edgeFLEX

D8.5

Publishable Project Progress Report, V2

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Abstract
This document provides an overview of the progress of the edgeFLEX project in the second project year and the achievements of the total project duration to date.

Keyword 5G, Mobile communications, Renewable Energy Source (RES), Voltage Control, Frequency control, simulation, co-simulation, hardware in the loop, field trial, VPP

Executive Summary

The edgeFLEX project has made excellent progress during the second of its three years planned duration towards achieving all of the planned goals of the project. All the project activities have progressed according to the originally planned schedule defined in the Grant Agreement.

The concepts for new energy services and 5G support of these services have been elaborated and implemented and integrated into the edgeFLEX platform. Tests of the platform functionality over live 5G networks were undertaken and their description in deliverables is under preparation. The detailed planning of the field trials has been completed. The equipment planned to be used in the field trials has been installed and commissioned for use in the trials and collection of live data has started in all three trial sites. Dissemination and communication activities have progressed well using virtual media. Recently, a presence exhibition stand was organised by the project at a live trade fair held in Italy in Q4, 2021.

The first Periodic Review of project progress was held in December 2021. Progress in all areas was deemed to be very good and a short set of recommendations were made to further optimise and improve the project outcomes and impact. An action plan to implement these improvements has been prepared and will be executed during the final reporting period of the project.

The focus of efforts in the third and final year of the project is on the execution and evaluation of the field trials, the provision of feed-back to the work packages who developed the concepts and implementations and the further preparation of the results for market introduction and exploitation.

As in the first year of the project's activities, the restrictions of Covid-19 have meant that project participants were not able to meet for presence meetings during the second year of activities. During this long and sometimes stressful situation, project participants have made exceptional efforts to maintain progress on all work items of the project and the project results to date demonstrate the results of these efforts. Partners have adapted their working methods to optimise them for virtual meetings and remote working.

The project is well positioned to achieve all its planned goals and KPIs in its final year of operation.

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1. Introduction

1.1 Objectives of the report

The aim of this deliverable is to describe the status of the project work at the end of the second year of the project and to highlight the key achievements made in years 1 and 2.

1.2 Outline of the report

The report consists of two parts. The first part describes the overall approach of the project and includes a short overview of the key achievements of year 1 and 2. Part 2 gives a more detailed overview of the achievements of the main topics of the project.

1.3 How to read the document

This report can be read as a standalone document. However, the interested reader can refer to version 1 of the progress report to find more detailed information about the achievements at the end of the first year of the project.

2. The edgeFLEX approach to addressing the challenge

The challenge

With the dramatic growth of renewables, now is the time to revise the Virtual Power Plant (VPP) concept. VPPs need to support not only the promotion of intermittent Renewable Energy Sources (RES) but also the integration of all Distributed Energy Resources (DER) into the full scope of grid operations. Such a leap raises challenges: the optimal combination of DER and RES in a new generation of VPPs is needed so that they can provide grid supportive flexibility, with slow reaction times appropriate for day-head and intra-day markets, as well as the real-time reaction needed to provide fast frequency and inertial response and voltage control ancillary services. In a nutshell, in a DER-based power electronics-driven network, VPPs need to play a similar role to the one synchronous machine play in a traditional system.

Flexibility can be provided by going beyond electrochemical storage and exploring opportunities offered by the dynamically controllable behaviour of power electronics driven DERs. Demand Side Management or low-cost solutions could be deployed in a neighbourhood. This could enable the expansion of the role and responsibility of Local Energy Communities, enabling them to cooperate with VPPs or even become VPPs as the role of VPPs evolves in future years. edgeFLEX links technical solutions to societal expectations. Short reaction times can be addressed by 5G-powered edge clouds linking dispersed devices in near real-time. In this respect, a new concept of VPPs becomes possible with communications corresponding to multiple layers of dynamics. edgeFLEX proposes a new architecture for VPPs deploying such a multi-layer solution, enabling the electrical system to cope with intermittent energy sources. VPPs are brought to a new level, enabling them to interact in markets which offer ancillary services to System Operators. edgeFLEX develops this next generation VPP concept and demonstrates it in the context of three field trials and sets of laboratory tests. It explores innovative optimisations, financial tools and business scenarios for VPPs and assesses the economic and societal impact. It works actively to remove barriers by contributing to standards and European level regulation.

The edgeFLEX Vision

VPPs are enabled to manage a new wider range of generation and storage assets, including those of Energy Communities, offering a set of new fast and dynamic services to grid operators, enabling the emergence of a new market for ancillary services and optimizing the role and deployment of storage. Our vision is illustrated in Figure 1below.

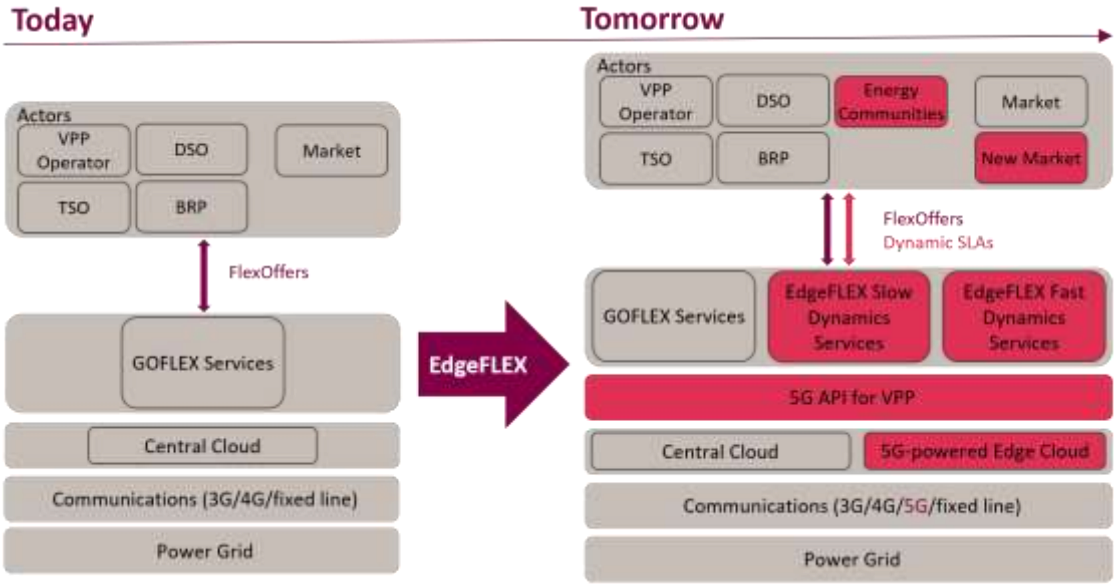

Figure 1 - The edgeFLEX Vision

The edgeFLEX Objectives

- To research new fast and slow dynamics ancillary services and a new market for trading them to VPPs and grid operators introducing an innovative new way to run VPPs offering increased flexibility.
- To develop competitive optimisations of the operations of VPPs with storage assets including Power2Heat and biomass reducing the need for grid re-balancing and increasing its stability.
- To develop a new sustainable investment model promoting increased investment and penetration of RES.
- To validate our services in field trials and lab tests, packaging results to prepare impact.

Virtual Power Plants (VPPs) have already been commercially developed to provide effective ways to integrate the capabilities of new energy sources into the wholesale energy market: edgeFLEX proposes a completely redefined VPP which is able, on the one hand, to play a more technical role in supporting grid operation and, on the other hand, to fulfil the growing interest of local communities to participate actively to energy system management. VPPs become Dynamically Controlled Virtual Power Plants, enabled by the resilience, low latency and cost-effectiveness of 5G-powered near real-time ICT, as illustrated in in Figure 2.

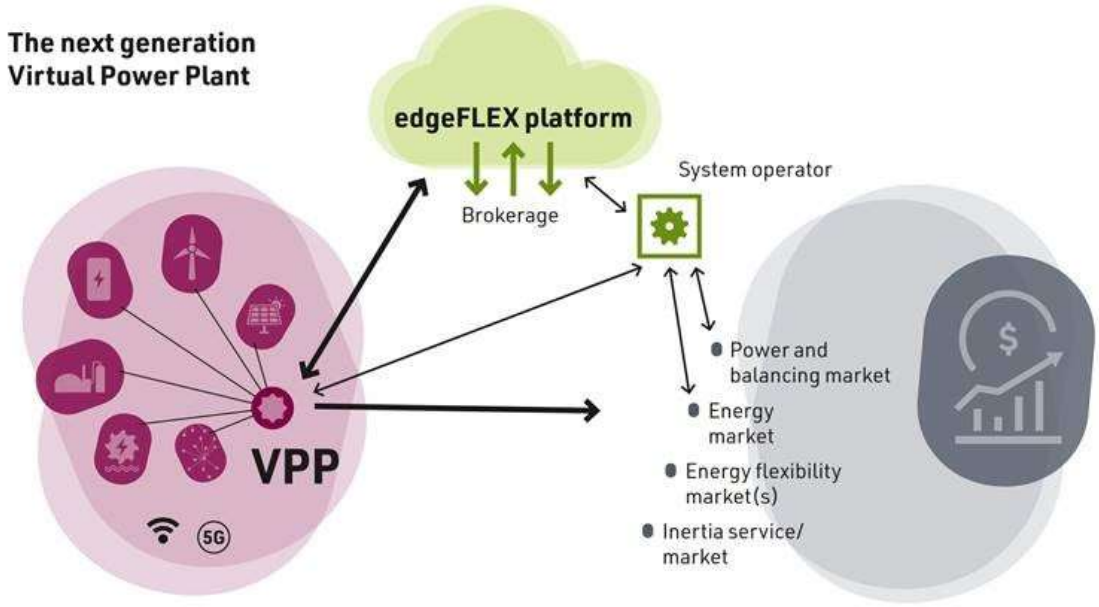

Figure 2 - The next generation Virtual Power Plant

Such solutions leverage the classical wholesale VPP level, while introducing new techniques for stabilising the power grid, i.e., enriching their operations with faster dynamics. At the same time, at local level, new solutions can enable Energy Communities to exploit their energy services in a new energy market. The edgeFLEX consortium partners believe that now is the time for them to meet these challenges, by undertaking joint research, innovation and communication actions leading to significant impacts on the energy stakeholders and markets.

Incorporating Energy Communities into the scope of a VPP means re-defining a VPP as an aggregation of anything that is connected to the community power network which can act as a resource providing flexibility to the grid. This enables prosumers and small generating units to play an active role in providing flexibility to the energy system and to form part of the energy value network. Such an approach brings significant advantages with respect to the simple application of electrochemical storage, and it will involve elements such as biomass units, boilers and various demand response capacities. The main point is that flexibility can be extracted from many existing assets with a dual-use concept which reduces the need for investment.

The role of storage has become a key issue. Electrification is of the utmost importance in the set of European actions to minimise green-house gas emissions. In the context of moving towards more competitive, fully decarbonised electricity generation, the electrification of both the transport sector and of the heating of buildings need to be urgently addressed. The edgeFLEX consortium has extensive experience of the use of electrochemical storage in both slow and fast dynamics applications. It brings this experience to bear on the definition and evaluation of appropriate solutions combining variable and dispatchable RES and electrochemical and other storage forms. In our field trials and business modelling, we challenge today's solutions based on electrochemical storage through the definition of new edgeFLEX solutions leveraging existing flexibility in the form of biomass units highlighting the competitiveness of flexibility based on new ancillary services for fast dynamics and based on including biomass, and other resources accessible via Demand Response.

edgeFLEX stimulates investment in RES through promoting new sustainable financial instruments increasing the profitability of RES assets and targeting RES asset owners. It expands the definition of the VPP to include a broader range of assets and optimises

the slow dynamics of VPPs for VPP owners, focussing on optimisations which could be implemented without the need for regulatory change. Finally, it provides VPPs with fast dynamics ancillary services, made possible using 5G-powered ICT, which they could offer to grid operators trading these services on a new energy market and enabling the grid operators to investigate their potential to exploit the TOTEX approach of the European Commission 2018/2019 Winter Package (Clean Energy for all Europeans Plan), if TOTEX is adopted by national regulators. Current regulation enables grid providers to offset investments in assets, but not investments in services, against the price they charge consumers for power. The TOTEX approach will allow them to offset the total costs of operating the power network, including services, against the price of power enabling them to purchase services while maintaining profitability. The European Commission proposal on TOTEX needs to be adopted by National Regulators if it is to come into force in Europe, opening new markets for services in the energy domain. This overview is illustrated in Figure 3.

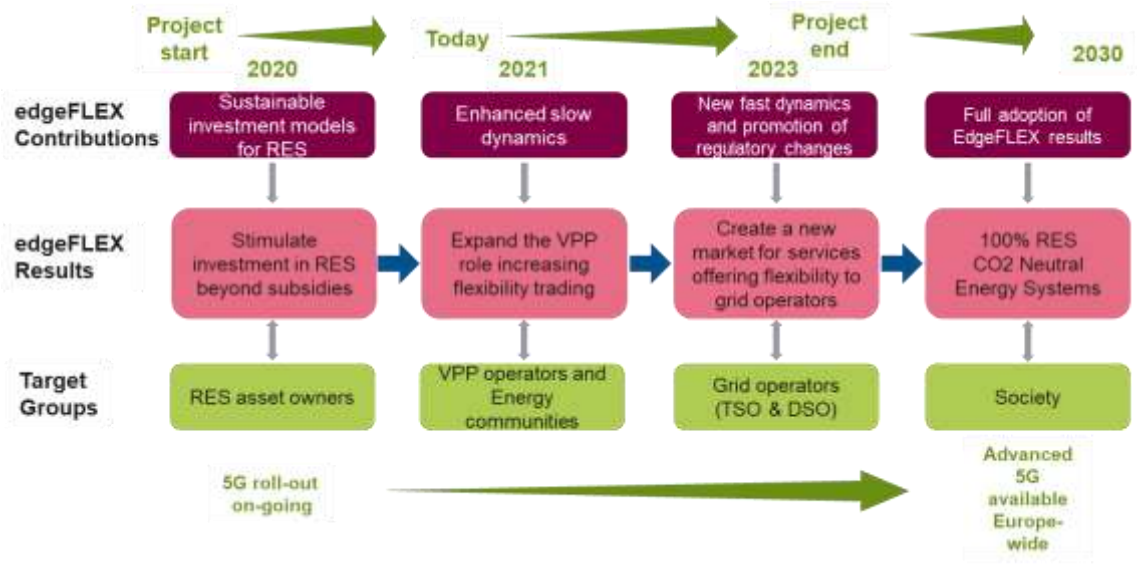

Figure 3 - edgeFLEX from start to finish and beyond

edgeFLEX develops innovative solutions with the help of key academic players, applies the concepts, thanks to experts in VPP and 5G technology, and verifies their effectiveness in cooperation with open and advanced grid operators. Concepts are tested in real life scenarios with the goal of understanding the concrete challenges to determine the right balance between system level and local requirements, slow and fast dynamics.

Validation of the edgeFLEX services and architectures in field and laboratory tests

edgeFLEX organises **innovative field trials** and laboratory tests in two countries, as illustrated in Figure 4 - The edgeFLEX field trial locations, validating our research and innovation results and creating confidence in our solutions.

Figure 4 - The edgeFLEX field trial locations

2.1 Expected impact results

edgeFLEX addresses the objectives described above in an innovative and structured approach. We combine our technical results with recommendations on how these technical results can be optimally deployed to provide:

- An investment environment and new financial tool making investment in RES more attractive. This can contribute to growth in investments in RES and hence growth in the penetration of variable output RES and can create jobs in Europe in RES manufacturing and services to RES asset owners.
- A boarder role for VPPs enabling them to manage a wider range of variable output and dispatchable RES assets, including storage assets and small plants, providing RES asset owners and VPP owners with new revenue streams increasing their interest in increasing their RES investment. This enables growth in the penetration of variable output RES and extends the flexibility which VPPs can offer to the grid as they will manage a larger range of assets with a broader range of capabilities. It can contribute to economic growth and new jobs in the VPP energy sector in Europe. It can provide new streams of income to the new RES asset owners, improving return on the investment in RES and leading to enhancement of growth in RES investment and hence to growth of the energy sector in Europe.
- A new set of 5G-powered dynamic control services, enabling the opening of a new ancillary service market for fast and dynamic services in which VPPs, in their expanded role, sell the flexibility of the fast dynamics of an expanded range of RES generation and storage assets to the grid operators to stabilise the grid.
- The new market enables Europe to optimise the operations of the European grid, maximising and aggregating the flexibility which can be provided by of all available assets and organising their participation in balancing markets through the new generation of VPPs. This will enable local grid balancing addressing one of the major challenges facing grid operators today to stabilise the gird.
- All RES asset owners again gain new sources of revenue, making investment in RES more attractive as the new ancillary service market for fast and dynamic services opens. Furthermore, European service providers and manufacturers

gain a new market for their products and services enabling them to expand their businesses and improve their competitiveness.

2.2 Key achievements in year 1 and 2

Short summary of key achievements in the period:

- Research concepts have been developed for the edgeFLEX services and many publications based on these results have been prepared.
- Services based on research concepts have been implemented and integrated into the edgeFLEX platform for use in field trials.
- The edgePMU concept was developed, implemented and tested in the RWTH power lab, tests of it with 5G undertaken in the Ericsson 5G lab.
- The platform architecture for the field trials has been defined and a first implementation is available and is being deployed at field trial sites.
- Extensive tests of the ability of standard 5G networks to support the latency requirements of the edgeFLEX services performed under normal and poor transmission conditions. Attenuation tests, and a set of latency tests using URLLC on a prototype 5G URLLC testbed, were undertaken.
- Planning of field trials is complete, as is the installation of equipment at trial sites, with trials already in live operation.
- The Italian power operator, A2A, has offered its power network infrastructure for use in the edgeFLEX Field trials at their own expense. A field trial of edgeFLEX fast dynamics services in the A2A infrastructure in Italy is now live.
- 4 regulatory change proposals have been prepared and many interactions with key stakeholders have already held and more are planned.
- 2 successful contributions to the 3GPP SA1 standards group were prepared and accepted for stardardisation. They are published as “Edge cloud driven data acquisition (edgePMU)” and “Use case of ensuring uninterrupted MTC service availability during emergencies” in TR 22.867, Release 18.
- Communication and dissemination reaching our target audiences through virtual events and publications has been prepared and undertaken. A Field Trial Open Day was organised in Italy in 2021 as a face-to-face event and many dissemination KPIs have already exceed target levels planned for the end of the project.
- 23 peer-reviewed publications have been prepared and published.
- Business models for edgeFLEX were defined and discussed at length in project meetings.
- Extensive planning of exploitation of project results has already been completed.
- Progress with all project KPIs and goals on or ahead of target with full achievement of all goals expected in the final year of the project operation.

2.3 Dynamic-phasor driven voltage control concepts

The work of WP1 has been dedicated to the development of the second drop of the voltage algorithm to engage customers belonging to an energy community. The result of the control algorithm is a flexibility request which can be exchanged with the local flexibility market. With this approach customers can be involved in the control of the grid voltage by providing a flexibility response, which is obtained by performing a market trade.

The control algorithm has been tested in a simulation environment and the external interface with the flexibility market has also been verified. The results have shown the ability of the voltage control algorithm to accept the flexibility response and to reformulate the control output tracking the result of the market.

The achievements can be summarised as follows:

Project Year 1

- Analysis of the state of the art related to VPP.
- Definition of a voltage control service scenario.
- Definition of use cases in which the voltage control will be implemented.
- Definition of the project technical terminology.
- Development of voltage control algorithm.
- Preliminary testing of the algorithm.
- Development and testing of the edgePMU concept

Project Year 2

- Development of the voltage control algorithm for engaging customers.
- Adaptation of the algorithm for WP4 further implementation and integration with the platform.
- Test of the algorithm in a simulated environment

2.4 Frequency control and inertial response concepts RWTH

The objective of edgeFLEX is to develop frequency control and inertia monitoring services that will enable VPPs to participate in providing frequency control and offer it for grid operators as an ancillary service.

In the second project year, the work of WP2 focused on the further development of the frequency control concepts for LECs, as part of Task 2.3. Furthermore, new work on inertia allocation has been developed within Task 2.5. Consequently, the scenarios defined in the first year of the project have been revisited and updated according to the latest research results within WP2.

The achievements can be summarised as follows:

Project Year 1

- Analysis of the state of the art of frequency control.
- Definition of frequency control and inertia estimation scenarios.
- Definition of use cases in which the frequency control and inertia estimation will be implemented.

- Definition of the relevant functional and communication requirements for full commercial roll out.
- Development of frequency control and inertia estimation algorithms.
- Preliminary testing of the algorithm.
- First drop of the developed algorithms as software packages for platform integration.

Project Year 2

- Update of the frequency control scenarios defined in the first year of the project.
- Definition of inertia allocation scenarios and use cases.
- New theoretical advancement: the development of the concept of the complex frequency.
- Development of the frequency control concepts for LECs, through reactive power/voltage feedback.
- Development of a scheduling tool for optimal allocation of virtual inertia.
- Proof-of-concept testing and validation of the frequency control and inertia allocation algorithms.

2.5 Concepts of 5G Dynamically Controlled VPP optimisation

VPP Optimisation Algorithm improvements achieved

Further development of the VPP optimisation service was undertaken and completed to increase the performance of the optimisation algorithm. A journal publication based on the results was prepared and published: “Optimal balancing of wind parks with virtual power plans” in “Frontiers in Energy Research”. The paper was peer-reviewed and published. The methodology was presented as part of a Stonybrook University Webinar which was live in March 2022.

The main focus of the work undertaken in the second project year was on the speed of computing optimal solutions of large-scale mixed-integer linear programming problems. The improvement achieved, when compared to the approach taken in project year 1, was two orders of magnitude. This was enabled by a newly developed method called Gradual Increase. Further progress in the development of this methodology and its new facets were achieved.

The results of this work can be leveraged in the business modelling work package (WP 6). In the business models, the optimised VPP can be leveraged to yield a viable economic scenario for the various actors involved in a VPP.

5G optimisations undertaken

In the second project year, the work on several tasks in the context of 5G use in project use cases continued. The 5G Device Management API proof-of-concept was integrated and tested with edgePMU software in the EDD 5G laboratory. The demonstration frontend, which is an easy-to-use graphical user interface to facilitate future 5G Device Management API demonstrations was further developed during the second project year

The 5G requirements defined in the first project year are being revised by partners. It may now be possible to make more accurate estimates of the 5G requirements of the edgeFLEX services improving on their original documentation during the first project year.

An investigation of the physical conditions of deployments of devices in the project field trials was conducted as input to the more detailed definition of the role of 5G in the project use cases

Finally, the results of the work described above is being documented in deliverable D3.1. D3.1 is currently under preparation.

PMU optimisations undertaken as the edgeFLEX edgePMU

In the scope of WP3, an innovative approach to the design and development of a new Phasor Measurement Unit (PMU), called the edgePMU was followed. The edgePMU, in contrast to classical Phasor Measurement Unit designs, splits the data acquisition and the phasor estimation algorithm into two separate tasks and deploys them on separate computational units to gain flexibility for the algorithm. During the second project year the final development of this concept was carried out, with integration of the full hardware configuration and of the software stack needed for data acquisition, processing and reporting. Additionally, the integration of the edgePMU with the edgeFLEX architecture and the IT services was completed.

The achievements can be summarised as follows:

Project Year 1

- VPP optimization Results of Task 3.4 VPP optimization algorithm have resulted in an academic publication.
- Research results showing that the intraday market does not behave in a stochastic manner; it has also been demonstrated that if suitable meteorological data can be provided to a neural network, then the intermittent energy forecast can outperform the commercial models currently available.
- Revision of the research will be proposed to leverage and document the experience feed-back that we will obtain through the field trial in Work Package 5.
- The definition of the ICT requirements of the edgeFLEX use cases was completed,
- The preparation of the edgeFLEX use case for consideration at the 3GPP SA1 meeting in March 2021 was completed and it was successfully adopted into the 5G standard,
- The preparation of the laboratory environment to undertake the development of new features for the 5G API was undertaken, and
- The definition of a solution sketch for 5G support of edgeFLEX services was completed.
- During year 1 the design of data acquisition, on a low-cost computational device, and the required data processing functionalities for the implementation of the edgePMU were completed. The first prototype of the edgePMU unit was completed and characterized in laboratory environment.

Project Year 2

- A new method to increase the performance and scalability of optimization assets in a VPP was developed and verified. Up to 200 VPP assets were modelled, demonstrating the capability for robust scaling of this optimization service using the new method
- The results and methods were published in a paper “Optimal balancing of wind parks with virtual power plants” in the journal Frontiers in Energy Research,

- The results and method were presented in Stony Brook University Webinar in March 2022,
- Investigation of the physical conditions of deployments of devices in the project field trials was finished,
- The integration of the 5G Device Management API proof-of-concept with the edgePMU software was completed and tested in the laboratory environment,
- The demonstration frontend for the 5G Device Management API proof-of-concept was fully developed,
- During the second year of the project the edgePMU prototype was further developed and refined. The first units needed for the deployment in the field trials were assembled and delivered to both the Italian and German trial sites. The integration with the edgeFLEX architecture was carried out, specifically with the data bus and the voltage control algorithm for demonstration and validation purposes.
- The edgePMU was submitted to the European Innovation Radar initiative and was accepted as innovation with a Tech Ready market maturity and a noteworthy market creation potential.

2.6 The edgeFLEX Platform and Services

One of the main aims of the edgeFLEX project from a technical perspective is to build the software components to containerise the research and innovation concepts from WP1, WP2 and WP3 so that they can be deployed in the field and laboratory trials. In the first year of the project work, the aim was to gather requirements, develop the architecture and to prepare the initial prototypes of the services, the SLA Monitoring Tool and the data interfaces. Furthermore, we aimed to develop the technological use cases that would shape the work going into the second year of the project.

In the second year of the project, the work was centred on deploying further iterations of the Grid Management services and the edgeFLEX Backbone in the laboratory trials and in the cloud so that we could further develop and harden the solutions in preparation for the deployment in the field trials. These further developments are driven by one of the aims within WP4 to assess and validate the platform in an iterative way throughout the final two years of the project. This is managed by a platform assessment template developed in conjunction with the relevant partners and the goal is to feed these assessments, once caried out, to the relevant researchers within the project to make the changes prior to redeployment. The research and innovation concepts from WP1, WP2 and WP3 also require data interfaces both internal to the platform and external to it and core to this activity was the development and deployment of the SLA Monitoring Tool and Policy Based Grid Management so that it could manage the sharing of data to external entities and also manage the connection with external data sources (like the KIBERNet system in the SWW trial).

The achievements can be summarised as follows:

Project Year 1

- Requirements Gathering
- The functional and non-functional requirements for the services were gathered, correlated and a generic basic container for hosting the services was defined.
- An identity matrix was created, and the project wide services and components were aligned to their specific actor and function in the energy sector. The output of the matrix was the identification of a natural synergy between three

components of the edgeFLEX Platform, namely the Voltage Control, the Dynamic SLA Monitoring Tool and the FlexOffer components.

- Solution architecture workshops were conducted to get a multi-layer view of the Grid Management Services so that the interfaces, goals and supplementary components and data streams could be identified.

Software Service Integration

- From the outputs of the requirements gathering phase a set of backbone services, ones that are needed for all the Grid Management Services, were identified and built so that the Grid Management Services could interface with them when delivered.
- Taking input from WP1 & WP2 in the form of software modules and using the outputs of the requirements gathering a set of containerised services were created for Voltage Control, Frequency Control and Inertia Estimation and they were integrated into the platform.
- One of the key activities of the integration work was to build a deployment method where the services could be configured when deployed to connect to trial site components as well as edgeFLEX specific components. This is carried out using configuration files that are injected to the service when it is being deployed and such configurations can include connection strings or data streams that the service can automatically pick up.

Architecture

- From the use cases that are linked to the trials a set of architecture diagrams were created to ensure that the goals of the first phase of the project were achieved.
- These provide the starting point around which the full edgeFLEX platform architecture can be developed.

Dynamic Service Level Agreement Monitoring Tool and Brokerage

- The requirements for this item were determined.
- The nature of the component was identified in terms of what technological. solutions it could provide for the platform.
- A proof of concept of the tool was built and deployed.

Voltage Control – SLA Monitoring Tool – FlexOffer Use Case

- From the identity Matrix this use case was identified that combined grid control with the creation of flex offers via the SLA Monitoring tool.
- This use case has now been finalised in terms of the components needed for it to work in the trials in SWW Germany.
- There has also a development plan created so that we can begin building the software and the data streams needed to perform the trial.

Project Year 2

Architecture

- The edgeFLEX architecture was developed using the SOGNO architecture and extending it from the System Operator towards the VPP and Energy Community by gathering requirements from the trials, the grid management services and other connected platforms like the GOFLEX platform

- The edgeFLEX architecture was validated in consultation with the relevant partners to ensure that the platform and minimal viable products built within the blueprint of the edgeFLEX platform would be fit for purpose and that the architecture would offer enough flexibility to cater for the wide range of scenarios within the project (and potential new ones beyond the project).

Grid Management Service Interfaces

- The Grid Management Services of edgeFLEX (Inertia Estimation, Voltage Control and Frequency Control) rely on to receive data as inputs and send set points or estimations. This involved the development of the edgeFLEX backbone services which contains a databus (based on the DockerMQTT open-source component developed as part of the RE-SERVE project), a data store and a set of monitoring dashboards.
- The data stream from the KIBERNet platform to the edgeFLEX Platform has been established and the data is available as an interface for the control services
- The deployment of the cloud element of the edgePMU (the Phasor Calculation service) was deployed within the platform so that field deployed edgePMUs could send data to the platform for use as inputs to the control services.

Grid Management Service Integration and Deployment

- The integration and deployment of the grid management services is an iterative process and during year two of the project focus mainly centred on getting the services trial site ready. This was carried out by using the platform assessment template developed in WP4 to identify areas where the services (and the platform in general) could be improved, making the improvements, and redeploying the services.

SLA Monitoring Tool and Policy Based Grid Management

- In year two of the project the SLA Monitoring Tool was deployed and policies developed and used to share data and request data, to request flexibility and to provide asset constraints to the grid management services so that they can remain within operating limits.
- A set of APIs have been defined and implemented to both provide observability to external actors via the SLA Monitoring Tool and Policy Based Grid Management and as a method to retrieve data from external sources, which is core to the integration of the platform in the SWW Trial where data from their existing platform, KIBERNet, is required.
- As a concept and as a system that can enable cross sector actor collaboration use cases Policy Based Grid Management was proposed to the Commission as an item that was suitable for the Innovation Radar.

Voltage Control – SLA Monitoring Tool – FlexOffer Use Case

- This use case was further advanced in the 2nd year of the project with developments to the Voltage Control, the SLA Monitoring Tool and the KIBERNet platform (that will facilitate the use case) in an advanced state prior to deployment to the trial in the early part of the 3rd year of the project.
- The components in the SWW trial have been identified.
- The data streams from the relevant components have been identified and established.

Platform and Control Service Assessment and Feedback Loop

- A comprehensive platform assessment has been developed will be completed and reviewed on a bi-monthly basis at each trial

  This platform assessment has been used within WP4 and in the 5G Laboratory trials and the feedback loop is in place to the relevant researchers and partners within the project to address any issues identified. The feedback loop will receive assessments of the platform deployment in the lab and trials and identify the improvements that need to be made to the platform via WP1, WP2 or WP3 and in within WP4 also.

2.7 Field Trials

Each of the technologies developed will be validated in one or more sets of tests, in the field or in a lab or in both contexts, as illustrated in Figure

Figure 5 - Overview of the edgeFLEX Field Trials and Lab tests of 5G

2.7.1 German Slow Dynamics Trials

The activities for the slow dynamics field trials in Germany in the 2nd year of the project work included further algorithm optimisation and running calculations for imbalances and revenue potentials.

The achievements can be summarised as follows:

Project Year 1

- The wind parks, the biogas powerplants in Germany were identified. Their locations cannot be disclosed by Alpiq for commercial confidentiality reasons.
- We elaborated the algorithms for the management of the systems with two biogas power plants and batteries operating on the day ahead and intraday markets and managing the imbalances.
- The algorithms have been optimized to work very efficiently to provide decisions in seconds.
- The platform in which the algorithms will be deployed was chosen. It runs on Python and can be deployed either on a cloud or on a personal computer, easily. Everything can be run on open-source software.

Project Year 2

Trial Deployment

- Calculations for utilizing biogas power plants for the balancing of wind parks also considering known imbalances as well as simulated.
- Forecasting algorithms was further elaborated and optimised.
- Data acquisition via back-testing of historical data and calculations of imbalances was carried out.

Initial Results

- Two thirds of the imbalance of the wind parks was balanced by the virtual power plant. The remaining imbalance had to be purchased from the market
- With additional biogas power plants in the virtual power plant, then full balancing (deficits) could be achieved. In 2022, Alpiq started to manage two more biogas power plants. These power plants will be included into the model of a VPP.
- With the VPP optimisation algorithm, profits for the biogas power plants were increased by >2%.

2.7.2 Italian Fast Dynamics Trials

The Italian fast dynamics field trials within 2nd year of the project included the beginning of the trial's deployment, which involved installation and integration of the edgePMU and platform as well as communication possibilities using 5G technology.

The achievements can be summarised as follows:

Project Year 1

- The integration of the hardware and software is being carried out as well as the preliminary testing of the project's edgePMUs.
- A nondisclosure agreement was signed with A2A to regulate the legal issues of their provision of their distribution network infrastructure to edgeFLEX for use in our field trials of fast dynamics, although they are not a project partner and not receiving funding from edgeFLEX.

Project Year 2

Trial Deployment

- Talks and agreements with A2A for Asset identification and edgePMU and platform installation and integration for running field trials.
- Voltage control measures integration for the purpose of the trials.
- Assessment of 5G communication availability in the field trial area.

Initial Results

- Trail site requirements defined.
- Development of voltage splitter to enable edgePMU installation.

Business & Dissemination

- Support and carry-out of dissemination activities as part of WP6.

- Creation and development of business modelling for ancillary services in line with national grid codes were defined.

2.7.3 Wunsiedel Slow and Fast Dynamics Trial

The fast and slow dynamics field trials in Germany within 2nd year of the project included the beginning of the deployment of the trials, which involved installation and integration of the edgePMU and platform as well as of communication possibilities using 5G technology as well as integration of the KIBERNet-EMS developed within the GOFLEX and also correspondence outlines with the edgeFLEX platform developed within WP4.

The achievements can be summarised as follows:

Project Year 1

- Mapping the grid's topology in PowerFactory.
- Possible locations were found for edgePMUs.
- Cloud was decided upon.
- Communication infrastructure was assessed.

Project Year 2

Trial Deployment

- edgePMU and platform instantiation.
- The KIBERNet system was integrated and FlexOffer requesting schemes were defined.
- Voltage control measures integration started.

Initial Results

- Harnessing data-flows from the GOFLEX project.
- Cash-flow sources identified.
- Flexibility price per kWh was identified.
- SWW–RES owners cooperation agreement was formed.

Business & Dissemination

- Support and carry-out of dissemination activities as part of WP6.
- Creation and development of business modelling for ancillary services in line with national grid codes were defined, including flexibility aggregation, ancillary services and for Energy Communities.

2.7.4 edgeFLEX Energy and 5G Laboratory Tests in Germany

In the second project year, EDD continued the 5G performance tests with synthetic data representing edgeFLEX services, and with deployed frequency control services and integrated edgeFLEX platform. The tests were conducted on two 5G networks: a 5G standard standalone network, and on an Ultra Reliable and Low Latency Communications (URLLC) prototype network.

The achievements can be summarised as follows:

Project Year 1

- Test cases for each edgeFLEX service were defined and synthetic data streams typical of each service were specified.
- 5G laboratory equipment was configured and integrated in the Ericsson laboratory in Aachen.
- The ICT requirements of each edgeFLEX service were defined. Tests of each edgeFLEX service were performed in the 5G network using synthetic data streams.
- The preparation of the laboratory environment for 5G tests of latency performance,
- A test series measuring latency performance under different conditions of attenuation of the radio communications link the required laboratory configuration was investigated,
- The testing of the ability of 5G networks to fulfil the edgeFLEX use case latency requirements on live 5G networks with synthetic data,

Project Year 2

- 5G performance test with synthetic data of edgeFLEX services on the 5G standard standalone network in the laboratory were completed.
- 5G performance test of the frequency control services with integrated edgeFLEX platform on 5G standard standalone and URLLC prototype networks in the laboratory were completed.

2.8 Regulatory and business model work

Our work on business modelling, regulatory assessment, and exploitation of the project results, is being achieved according to the planned schedule for the two implementation phases:

- with reference to edgeFLEX service development in the first year of project implementation, and
- during years 2 and 3, undertaking the steps as presented in Figure 6 below:

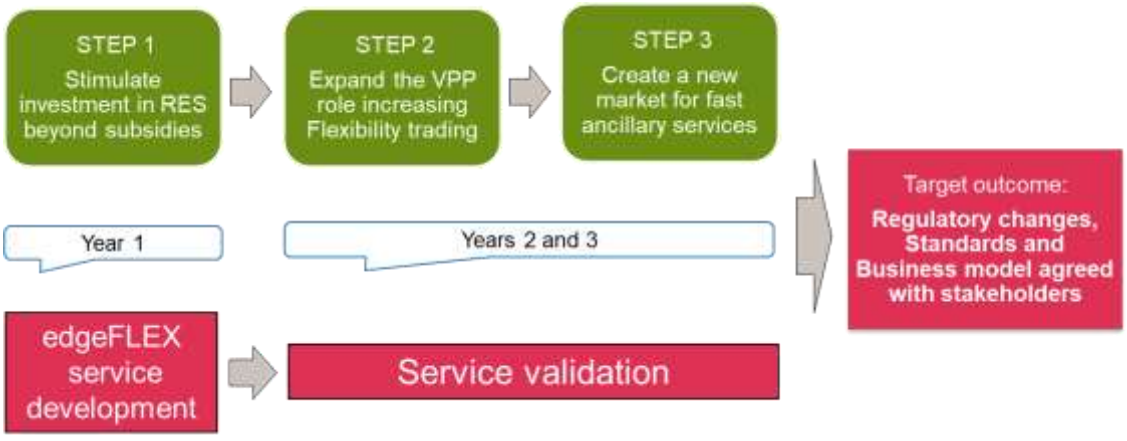

Figure 6 - The pathway from technical challenges to business models and regulatory framework

Project year 2 represents the initial year of the second phase, in which we did focus on service validation.

Our work on business modelling and regulatory assessment within the second phase of project implementation started by creating permanent feedback methodology framework with relevant organisations and practitioners, for the validation and completion of the results of our work from the first phase. The edgeFLEX solutions developed in the first project year have been further developed by looking into specific stakeholders' needs and requirements to validate them and to develop a straightforward approach to their adoption.

Task 6.2 has taken care to undertake the successful design of all solutions and expected business models using the smart innovation and agile methodologies, thus making sure that the solutions developed in edgeFLEX will meet the needs of a broad range of stakeholders and preparing their adoption in future exploitation and business development activities. More specifically, in the second phase of project implementation starting in month13, the activities in this task focus on the edgeFLEX solutions economic value assessment, considering the DSO and Aggregator centred scenarios, by identifying actors, roles and formulas that lead to the definition of functional and sustainable business models, and effective exploitation of the project results. The results of the Task 6.2 work from the second phase of the project implementation are the object of the following deliverables:

- D6.6 - Preparing exploitation – submitted within the reporting period (month 18), and
- D6.2 - Comparative analysis of potential business impact v2 – to be submitted in month 36.

In the framework of the Task 6.3, an important action taken to develop a deeper understanding of the position of stakeholders, such as policy makers, regulators, and practitioners, but also of the market needs for a precise correlation with the activities scheduled and performed within the project for the validation phase.

Since the beginning of year 2, we have continued the activity of identifying and formulating additional market-related proposals in regulation and standardisation, in close corelation with the definition of business models applicable to the edgeFLEX context, as represented in Figure 7 below.

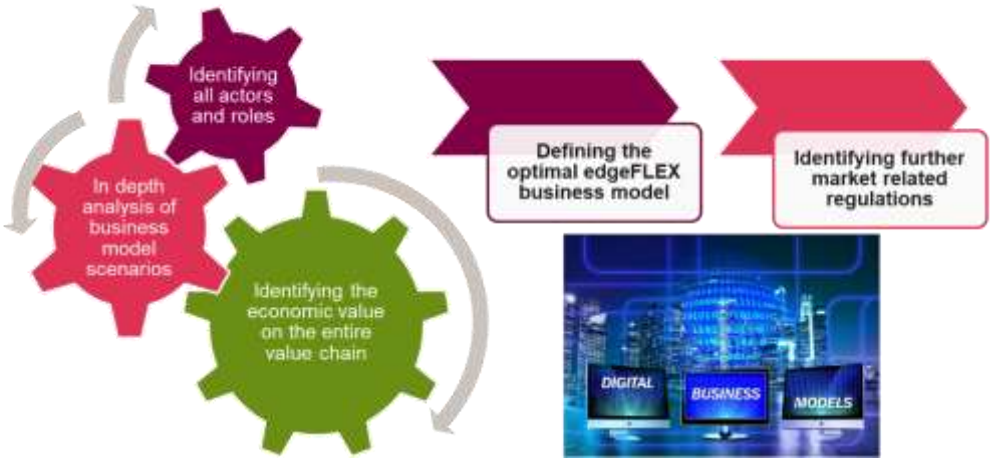

Figure 7 - Digital business models requiring further market related regulations

We also started the validation of and lobbying for the outlined proposals with the main categories of stakeholders. We have already run several bilateral meetings with the main European regulation and standardisation organizations and have organised consultation

events with large international participation and we plan more such events in the final project year.

In this context, of the validation of the proposals, a series of bilateral meetings took place with ACER, VDE / FNN. In parallel, the interactions with all categories of stakeholders continued, both from the perspective of the regulatory framework proposals, but also for the exchange of ideas and input collection in business modelling based on edgeFLEX solutions, advancing with the reformulation of the two main scenarios (DSO and Aggregator centred) towards two better-founded scenarios taking into account the realities of the specific market: either the system operator or the energy community operator playing the aggregator role.

This process will continue with the formulation of the final set of proposals regarding the regulatory framework, potential additions in the context of standardization, defining the optimal business model and carrying out lobbying activities in relation to policy makers and other key stakeholder categories.

The achievements can be summarised as follows:

Project Year 1

- The comprehensive plan of the business modelling and regulatory assessment activities.
- The definition of a new financing model for RES, to simplify investments in RES beyond subsidy schemes.
- Preliminary comparative analysis of potential business impact.
- Defining initial proposals in regulation, mainly addressing in a first stage the technical challenges of edgeFLEX solutions.
- Laying the foundations for preparing the exploitation of the project results.
- Carrying out an intense activity in the process of engaging with policy makers, with organizations and experts in regulation and standardization:
    - participation in specific events and workshops where we had interactions and exchange ideas with the main stakeholder categories.
    - organization of sessions dedicated to the regulatory aspects of the edgeFLEX project within consultation events with wide international participation.
    - bilateral meetings.
    - organizing the first virtual meeting of the edgeFLEX Advisory Board.

Project Year 2

- Organizing workshops within the project to analyse all relevant aspects on exploiting the project results, referring to the specific context of each partner in the project, but also from the perspective of the main stakeholders, and submitting the deliverable D6.6. – Preparing exploitation.
- Part of the second phase of consultations with stakeholders was carried out, from the perspective of validation and completion of regulatory proposals.
- Further assessment and advancing with the reformulation of the two initial business modelling scenarios, which will be the basis for further analysis towards the definition of the optimal business model for edgeFLEX Dynamically controlled VPP solutions: system operator or the energy community operator playing the aggregator role.

- Publication of a scientific article in Frontiers, to generate debates at the academic and practitioners' level regarding the promotion of regulatory measures applicable to the edgeFLEX context.
- The activity of involvement and participation in seminars, workshops and international events continued in the second year of implementation, having the same perspective of validation and completion of concepts and solutions outlined in the first year of implementation.
- Organisation of sessions dedicated to the regulatory aspects of the edgeFLEX project within consultation events with wide international participation.
- Bilateral meetings with key stakeholder organisations, including Agency for Cooperation of Energy Regulators (ACER).
- Planning on further consultation with stakeholders focusing on the regulatory authorities and practitioners.

2.9 Dissemination and Communication

The overall edgeFLEX dissemination and communication strategy follows a 3-step process, aiming to stimulate investment in renewable energy sources, to provide new options in flexibility trading exploitable within the current regulatory framework by a new definition of a VPP and to enable the creation of new local energy markets with new fast dynamics services requiring extensions of the current regulatory framework to be adopted at national level.

In the first project year, the focus was on creating awareness for the project, its general goals and technical developments and getting in touch with selected key stakeholders. An overall identity was created to ensure a high recognition value for all dissemination and communication activities. Based on the project's corporate identity, the communication tools and channels were set up. The main communication channels – the project website and the LinkedIn channel – are regularly updated with non-sensitive and publicly available information on the progress and outcomes of the project and serve as a means for engagement with stakeholders.

Eighteen scientific papers have been published by the academic partners in the consortium; making a total of 27 published papers and already exceeding the KPI of 15 scientific publications for the whole lifetime of the project.

Events, as an indispensable means to distribute information about the project, initiate cooperation activities and make contact with users and customers have been continued to be held online with the exceptions of the Italian Field trial Open Day and Enlit in Milan, which were face-to-face, as well as some hybrid events in October and November 2021.

The "big picture" of the project has been worked out based on project outcomes and a slide set with an overview for presentation at events was prepared.

Together with the consortia of the H2020 sister projects FEVER and Platone, the *FlexCommunity* had its kick off in February 2022 with a total of over 150 participants. It brings together projects and stakeholder that focus on flexibility issues. By joining forces, the number of relevant experts is expected to be maximised thus reaching a critical mass of participants and creating a bigger impact. This goal will be reached by having partners from different project consortia on board, but also by being more attractive to external stakeholders due to a broader scope and higher number of members. The community is organised as a knowledge community on different levels (technical, business & market aspects, energy communities etc.), but also reach out to potential adopters and users of the project's technology and solutions. A new logo has been designed for the

FlexCommunity and a dedicated website was set up with different subsections for specific topics and groups.

Figure 8 - FlexCommunity website

Figure 9 - Partners of the FlexCommunity

The achievements can be summarised as follows:

Project Year 1

- Design of visual identity: an overall design was developed to make sure all project activities will be recognized as part of edgeFLEX.
- Set-up of website as the communication hub for the project containing all central information on edgeFLEX.

- Set-up of edgeFLEX LinkedIn group.
- Creation of template for slides, deliverables and milestones; set of basic slides.
- Publication scientific papers, nine in 2020, eight more already submitted and to be published in 2021.
- Production of a video describing the Wunsiedel trial site.
- Participation at the projects zone of the online IEEE Smart Grid for Smart Cities conference.
- Organisation of Wunsiedel trial site workshop (virtual).
- Project presentation at ten invited talks talks in workshops and at international events, all of them at digital events.
- Co-organisation of online event for closer collaboration with H2020 sister projects FEVER, Platone and DECIDE.

Project Year 2

- Slide set with an overview of the project for presentation at events prepared.
- Project roll-up.
- 18 peer-reviewed publications, in total 27, already exceeding the KPI of 15 scientific publications for the whole runtime of the project.
- Organisation of 20 workshops, special sessions, summer schools, participations in conferences and project presentation at third-party events, most of them online, as of October 2021 also hybrid and some face-to-face.

  Of the 20 workshops, the following are particularly noteworthy:

  - Project presentation at EUSEW policy session and virtual booth at EUSEW energy fair.
  - Booth at EU project zone at Enlit in Milan (face-to-face event!).
  - Official kick-off event with other projects of the *FlexCommunity* in February 2022.

2.10 Project Management progress

The project management has progressed smoothly during the project lifetime with only minor problems which were resolved with frequent and effective communication between partners. The Covid-19 pandemic brought restrictions on meetings and travel right from the from start of the project. All project meetings have been held virtually and partners are constantly improving their ability to work through digital media. The collaboration between partners in the first two years of the project was excellent and a key factor in the success of the project so far in reaching and exceeding its goals.

With virtual meetings, we were able to organise our project work and to build on the well-developed relationships between several of the project partners who have worked together in earlier projects. We were lucky that we had no serious problems due to project members became ill. We encountered only minor problems when purchasing and installing equipment for field trials and lab experiments, resulting in timely execution of the project plan and the achievement of goals and KPIs planned for year 1 and 2.

The first periodic project review of the first reporting period, which ended in September 2021, took place in December 2021 and the reviewers evaluated the project as achieving exceptional results with the potential to have significant impact.

3. Conclusions

Progress in the first two years of the edgeFLEX project has been excellent. All planned goals were reached and even exceeded in some areas. Progress towards achieving several project KPIs exceeded the achievement level expected at the end of the project.

The restrictions imposed by the Covid-19 pandemic have meant that almost all project participants have been working from home with restricted access to laboratory and field trial locations. Despite these difficulties and the absence of any presence meetings of project participants, we have been able to develop a good team spirit and to cope with the high stress level many project participants have had to endure due to the pandemic. We ran many virtual project meetings and organised and took part in many virtual dissemination events. We are continuously adapting our working procedures to the new working environment to optimise our output.

edgeFLEX is well positioned to achieve its full potential in the coming final year of the project.

4. List of Figures

5. List of Abbreviations

API	Application Programming Interface
DER	Distributed Energy Resources
DSO	Distribution System Operator
edgePMU	edgeFLEX Phasor Measurement Unit
ICT	Information and Communication Technology
PMU	Phasor Measurement Unit
RES	Renewable Energy Source
SLA	Service Level Agreement
TSO	Transmission System Operator
VPP(s)	Virtual Power Plant(s)
VPS	Virtual Power System
WP	Work Package