
LEC	Local Energy Community
mFRR	manual Frequency Restoration Reserve
REC	“Renewable” Energy Community
RES	“Renewable” Energy Source
TRL	Technology Readiness Level
TSO	Transmission System Operator
VPP	Virtual Power Plant
VPS	Virtual Power System