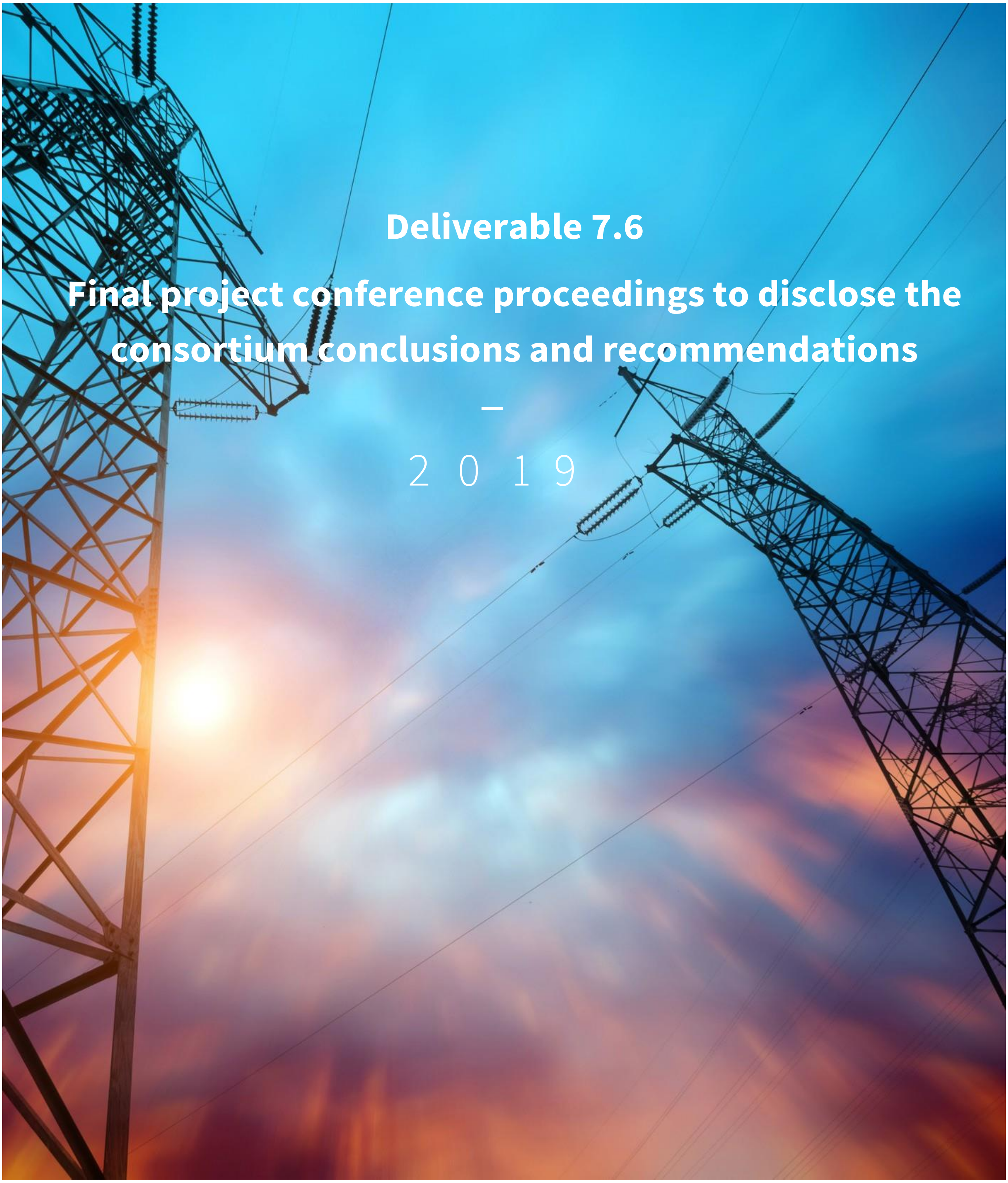

Deliverable 7.6

Final project conference proceedings to disclose the consortium conclusions and recommendations

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FutureFlow

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TABLE OF CONTENTS

INDEX OF FIGURES AND TABLES

GLOSSARY

Area Control Error	The ACE is the sum of the power control error ('ΔP'), that is the real-time difference between the measured actual real time power interchange value ('P') and the control program ('P0') of a specific LFC area or LFC block and the frequency control error ('K*Δf'), that is the product of the K-factor and the frequency deviation of that specific LFC area or LFC block, where the area control error equals ΔP+K*Δf (see EU Reg. 2017/1485, Part I, art. 3, point 2(19)).
Balancing Service Provider	A market participant with reserve-providing units or reserve-providing groups able to provide balancing services to TSOs (see EU Reg. 2017/2195, Title I, art. 2(19)).
Common Activation Function	The function of operating the algorithm applied to optimise the activation of balancing energy bids (synonym of 'activation optimisation function' as per EU Reg. 2017/2195, Title I, art. 2(39)).
Commercial and Industrial consumers	Synonym adopted in the project for Significant grid users (see).
Common Merit Order List	Common merit order list (CMOL) in the European Union Internal Electricity Balancing Market is a list of balancing energy bids sorted in order of their bid prices, used for the activation of those bids (Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, Article 2(37)).
Cross Zonal Capacities	Cross-zonal capacity in the EU energy market is defined as the capability of the interconnected system to accommodate energy transfer between bidding zones (see Article 2(10) of the Regulation 543/2013 of 14 June 2013 on submission and publication of data in electricity markets, or Article 2(70) of the Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity (recast), as well as Article 2(5) Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector).

Distributed Generation	Generic term referring to a variety of technologies that generate electricity at or near where it will be used, such as solar panels and combined heat and power. Distributed generation may serve a single structure, such as a home or business, or it may be part of a micro grid (a smaller grid that is also tied into the larger electricity delivery system), such as at a major industrial facility, a military base, or a large college campus. When connected to the electric utility's lower voltage distribution lines, distributed generation can help support delivery of clean, reliable power to additional customers and reduce electricity losses along transmission and distribution lines.
Demand Response	Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized (see Balijepalli, Murthy; Pradhan, Khaparde (2011). "Review of Demand Response under Smart Grid Paradigm". IEEE PES Innovative Smart Grid Technologies – this is the definition formally adopted by Department of Energy Regulation in the US, in Europe there is no formal definition in the presently approved Grid codes).
Full Activation time	It is the period between the activation request by the connecting TSO in case of TSO-TSO model or by the contracting TSO in case of TSO-BSP model and the corresponding full delivery of the concerned product (see Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing, Article 2(30)).
Load-Frequency Control	Methodologies adopted by TSOs to maintain frequency reasonably stable around the 50 Hz value and power interchanges with neighbouring control areas at the scheduled values.
Power Flow Colouring	Methodology developed by EKC to allocate sources and sinks of power flows on transmission lines, so to identify responsibilities for imbalances and system security breaches.
Renewable Energy Sources	Energy sources that do not rely on fuels of which there are only finite stocks. The most widely used renewable source is hydroelectric power; other renewable sources are biomass energy, solar energy, tidal energy, wave energy, and wind energy (see European Environment

	Agency, Glossary - https://www.eea.europa.eu/help/glossary/eea-glossary/renewable-energy-source).
Regional Security Centre	The entity or entities, owned or controlled by TSOs, in one or more capacity calculation regions performing tasks related to TSO regional coordination (see EU Reg. 2017/1485, Part I, art. 3, point 2(89)).
Significant grid user	The existing and new power generating facility and demand facility deemed by the TSO as significant because of their impact on the transmission system in terms of the security of supply, including provision of ancillary services. Could be used as a synonym for main VPPs directly connected to the Transmission Network. There is no formal definition of SGU in the network code, but a precise indication of their role and responsibilities is available in: ENTSO-E Supporting Document for the Network Code on Operational Security of 24 September 2013 2nd Edition Final, p. 61, 62.
Transmission system operators	An organisation which is responsible for the transport of electrical energy at national or regional level using fixed infrastructure.
Virtual Power Plant	A virtual power plant is a system that integrates several types of power sources to give a reliable overall power supply. The sources often form a cluster of different types of dispatchable and non-dispatchable, controllable or flexible load, distributed generation (DG) systems that are controlled by a central authority and can include micro CHPs, natural gas-fired reciprocating engines, small-scale wind power plants (WPPs), photovoltaics (PVs), run-of-river hydro power plants, small hydro, biomass, backup generators and energy storage systems (ESS).

ABBREVATIONS

ACE	Area Control Error
BSP	Balancing Service Provider
CAFx	Common Activation Function
C&I	Commercial and Industrial consumers
CMOL	Common Merit Order List
CZC	Cross Zonal Capacities
DG	Distributed Generation
DR	Demand Response
DG&DRs	Distributed Generation and Demand Response resources
FAT	Full Activation time
LF	Load-Frequency
PFC	Power Flow Colouring
RES	Renewable Energy Sources
SGU	Significant Grid User
TSO	Transmission system operators
VPP	Virtual Power Plant

EXECUTIVE SUMMARY

The FutureFlow project has shown the true potential of flexible resources that are available within the power system. The results and products of this project will help TSOs to get access to all this resources and affirm their central role as the most reliable “system frequency manager”.

The energy market has evolved from a power system, reliant on a bulk, concentrated generation towards geographically sparse wind and solar sources often connected to voltage levels out of the direct control of the TSO. This requires technical, operational and market solutions featured in the FutureFlow project to process ever increasing amounts of data from which the frequency signal is dependant and will be even more dependent in the future. Besides this, the flexibility price is on the way to become a fundamental price signal of wholesale electricity for the European market.

The Energy Regulation 2019/943 indicates full marginal pricing for balancing as the recommended pricing practice. However, to avoid price distortions, the overarching and detailed views of the actual volume of generation and demand to modulate the frequency signal is the only acceptable precondition to deliver transparent and cost-reflective market prices. Nowadays, the coordination between balancing and redispatching resources, cross-border exchanges and different voltage levels is constrained. These constraints are also due to the lack of targeted business solutions that favour the cross-border market access and the contribution of new flexibility sources to the stability of system frequency. Other dimensions of power system stability and control, including the cross-voltage coordination, voltage control, influence on system inertia are have not been in scope for FutureFlow due to limited time and personal resources, but the project has demonstrated that crating the link between the distribution voltage level and the high-voltage level, between the smallest control units and TSOs control centres, the aggregated DR&DG resources can be very beneficial for system operation with the proper coordination among involved stakeholders. Particularly in the future, when more and more energy will be provided by renewable resources and the need for power reserve will be huge, the new flexibility sources will represent real and healthy competition to the conventional units taking part in the aFRR yesterday and today.

With FutureFlow, the energy market coupling for the day-ahead and intraday markets are compressed into a response timeframe of a few minutes, bringing transparency to the available flexibility in the system in the timeframe where flexibility reveals its real value to system balancing and congestion management.

How does FutureFow works? FutureFlow relies on the exchange of balancing energy between the TSOs, implying that the exchange of any kind of balancing services is possible exclusively by involved Transmission System Operators and that activation of aFRR energy in a specific control zone, both from conventional and DR/DG providers, is realized through the local TSO. The usual sequence of steps is then followed for process of exchange of aFRR balancing energy: prequalification, bidding, activation and exchange and settlement. For each of these steps the project has introduced important steps in procedural alignment and technical innovation. The full activation time of reserve and the product resolution have been aligned in the four involved countries, and the stochastic rate of change of load or generation (particularly renewables) within each of the involved country has been linked to the steeper ramps to be produced by activated reserve in

the environment registering a generalised system inertia decrease.

These features have been integrated with the latest achievements reached by TSOs for optimizing the calculation and sharing resources for operational reserve and re-dispatching across control zones. The sharing of resources is not limited to those available at the transmission level but can reach distributed generation and demand side resources connected to the lower voltage levels.

Testing this solution would have not been possible if Virtual Power Plant (VPP) technology would have not been modelled and tested in real-life pilots with various flexibility portfolio structures for this project. This fundamental project result has created a composite library of business cases and solutions that can be used for industrial applications in areas where the flex potential of, e.g. small hydro, has been largely untapped, thus allowing the fast and quick inclusion of the VPP flexibility into the market.

All VPP building blocks have been integrated into “cyberNOC”, an ICT platform developed by cyberGRID that enables seamless integration of renewables, distributed generation, C&I customers, EV charging stations, batteries and prosumers to European energy markets. Its functionalities comprise real-time metering data collection, advanced analytics for flexibility forecasting, baselines and evaluations, optimization of aggregation portfolio, flex product placement and market arbitrage, automatic bid generation, monitoring and controlling of activations, market integration protocols, etc.

In this respect, FutureFlow works both as a power system “telescope” and “microscope”, gathering a broader geographical scope for collecting flexibility resources and, at the same time, with more detailed views of available generation and demand-side resources niched at lower voltages, thus contributing to determine system security perimeter every 15 minutes for the coming day.

The unprecedented results of this project pave the way to resolving other issues TSOs are facing. Providing, for example, increasing support to Regional Security Coordinators in their day-to-day security assessment processes. The data collected by FutureFlow tools could provide increased precision for cross-zonal capacity calculations and system security when used for forecasting purposes, allowing more precise provisions on how to tackle congestion at the borders is handled with a higher level of flexibility. Based on 15-minute market intervals or longer term scenarios, when developing new infrastructures, the combined use of FutureFlow databases with robust market price forecasting tools can offer a basis to develop new tools to enhance the precision of cross-border cost allocations (CBCA) for Projects of Common Interest (PCI). Leveraging on the more accurate assessment of balancing resources and the positive economic effect of their cross-border sharing the CBCA assessment process is another benefit of this project.

ACER has recently expressed expectations and perception of the future balancing markets. Their representative at the FutureFlow’s final conference in Vienna summarized these goals:

- **To allow and enable new, environmentally friendly sources to enter balancing markets** and became important players offering TSOs their flexibility.
- **To decrease the need for system reserves.** This is expected to be achieved by regional dimensioning of system reserves.

- **To integrate local markets into the regional cross-border balancing**/flexibility markets.

With its exploitable results and findings, FutureFlow strongly contributes directly to the achievement of these goals. The ambitious target to engage 35-45 MW of flexibility coming from DR&DG supports the first bullet above. The initial goal has even been exceeded by about 50%. Together with the objective to decrease the need for system reserves by enhanced TSOs regional coordination, new flexibility providers will make a strong pressure on conventional resources, notably on thermal units, currently detaining the largest share in the aFRR and mFRR markets. The real-time tests with DR&DGs showed that the quality of aFRR and mFRR services from new flexibility providers is comparable with the performance of the conventional power plants. Finally, besides local activations, the DR&DGs have also been tested in numerous cross-border proving the benefits of an integrated balancing market. In average 23% less aFRR energy needs to be activated in case of integrated markets compared to the local mode operation of four power systems. This is an additional strong driver for TSOs and regulators to integrate balancing markets at the shortest possible notice.

1 The aim of the FutureFlow Project

Four European TSOs of Central-Eastern Europe (Austria, Hungary, Romania, Slovenia), associated with power system experts, electricity retailers, IT providers and aggregators, propose to design a unique regional cooperation scheme: it aims at opening Balancing and Redispatching markets to new sources of flexibility and supporting such sources to act on such markets competitively. By means of a prototype aggregation solution and renewable generation forecasting techniques, flexibility providers – distributed generation (DG) and commercial and industrial consumers (C&I) providing demand response (DR) – are enabled, to participate on the aFRR market with participation in the portfolio for Frequency Restoration Reserve (including secondary control activated with a response time between 30 seconds and 15 minutes). Retailers act as flexibility aggregators and pool the resource in order to provide the products required by the TSO. A comprehensive techno-economic model for the cross-border integration of such services involves a common activation function (CAFx) tailored to deal with congested borders and optimized to overcome critical intra-regional barriers. The resulting CAFx is implemented into a prototype Regional Balancing and Redispatching Platform, securely integrated within the four TSOs' IT systems: this makes research activities about cross-border integration flexible while linking with the aggregation solution. Use cases of growing complexity are pilot-tested, going from the involvement of DR and DG into national balancing markets to cross-border competition between flexibility providers. Based on experiences with mFRR, participating C&I consumers and DG are expected to provide between 30MW and 45MWof aFRR. Impact analyses of the pilot tests together with dissemination activities towards all the stakeholders of the electricity value chain will recommend business models and deployment roadmaps for the most promising use cases, which, in turn, contribute to the practical implementation of the European Balancing Target Model by 2020.

1.1 Project Partners

No	Name	Short name	Country
1	ELES DOO SISTEMSKI OPERATER PRENOSNEGA ELEKTROENERGETSKEGA OMREZJA	ELES, d.o.o.	Slovenia
2	AUSTRIAN POWER GRID AG	APG	Austria
3	MAVIR MAGYAR VILLAMOSENERGIA-IPARI ATVITELI RENDSZERIRANYITO ZARTKORUEN MUKODO RESZVENYTARSASAG	MAVIR ZRT	Hungary
4	COMPANIA NATIONALA DE TRANSPORT ALENERGIEI ELECTRICE TRANSELECTRICA SA	TRANS	Romania
5	ELEKTROINSTITUT MILAN VIDMAR	EIMV	Slovenia
6	ELEKTROENERGETSKI KOORDINACIONI CENTAR DOO	EKC	Serbia
7	ELEKTRO ENERGIJA, PODJETJE ZA PRODAJO ELEKTRIKE IN DRUGIH ENERGENTOV, SVETOVANJE IN STORITVE, D.O.O.	EE	Slovenia
8	GEN-I, TRGOVANJE IN PRODAJA ELEKTRICNE ENERGIJE, D.O.O.	GEN-I, d.o.o.	Slovenia
9	SAP SE	SAP SE	Germany
10	CYBERGRID GMBH	CYBERGRID	Austria
11	GEMALTO SA	GTO	France
12	3E NV	3E	Belgium

Table 1: The list of FutureFlow project partners

2 Introduction: the FutureFlow project

The sheer increase of electricity generation from renewable sources in many European regions has determined on one side an accelerating movement towards the decarbonisation of electricity generation but has also created increasing issues to the system operators and to market actors with classical, large thermal power plants. Both grid and conventional generation have been facing increasing hurdles to manage volatile energy flows without being in condition to determine duly in advance their operational security limits and the generation capacity to be reserved for balancing and redispatching purposes. As a direct consequence, the cost of redispatching actions has become dramatically high in several Central European countries.

Despite the attempt of creating markets for these grid related services, costs are still largely translated to final consumers, instead of being allocated to those causing them. The widening gap between expectations (cheaper energy produced via renewable energy resources) and reality (higher bills due to the increasing operational costs, or “system service charges”, for transmission and distribution system operators) is pushing many grid users to evaluate “grid-independent” forms of supply, often without appreciating the fundamental role that system operators have when it comes to system frequency control and maintenance of the dedicated assets. The role of TSOs remains therefore central but in order to secure this role throughout the long process of the electricity transition towards a largely decarbonized system, research and innovation activities are needed to ensure that consumers and distributed generators can be placed in condition to provide balancing and redispatching services, within an attractive business environment.

It is in this complex framework that FutureFlow targets the design and the pilot test of comprehensive techno-economic models for open and non-discriminatory access of advanced consumers and distributed generators to a regional platform for ancillary/balancing and redispatching services. FutureFlow lays down the case for several success stories:

- industrial consumers and distributed generators can learn how to leverage on their production assets to reduce energy costs and increase their capital turnover,
- Aggregators can expand their potential customers' base, disposing of a concrete case to justify their business and opening new business opportunities into unexploited value pools;
- TSOs can extract the maximum system flexibility they need on a cross border, gathering much deeper insight into their system capabilities and learn further how to plan with advanced techniques the operational security of the future electricity system. FutureFlow will create more competition in reserve markets, a potential decrease in the total volume of contracted operational reserves and more efficient (technical and economic) congestion management.

The FutureFlow project is expanding its scope of operation of so-called secondary frequency control from generation to consumption and will provide for the international performance of such activities. With this goal in mind, the partners of the FutureFlow project are exploring new solutions for balancing the electricity system and managing flows in the European electricity network. The progressive consumers addressed by the FutureFlow project will be capable of increasing or reducing their consumption in a few seconds and will in this way be performing functions that are predominantly carried out by traditional, hydro or thermal power plants.

As a development project, FutureFlow will not remain solely on the level of scientific contributions. The results of its work will include prototype solutions which industry can also apply in the real economy after the project's conclusion.

The Figure 1 below illustrates the functional interactions between the prototype flexibility aggregation platforms and the prototype regional balancing and re-dispatching platform as the central point for the cross-border and other transmission system operators (TSO) oriented businesses. The field tests with real energy customers and distributed generation owners aim show the synergetic benefits from the collaboration of such commercial and industrial (C&I) consumers, prosumers and distributed generators in frequency restoration reserve markets combined with the cross-border integration of such markets. FutureFlow also intends to analyse the scalability and replicability potential at European level of the most promising tested use cases as designed for the four involved countries.

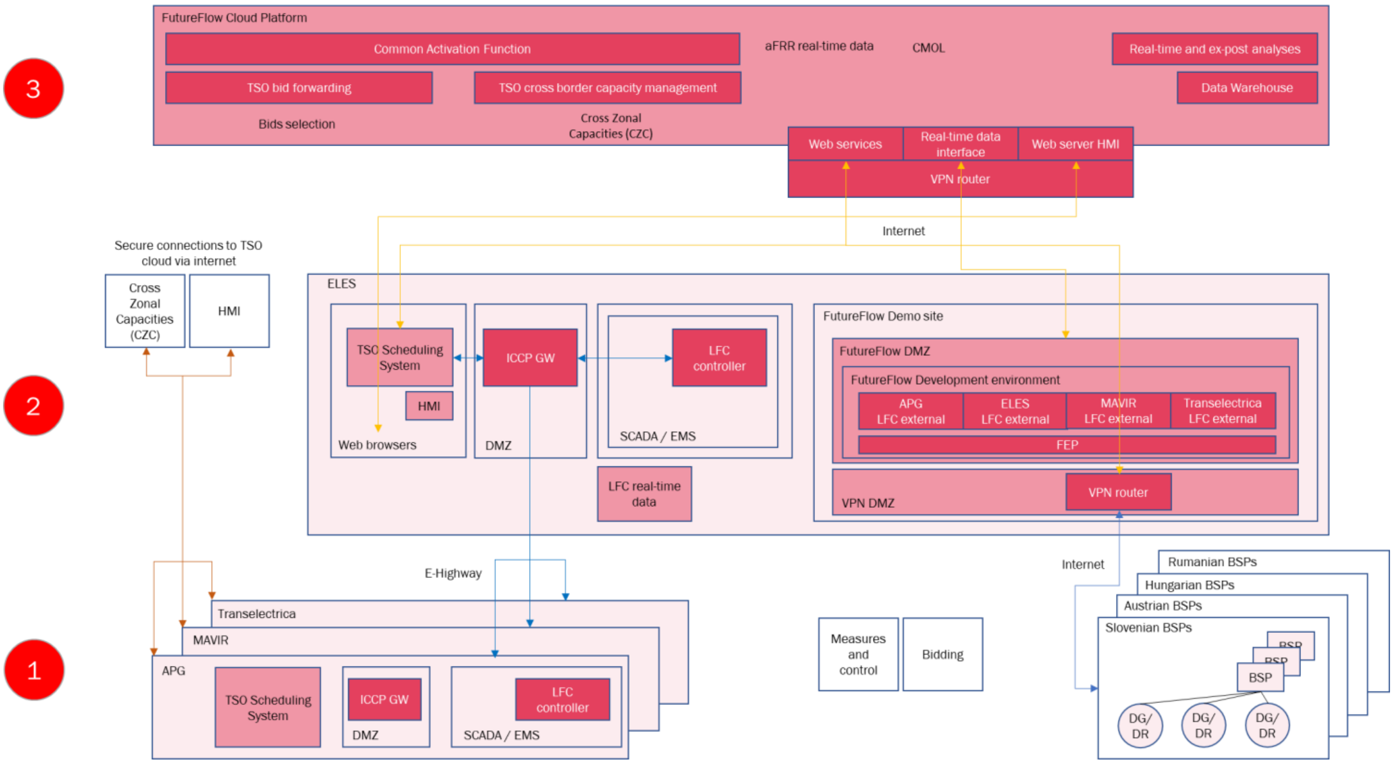

Figure 1: The high-level architecture of FutureFlow

The different levels of system integration are described by the red dotted numbers on the right of the picture:

1. The lower level, indicated by number one, reports the local schemes and a high-level representation of a generic BSP, aggregating distributed generation and/or demand response in specific TSO control areas (the example is provided for Slovenia but, generalizing, can correspond to any of the four control zones participating to the project).
2. The middle level, indicated by number two, is the demo site, a fully functioning solution implemented by EIMV to allow a full-sized simulation about how to prepare the DR&DG bids to be activated, how the system will behave once DR&DG will be activated, so that actual activations are possible, without the hurdles posed by prequalification barriers. The optimization itself is located into the optimization platform at level 1 above.
3. The higher level, indicated with number three the production platform, represents the cloud-based platform integrated by SAP. This platform pulls together the information calculated by from the TSOs about Cross-Zonal Capacities (CZC), the Common Merit Order List (CMOL) so to allow TSOs selecting the most economically efficient bids for aFRR activation a redispatching actions via the Common Activation Function (CAFx) developed by EKC and tested in the demo site by EIMV.

3 Scope of the project and of its exploitable results

The project has been targeting several classes of market stakeholders.

3.1 TSO and NRAs

FutureFlow is addressing several hot topics for which TSOs have not yet been able to define solid outcomes.

3.1.1 Integration of renewables into balancing markets

The test runs in the framework of FutureFlow have been proving that Demand Response (DR) and Distributed Generation (DG) units can provide balancing services, such as automatic Frequency Restoration Reserve (aFRR), not only in regular operating conditions but even (and in particular) when the system is under stress. In these cases, the available DG&DR volumes are capable of driving down prices, far from balancing market price caps. This has proven the ability of industrial technologies to be as well as the conventional generation for the participation in aFRR markets.

3.1.2 Establishment of regional/EU wide markets for cross-border exchange of balancing and redispatching services

FutureFlow has been aggregating the electric power systems under the control of four TSOs. Each of these systems is different from others in terms of their size, market maturity, amount of flexibility resources for balancing services and redispatch. These four TSOs have been implementing a Regional Balancing Platform with Common Activation Function for cross-border exchange of aFRR and redispatch services, relying on a dedicated solution for combining and coordinating their area control signals (ACEs). Adding to the flexibility volume traditionally delivered conventional power plants, the participation of demand-side response and distributed generation to the future joint procurement process and to the regional activation platform has paved the way for new flexibility providers on a wider scale. The four TSOs have been demonstrating benefits for its own electric power systems, prosumers, as well as for broader TSO community with field pilot tests of increasing complexity.

3.1.3 Grid Security

In the environment with significant influence of Renewable Energy Sources (RES), the concern of grid security has been growing. Despite the support of Regional Security Centres (RSC), the day-to-day assessment of the security margin requires additional information for a more reliable assessment of how the system will behave the day after. FutureFlow has been establishing a very strong link between Grid

Security, Consumers and RES, thus letting the TSO access the information related to distributed generation and demand side response, until now brought into the calculation only as estimates. Consumers, instead of being passive observers become, as any mature balance service provider, the guardians of the Power System.

3.1.4 Implementation of regulatory policies

FutureFlow has been creating the sound preconditions for a more extensive debate about the role and the responsibility of distributed generation and demand side response in the electricity market and in the assessment of the grid security conditions by TSOs. FutureFlow has been leaving the usual track of the classical balancing products for fast reaction to disturbances and system frequency restoration to explore new solutions for new, suitable products to face the challenge of integrating increasing volatile volumes of renewable power. These new products have been defined and tested with the aim of searching and testing which product and its characteristics fit most for distributed generation and demand side response.

3.2 Industrial target groups

Opening a direct communication channel between distributed generation and the fundamental signal that the TSOs are using to manage the system frequency (the ACE) brings the cyber security issues at the centre of the scene. It is of paramount importance that the extreme security standards that TSOs are applying to their communication with power plants to activate and steer centrally the procured operational reserve is still delivered under the maximum-security standards. If this would be breached – and the risk increases as the number of points involved in the balancing service provision grows, the damage might be catastrophic for the system security, increasing exponentially the risks of wide scale blackouts. The whole aFRR information value chain, from field units up to the market, needs to be sufficiently secured against attacks and fraud. An innovative approach is being led by Gemalto, setting new standards in this domain.

Besides cybersecurity, the integration of balancing markets is recognized to be one of the most important facilitators of the successful renewables' integration and to the achievement of a fully coupled European electricity market. SAP has been leading the development of a HANA Cloud based aFRR regional platform, allowing seamless exchange of biding information between TSOs, conventional players and new market players like aggregators, renewables, storage operators and any other flexibility provider.

It has been then necessary to interface this cloud-based aFRR regional platform with the TSO SCADA system, which have been extended to cope with the capability of finding balancing and redispatch resources on a much wider and system-deep scale than before. As it appears from Figure 1, the connection was established only between the platform and the SCADA of ELES; the other TSOs SCADAs were connected in cascade to the Slovenian TSO's. This has been producing the same results as for a parallel connection though being still a suboptimal solution. New modules are being developed and have been tested against different use cases by the four partnering TSOs. These innovative modules will in the future become a standard feature of advanced SCADA systems for the TSOs, integrating additional feeding signals to improve the quality of their system control signal.

But extending the TSOs systems has not been enough to grant the targeted increase of service level from all available resources. The other side of the medal, i.e. the flexibility platforms used by retailers or independent aggregators to pool flexible loads, renewables, distributed generation, storage and other flexibility providers to deliver tertiary (cold) reserve, needed to be adapted to become capable of delivering the regulating power to the TSO systems. New DR&DG aFRR aggregation platform modules have been developed by cyberGRID and 3E, with a clear objective to enable alternative distributed resources to become a secure and reliable asset for aFRR provision.

3.3 Prosumers

Real consumers and producers (prosumers) of electrical energy have been invited to collaborate in FutureFlow as flexibility power test providers.

The actual prosumers have had the possibility to learn and to prepare for the future market developments, not only on the national but also on the regional level. By including their staff in FutureFlow project, parties interested in the delivery of demand side response and owners of distributed generation have been not only raising their theoretical knowledge or gathering informative awareness on balancing services, but have also won practical skills of operating flexible technical units under balancing market rules. The industrial prosumers have been benefitting from the interaction with the aggregator member of the project pool, identifying clearly their technical and technological constraints and assessing their overall readiness for participating in the FutureFlow envisaged balancing market environment. After only a few months, the very tight collaboration between energy agents and prosumers has been already delivering promising results.

The prosumers interested in joining the results of FutureFlow will be able to learn from the experiences of pilot participants, which will be published on the project website.

3.4 IT industries

IT is a game changer in business nowadays and can make the difference between staying on the brink of innovation and being a follower. The FutureFlow project has been offering a great opportunity for the energy industry to disrupt the electricity market structure with value-adding opportunities that reflect in overall social welfare, sustainability for energy producers, stability of the energy grids and improved service for the customers.

With its extensive experience in Big Data management and cloud projects, SAP has been bringing to FutureFlow a new infrastructure for data and analytics – HANA Cloud Platform (HCP) – that is reliable, powerful and highly scalable. HCP in an open platform-as-a-service that provides unique in-memory database and application services that enables the rapid deployment of new applications or the extension of SAP applications in the cloud.

HCP is already used by thousands of clients, mostly operating in the automotive, retail, healthcare, chemicals, high tech, utilities and oil and gas industries.

4 Contribution of project parties

4.1 EIMV

EIMV has been dealing with three key topics:

1. How to prequalify distributed generation and demand side response for the provision of aFRR services.
2. The "Envelope": Design of new criteria for the performance analyses of demand response and distributed generation response to CAFx orders for the delivery of aFRR services.
3. DEMOx side: This is a demo architecture, designed to minimize impact on TSO real-time functions and tools due to the needs of the project. EIMV designed digital twins of each TSO and a digital model of each power plant in the four countries region. This led to the core simulation system that was then connected in the final stage to the production platform. This latter sends information to the cloud system and the VPPs. The ACE control is then integrated with their response to account all power delivered by distributed resources. The platform provides support for the practical simulations and can be used as a simulation platform for new TSO, that want to join the region, or new type of flexibility to include, new market models to test.

4.1.1 Prequalification of distributed generation and demand side

Prequalification has been recognized as a complicated issue, as it has been in several other circumstances in the past, especially in relation to the baselining on the demand side.

EIMV has been developing the simulation tool called DEMOx, which has at its heart the model for the optimization procedure for the use of the available resources. This platform allows a full-sized simulation about how to prepare the DR&DG bids to be activated, how the system will behave once DR&DG will be activated, so that actual activations are possible, without the hurdles posed by prequalification barriers. The optimization itself is located into the optimization platform, which is an out frame (developed by SAP). The choice was done after many simulations done to select the target model.

The testing of the VPP models has been done with real units – which then worked as full BSPs: the unit went through the usual prequalification procedure, looking particularly to the unit FAT and gradient. Furthermore, a dry-run test was run just to see how the unit responded.

Once the units were virtually prequalified in FutureFlow, they went to more complex tests in the pilot project, which were run by GEN-I in cooperation with the flexibility providers.

4.1.2 Design and development of the Envelope concept

The present approach to evaluate the delivery performance of aFRR balancing energy from BSP is based on two methodologies:

1. Searching for special events in which set point was constant for a prolonged time (usually several minutes), then changed to another constant value which is kept for long time period again (another several minutes usually). Namely, it is well known what BSP response is acceptable in such cases. As shown in Figure 2, acceptable response is depicted with grey area, with full activation time of 5 minutes and maximal response time up to 1 minute. Overswing tolerance (allowed exceed of delivered product over set point) varies in 5 minutes interval from 10% of change of power to 5% of offered power.

   This first approach is applicable to the cases where set-point changes rarely (e.g. several minutes). However, when set point changes frequently (e.g. every 2 seconds), this method doesn't provide insight into quality balancing product delivery by BSP and can't be utilized for such use cases.

2. Computing amount of produced energy if BSP would operate exactly on set point time series and comparing it to the measured amount of energy over longer periods of time (e.g. 15 minutes). If the difference between these two values is under an acceptable range, the delivered energy is paid as bid or as marginal price.

This second approach is simple for implementation but doesn't provide satisfying accuracy. This method lacks any acceptable tolerance on one side (amount of energy is computed exactly from set points) and everything is averaged over very long time periods with no details, so all shorter time violations (even very severe ones) of operation could get annulated if half of them is positive and another half negative. With such low accuracy, numerous violations of product delivery can't be detected.

EIMV has developed a novel approach with an envelope (interval of variations during time) of acceptable power (lower and upper bound) around set points, which is computed at all points in time where set points are sent to BSP — at every optimization cycle, usually every 2 seconds. In practice, this solution creates on one side a "tolerance" band around the set-points and makes sure that the counting of activated energy does not necessarily starts from the very initial instant after the activation order (which is unrealistic due to the physics of the system) and on the other side prevents that frequent activations up and down are not causing set-point deviations which, due to their opposite sign, are netting out with each other and therefore are not detected as scheduling violations. The algorithm is considering general tolerance, maximal response time, full activation time and overswing tolerance at every change of a set point which may be completely arbitrary at every optimization cycle. All considering quantities are parametric. In a specific user case, EIMV has recorded a used 5% general tolerance, 1 minute of maximal response time, 5 minutes of full activation time and 10% of change of overswing tolerance. With this envelope, it is possible to validate if a BSP is inside of an envelope or to precisely evaluate violation[1] of product delivery (when measured P arrives outside the area bounded by the envelope.

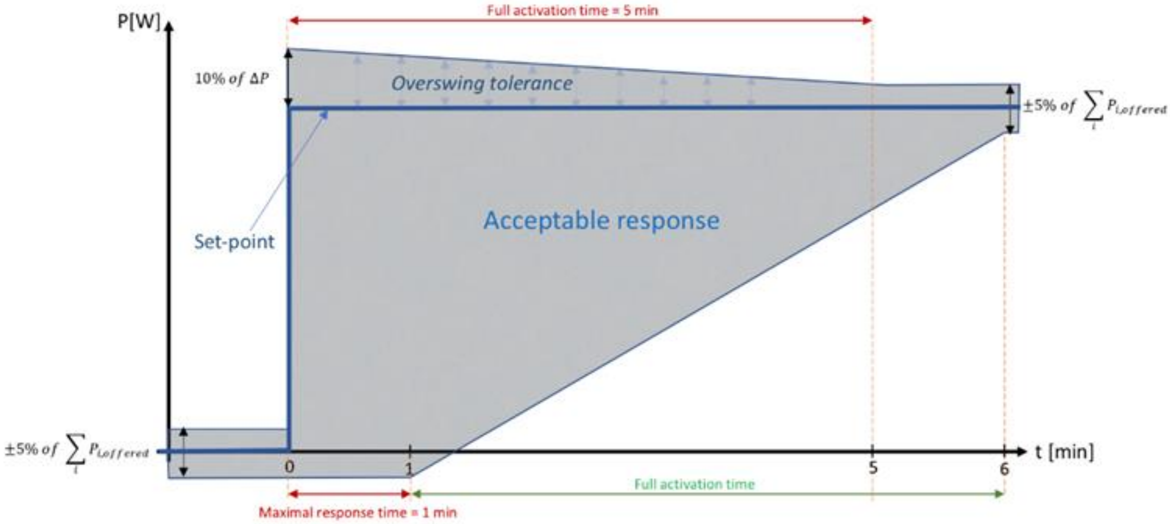

Figure 2: the tolerance band described in terms of power as function of the activation time

EIMV has successfully implemented an evaluation of four actual BSPs using real demand response and distributed generation in four different control zones, operating in an actual environment in real-time. Two examples of envelope determination for different set point signals are given in the figures below.

Figure 3: Envelope determination for fast-changing set-points (steps)

Figure 3 represents the use case when set point changes suddenly in steps. It can be observed that the

[1] "Violation" is defined as a difference between measured active power and calculated envelope.

proposed method accurately follows such intensive set-point changes.

Figure 4: Envelope determination for smooth changes in set points (without step changes)

In Figure 4, the proposed method easily follows the dynamics of smoothly set-point changes. The two showed use cases are boundary cases that are seen in the practice of balancing product activation.

The envelope has been determined based on several recorded inputs, and it allows a precise tracking how the provision was performed. Model build by EKC and EIMV put in real time loop produced bids, and the signal was sent to the VPPs. EIMV has been simulating the responses to the FRR set point values, looking at the operation parameters, chosen from one time series (for the test performed when platform fully upgraded). Looking at TSOs, open loop ACE has been recorded on one month of data and based on this time series the controller produced control demand, a mirror signal for open loop ACE. After that, the controller was in the condition to also calculate the correction due to imbalance netting and cross border flows. The assessment has been done for each technology, the respective response has been analysed and it was determined when the response was not following set point correctly.

4.1.3 The DEMOx platform model

The structure of the model for the ACE optimization process is described in the picture below:

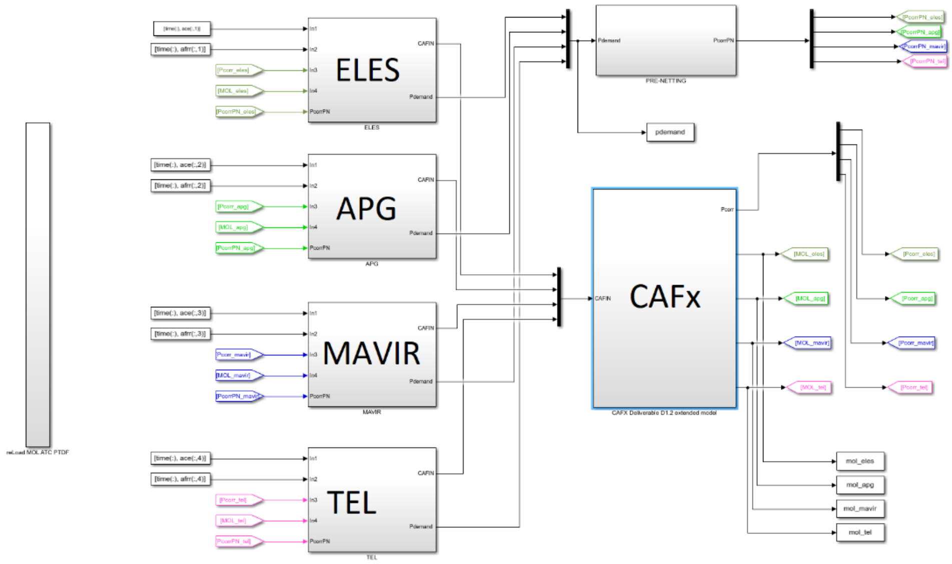

Figure 5: The location of CAFx module within the DEMOx module program

The simulation model has been developed in Simulink: on the left side, there are the four boxes representing the four TSOs, and on the right the Common Activation Function. Time series were transmitted onto these lines. Time series of ACES are processed for month or weeks in 2s granularity. The signal comes from the left to the right. TSOs are in an operating point, and they have a certain response going into the marketplace, i.e. the Common Activation Function: bids are selected and passed onto to TSOs for their activation, while new bids are received to create an updated CMOL into the marketplace.

As for input of models, Open loop ACE as if there is no regulation, for day week or months and with the granularity of 4 sec max. Bids can be positive to regulate upwards or negative for regulating downward. Standard execution is requested with a FAT of 5 minutes: if a generating unit can do that only on a longer time-lapse (e.g. 15 minutes), this belongs to another, in terms of flexibility less valuable category of balancing resources. A TSO can declare to be ready to accept only standard bids or it can accept also specific bids, i.e. bids that are not configured according to the standard TSO specifications for balancing products. If standard bids are the only bids accepted, the market is supported by a lower market liquidity and, even if the maximum possible amount of resources delivering aFRR participates to the market, the resulting regulating signal might not be as good as all bids were accepted.

Each TSO is then characterized by two subsystems: a first part is a PI controller of each TSO, producing a setup point for the units of this TSO domestically, delivering information for a first order response by receiving a response of real units to a real set point order. The power correction signal is introduced by the Common Activation Function market unit and indicates how the open loop control should change due to the orders processed by the Common Activation Function. The second part accounts for the Imbalance netting signal in the signal processing, so to consider the correction on the control signal introduced by already existing mechanisms at EU level. It is important to notice that the model can keep under control the level of imbalance netting and ensures that the minimum cost is really achieved. Additionally, some variants for pricing have been introduced as marginal prices for zones and total, while special bids have been tested in not all cases.

EIMV has been paying time and attention for the selection of the target model and the specific bids, because it was clear from the very beginning that the achievement of these features would have been a key to support testing of the possible broadest set of cases being confident of the model reliability in the background.

The CMOL which serves as database for the CAFx presents offers to the TSOs which are – as input - always priced positively. After the activation, the FutureFlow platform regulates the cash flow associated to the balancing energy provision by the providers: in this case output prices can be positive or negative. If the price is negative, the balancing energy provider has been producing less and therefore pays to the FutureFlow platform what he saves. The CMOL has been created for offers in both senses of regulation, i.e. for upward and for downward offers and bids are jointly dealt in the same list.

The CAFx is also the place where the activation of BSP offers takes place, the systems balancing requirement to correct the ACE is calculated every 2 s and it takes just 20 ms to find a solution for the selection of the most appropriated offer at every refresh of the ACE correction requirement. On one side this allows to maximize social welfare, while respecting technical limits – as the power plants technical boundaries or the cross-zonal capacities. Accounting also for the imbalance netting when two countries are in opposite balancing positions helps to minimize the effort to operate into the technical system boundaries. The mathematical description has not been included in detail into the EMVI report, but it is available in the project material dedicated to the design of the control signal modelling. Finally, it must be noted that the underlying grid model can handle indifferently ATC or Flow-based capacity allocation methodologies.

As mentioned, another CAFx platform feature consists in its ability to handle specific and standard offers: this can be handled via a two-layer organization, on one only standard bid are accounted, and on the other special bids are retained. In order to make the most opportune selection between the two sets of bids at every iteration (2 ms) it was necessary to increase the complexity of the mathematical model in the background so to let Simulink model proceed with the optimal choice.

The issues met during the testing phase have highlighted the need for aggregators to know the business process of their customers to be in the condition to predict unexpected fluctuations. Beyond these, other issues were scrutinized: for instance, the settings of LF controller have also been analysed so to improve the quality of the modelled system control signal, when power fluctuations are occurring. The set point changes continuously but the prequalification has a much more stable signal, changes every 15 min. Measurements from VPPs have been used to model how the average VPP will respond from the variation of set point, and they were fed into a model that elaborated the respective response. Unfortunately, this has been dealt with only as a test, having a response from actual DR/DGs would have been the ideal form of modelling, but data are BSP owned so not extensively usable.

Weather forecasts are presently managed by VPP operators to build the portfolio for the bids and predict response of their units, but they could also be integrated as input to increase the model predicting capability for TSOs. Having wind/solar/hydro plants and their location, it is possible to use weather data or river hydrology to run a mixed-linear algorithm and to “pre-select” bids for the activation periods beyond the closest upcoming one. The solution allows to solve also the energy disaggregation problem and assess what are the consumers operate behind the meter.

4.2 EKC

EKC has been responsible for the delivery of four exploitable results.

4.2.1 Testing the Model for the Common Activation Function

In this task, EKC has been supporting EIMV to ensure that the CAFx mathematic was designed so to be in the condition to cover the general purpose aFRR target model. In particular, EKC has been delivering support for the development of the methodological approach and the know-how base to assist the programming teams to develop the CAFx software solution so to let it be used as a knowledge and experience database to support similar processes across Europe and in other regions. The value of the knowledge base is justified by the fact that every region has specific features characterizing the local balancing portfolio, which evolves over time embedding new technologies for generation or, more in general, to respond to market price evolutions. In case of larger time gaps between the balancing projects, applied approach and solutions might become outdated; therefore, constant upgrades and improvements needs to be considered.

4.2.2 Areas of improvement and possible alternative applications

Possible other application are difficult to find out of the transmission system business, but despite this, interesting material can be gathered in other initiatives where TSOs are working already on the basis of another algorithm based on the nodal network representation, supporting the fast activation of reserve not triggered by LF controller but by the operational reserve price difference. The cross-border capacity granting the cross-border exchange of balancing energy transits on the total reliability margin/residual available margin and not on ATC/part of the critical lines allocated to market flows. This solution is of course for the use of cross-border capacity to exchange flexibility at the last moment.

Before this, however, a more immediate application of the solution could consist in delivering concrete support to the Cross-Zonal Calculation refresh. In order to make the entire FutureFlow solution adherent to the physical reaction of the grid once the reserve is activated, the CZC should be recalculated accordingly, so to increase the visibility of how border capacity modifies to accommodate cross-zonal flows resulting from the balancing activation. In this respect, the CAFx can be used as a forecasting tool for CZC values, if the CAFx is embedded into the regional security analysis so to assess the effect of all possible balancing offers which might access the grid on the basis of an economic merit order. With the support of some artificial intelligence, relying on an increasing historical database of bids and offers and of the correlation with their impact on cross zonal flows, it could be possible to increase the reliability of the operational security calculation while increasing the speed of recalculation for CZC.

4.2.3 Power flow colouring (PFC) methodology

The FutureFlow project has launched an innovative methodology for the decomposition of power flows called Power Flow Colouring (PFC). The main idea behind the PFC was to determine total flow components (loop flows, internal flows, exchange flows, transit flows, and PST flows) with the essential information on their sources.

The PFC methodology is suitable for establishing the cost-share principle, i.e. determine the responsibility of each control area for causing overloading on a line in the system. In that sense, as a constituent part of the redispatching platform, it could be used for sharing of costs among TSOs who provided redispatching and those who caused it.

The PFC methodology is based on the nodal Power Transfer Distribution Factors (PTDFs) and injections/withdrawals to which network losses are added. Its essence represents the superposition principle, i.e. division of the starting model to the “balanced model” (containing only internal/loop flows) where balancing takes into account area’s net position, and the “model with exchanges” (containing export/import and transit flows), where electrical distance principle is applied for the determination of source-sink pairs PFC decomposition method is currently in discussion between European TSOs to be selected as a possible mean to allow for allocation of the total redispatching costs among European bidding zones. In such a way, method could be applied with the goal to fulfil legal requirements imposed to TSOs and related to the implementation of electricity network codes and guidelines.

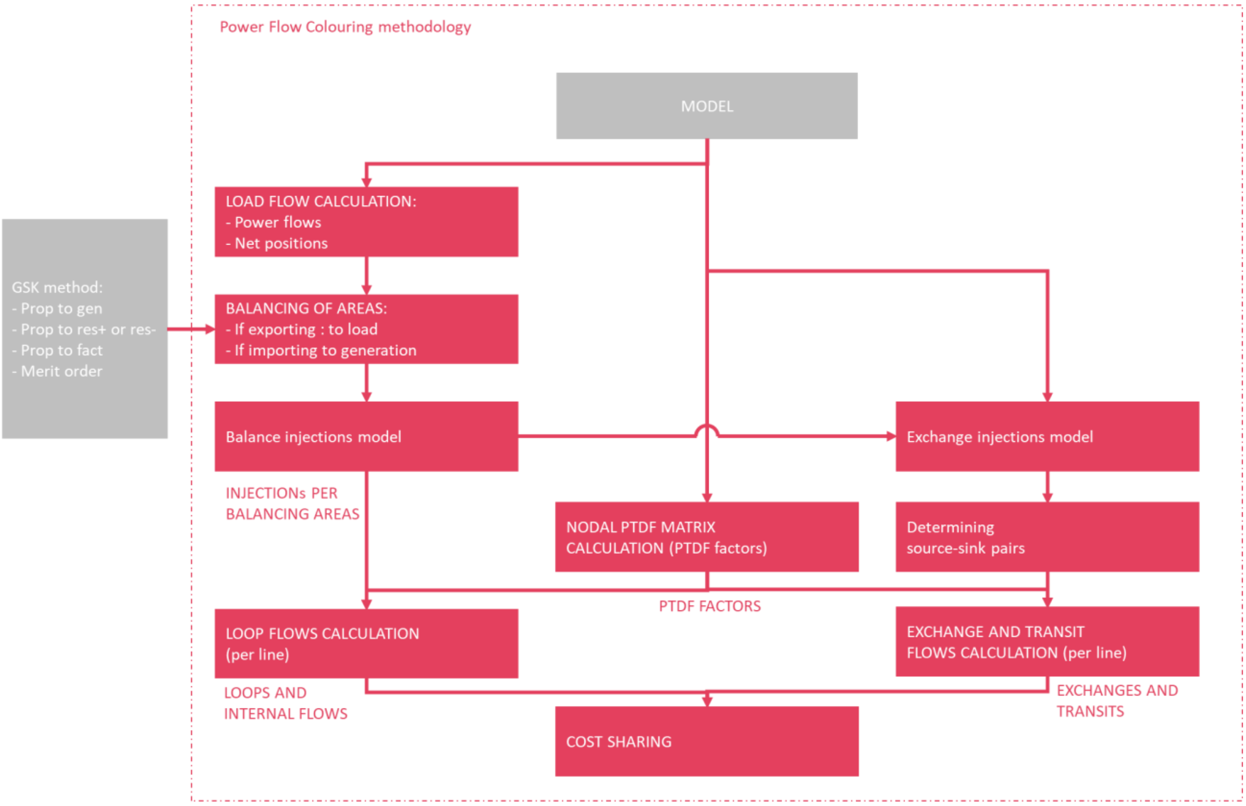

Figure 6: The methodology of the power flow colouring

4.2.4 A method for empirical analysis and tuning of the target model for cross-border aFRR exchange

The main objective of the analysis of balancing aFRR energy exchange integration options is to decide which model of cooperation among the available Integration Cases must be analysed and what should be implemented as a solution for the FutureFlow project. The choice should be reached by an analysis of the impact of all FutureFlow models on ACE control quality performance and other relevant KPIs.

During the selection of a target model, the technical performances (such as ACE quality) are evaluated numerically, while also other indicators are considered qualitatively, such as aFRR market liquidity, the complexity of implementation, volatility, etc.

EKC has been providing the project with a methodological approach for the empirical analysis and the fine-tuning of the target model for cross-border aFRR exchange, partially already correlated with the indications provided to this purpose by the European target aFRR model (PICASSO), so to dispose of a solution to be integrated into to it in an early stage. Since aFRR exchange and target model are alive processes and further fine tunings can be expected after more experience take place, the simulation approach exercised within the FutureFlow can further contribute to the stakeholders (TSOs, ENTSOE, RSCs, NRA, ACER, BSPs) in continuation of these processes.

The concrete case analysed in Deliverable D1.4 of the FutureFlow assumes three potential integration cases, and two definitions of Cross Zonal Capacity and Redispatching common optimization function (RCOF). The idea consists in the development of an algorithm for cross border redispatch going at nodal definition, based on their network location based on PTDF produced on congested branches in combination with their offers. As expected, the quality of results has been increasing considering larger regions and a higher number of BSPs. For redispatching, the CMOL accounts also for the nodal position and the geographical location of the offer (i.e. in which control zone it is located) and not only for the economic offer. The algorithm selects the optimal option in economic terms as the maximum possible response in MW for the minimum cost. Markets are however simulated independently from each other, and they can be kept separated. In each of local market, participants can provide tertiary control bids plus redispatching.

4.3 SAP

SAP integrated the FutureFlow platforms covering three main areas:

1. Operational real time balancing platform,
2. Redispatch simulation and
3. Data warehouse.

Concerning the first platform, in the cloud the main component is the CAFx platform where received bids are selected and consequently activated so to reduce the imbalance at min costs. To do this, CAFx module is using the bids as options at a specific expected earned price. CZC also in scope and are accounted as boundary conditions. The optimization scenarios are calculated at regional level. Connection capacity between the four countries are made available by TSOs but are kept as they have been calculated for the day ahead market, so with no intraday refreshing. This sets the scene for the real bidding process.

When bids are received, and every awarded power plant keeps ready for activation. Several VPP models have been developed by cyberGRID and implemented on-field by GEN-I, creating a vast database of models and references which has as well been integrated by SAP in the FutureFlow external shell framework. The extendibility of the geographical perimeter is possible, and each platform allows the inclusion of other borders.

Multiple platforms have been developed in FutureFlow, SAP has been creating the framework to integrate all them and to pass into the production phase.

As an example, let's assume that, during the hours 14-15, for a VPP there is the possibility to ramp up to 100 MW at €10/MWh. The Bid aggregation platform passes the aggregated bid to DEMOx. Then bid goes to FutureFlow cloud platform for Regional balancing process. Now it is 14:15: in a 2 second cycle, the decision is taken to use this bid in AT. FutureFlow cloud platform decides then to generate an upward ramp of 50 MW. The decision is sent from FutureFlow cloud platform to FutureFlow DEMOx and then to FutureFlow bid aggregator platform, and then further down to the power plant to be activated. All decisions are separated from each other, therefore there is no monitoring of what happens into the other platform: this means that the cloud takes just an economic decision, but the technical activation is sited into the CAFx.

From the aggregation platform, the bids are going to DEMOx which is a replication of TSO system: this choice has been dictated by the TSOs requirement to avoid direct interaction with LFC controller in the testing phase. This DEMOx goes to FF cloud, when TSO has an imbalance, the TSO goes to the platform where all information is stored, and the FFCP then calculates the optimal activation and sends back the information for optimal activation.

The use cases designed of the FutureFlow cloud platform have been designated to account for national solution fall-backs and backstops. For example, if the connection between the local frequency controllers and the FutureFlow could platform is interrupted, operational information (bids, activations…) is managed locally.

This function is implemented into the FutureFlow cloud platform. EKC and EIMV are responsible for the mathematical modelling of the balancing activation process. During the first phases, the business connection was particularly strong with EKC for the integration of the mathematical functions, which supported the initial prototyping not only of the DEMO platform but also of the FutureFlow cloud platform. During the implementation, there was a tighter connection with EIMV to choose the tool and make it work and for all integrated testing and specifications, to control the platform response to critical situations occurring like communication failures or timed-out calculations. These interactions were crucial to support the correct implementation of the operational platform. During the entire process, the TSOs were regularly consulted and informed about the development. For optimization, SAP has been using a commercial optimization tools, intended to solve problems formalized in a very specific way. Due to time constraints, SAP decided to take a commercial solver instead of developing an own tool, also relying on the vast choice available on the market allowing solutions for the different process (linear, non-linear…)[2].

Thanks to its capability of processing complex, time-related information, the cloud platform can be reverted also to banking applications (e.g. for taking close-to-delivery decisions in another commodity trading. In the future, the time required to converge on a solution could be further reduced in comparison to the present 0.5-0.6 ms. SAP has been adopting an algorithm which delivers a precise result but applying some heuristic techniques on the case history (i.e. the stored historical activation results, considering also the preliminary situation and the causes determining the activation of specific resources), or, even better, additional analysis led via artificial intelligence, an even quicker response from the CAFx might be feasible.

Now, the automated interface for bids selection is offered by the DEMO side, but in the real solution, there will be a connection between the CAFx and the TSO platforms. TSO can influence this process in real time, seeing bids and freely deciding to remove them from the CMOL for redispatching purposes. In this sense, TSOs can influence the CZCs to change their values, having the possibility to exclude even a complete part of the system from the joint mechanism. The calculation of CZC is a side calculation which derives from the internal TSO processes (national and coordinated via the Regional Security Centres), at a specific gate closure time also CZC must be submitted to complete the dataset required for the calculation of the solution. TSO target solution for CZC can of course have an influence on the balancing process and to the possibility to exploit the flexibility available in the region.

[2] A commercial tool is in general much quicker and respects the time-critical issues without needing an intensive refinement phase.

4.3.1 Areas of improvement and possible alternative applications

The economic analysis accompanying the results generated by the DEMO platform confirm that the significant improvement of the technical performance comes together with an overall reduction of costs for balancing service provision. Possible areas of improvement consist in the implementation of a feedback mechanism might prove the results in the day-to-day practice[3]. Additionally, redundancy for the whole platform should still be introduced so to secure a safe backup in the operational phase, as well as a real time trailer of the delivery, so to ensure that all activated energy has been effectively delivered according to the required ramping profiles.

4.4 cyberGRID

The company is operating as a software provider specializing in the development of the DR&DG platforms (VPP). CyberGRID came to the market in 2013 with their first version of product – cyberNOC, which at that time supported the tertiary (mFRR) reserve processes. cyberGRID has been upgrading its systems so to support FutureFlow goals. These add-ons on the existing software have been bringing additional functionalities to the DR&DG aggregation platform to support also aFRR provision. Three models were implemented to integrate their system for FutureFlow:

1. aFRR activation control module;
2. aFRR real-time communication module;
3. Automatic marginal bidding based on the pool data.

The first module was needed so to make their system in condition to react to TSO activation orders to ramp up or down according to the accepted bids. To do this, the module is checking all available resources in the VPP pool. This calculation, based on the set point from the TSO, is then spread to the aggregated resources so that each part of the VPP can do its required action to deliver the TSO order. The module is also monitoring the response by a closed loop PID algorithm so that in case the response is not following properly the set point from TSO, the set point is corrected or additional resources are added to follow up the TSO request.

The second module supports real-time communication: the cyberGRID monitoring system needed to be able to have real-time measurement from flexibility providers, and be able to send to them set point in real-time, every 2s. GEN-I was responsible for aggregating the signals from the DG&DRs and physically connecting them by installing the RTUs on the providers' facility.

Scalability was also accounted: once the real-time measurement has been introduced, scalability issues could have been emerging so cyberGRID decided to take a different approach, they changed the architecture

[3] It should be noted that feedback loops to prove the effective activation of the balancing orders must cope also with the "envelope" methodology proposed by EIMV as part of its integration work.

and now they can work relying on the scalable horizon without jeopardizing processes and time of execution.

The last module addressed automatic marginal bidding. Every source of flexibility has its own characteristic (time response, maximum output…): the module is into all technical characteristics and then provides suggestions to traders how much of the capacity can be traded on the market for each price. The energy price is constantly refreshed on the trading screens and this is helping the trader to know how and when to bid on the AS market, thus optimizing the value creation of each bid. This process is straightforward when the number of resources to be managed in a portfolio is low, but if the balancing resources portfolio increases in size (both in volume and in number of resources to be managed) it becomes difficult to understand what to activate and at what price[4]. This automatized process will help the trades in their daily business.

In order to make the three modules operate with the rest of the system, many interactions needed to be accounted at a different level of abstraction:

- Have been working closely with the GEN-I, who contracted and wired all the flexibility units (DR&DGs) which were than connected to the local DR&DG aggregation platforms.
- Gemalto provided the thorough security penetration tasting on all levels, to ensure the security of the platforms and the integration with others. On a device level they have provided the demonstration laboratory environment where they demonstrated the beyond state of art technics and accounted all the potential security issues starting from the electrical board manufacturers to the end user.
- More above, they were working with 3E for RES forecasting, which were continuously calculate RES forecasting data based on the different input data, such as: various weather forecast and real-time measurements from the forecasted flexibility assets using different machine learning algorithms.
- On the topmost level, cyberGRID has been working with EIMV and SAP to defined and connect to the central CMOL while proxying via emulated TSOs local AGC centres.
- Finally, on the higher level, a close cooperation with EKC and TSOs was needed to specify the desired model outcomes set as FutureFlow requirements and validate the results.

4.4.1 Areas of improvement and possible alternative applications

Extendibility beyond FRR was also accounted. Considering the whole system managing RR and aFRR and interacting with ID and DAM, a peak shaving functionality was implemented as additional possible offering to the market. The system they can be further scaled to include other resources, as dispatchable RES, or batteries, which were not tested extensively due to the absence of significant capacity for these technologies

[4] Deliverable 6.4.3 provides an extensive description about how specifications are structured.

in the region.

The cyberGRID solution could also help to understand the cost of flexibility on a defined geographical area and how this flexibility can be aggregated to prevent additional investments. Sources of flexibility could be placed on each side of the trace for a new line so that TSO and DSO can understand if is worth to extract additional flexibility or to build a new line by running simply some simulations leveraging on the FutureFlow platform. According to the existing incentive scheme for grid reinforcements, TSO and DSO can help to decide if it is the case to invest in physical assets or to opt for business intelligence.

4.5 GEN-I

GEN-I has been mainly involved in securing the participation of external flex providers, as distributed generators and demand response providers. In this sense, several actions were undertaken to identify the most interesting segments in the distributed generation and on the demand response side to be involved in the experimentation. In order to do so, GEN-I has been going through a thorough analysis of the potential business partners screening through the four countries the sector of distributed generation and each most likely concerned industrial sectors, talking with energy managers, maintenance managers, purchasing officers and other roles involved in supply and operations. Tools to support the identification process have been classical surveys via phone, email and online research so to collect the broadest possible volume of data to define the respective flexibility volume potential and the type of flexibility which could be offered.

Based on this action to define the market depth, it was possible to give the project estimates about the potential for additional flexibility volumes in each system. Other partners have been supporting the action by preparing questions and information requests to be collected from the interviewee, as well as their availability to take part in the experimentations.

The involvement of GEN-I went then further. Once the use cases have been defined and the KPIs for controlling and evaluating the performances of the different tests have been completed, GEN-I has been ensuring that the communications with them was running smoothly among the flexibility provider, the involved TSOs (with the coordination from ELES), the concepts lead (EKC and, predominantly, EIMV) for the CAFx (implemented by SAP), the platform developers (cyberGRID) and it was properly supported by tools and timely reactions. This step has allowed to execute the test cases with the selected external flexibility providers.

All kind and all sizes of power plants have been included in the experimentation (from 8 MW of flexibility availability down to 5 -10 kW of small hydro) that, due to many participants, resulted particularly successful. In terms of technology, all forms of RES were included, from 0.9 to 2 MW, several small hydroelectric plants (largest with an installed power of 1 MW), many diesel engines, natural gas CHP units, biogas fired plants, but also more conventional steam and gas turbines. In Austria, participation reached almost 50 individual customers, with 80 technical units. Some loads have been also integrated, like cooling units of industrial size from a plastic producer or electrolysis plants from a major aluminium production, which provided overall 4 MW flexibility.

Several hurdles were also met:

1. Financial problems: here we have real customers, companies on the market, they were not looking at it as a research, but what they can extract from it financially. Coupling with risks was essential. Funds available were not too motivating to participation. They said that the upside they would have been paying was updated to let the unit work more automatically.
2. Another benefit was oriented to the future. Only when they would have been ready, they might have been available to participate for 6 months or something.
3. Knowledge: for those companies, energy is not the primary source of revenues, they are not concerned too much by energy cost, and all improvements to be done in terms of energy were always the last one to be accounted. It took a lot to keep them motivated.
4. Integration was easy, not too big changes, getting the integration and the integration. Loads such as major lads in the manufacturing industry have been proving to be too challenging in terms of risk related to the interruption of the manufacturing process, so even if there is flex, they don't want to stop the process for avoiding issues related to the quality of their final products.
5. It will take more time to manage these processes to make the processes more automated.

Moreover, in some remote areas, it has been difficult to lay down wired telecommunication lines as well as dispose of sufficiently strong wireless signal to control the VPPs, as hydroid has happened for some remotely located small hydro power plants.

4.5.1 Areas of improvement and possible alternative applications

Crossing the project information with other experiences, it results clear that the industrial customers have difficulties to accept the potential advantage of better energy management of their productive assets. This is mainly because evaluation costs might be considered stranded costs in case the energy usage audit leads to uninteresting results. The effort shall be placed on communication not only from the project promoters but also from the institutions (e.g. ministry of industry) who should encourage such screenings with appropriate incentives.

Additional issues were emerging especially in Romania and Hungary due to the estimated lower industrial development, aged technology, less readiness than elsewhere to acknowledge a value in flexibility, having local manufacturers only focus on the final product than in the side value generated by the interruption of the production process. This confirms the problem with the involvement of the demand side in the market design and the risks associated to the potentially high penalties to be paid in case of marginal imbalance pricing striking back in case of deviations from the schedule – and forces demand side again out of the market.

5 Key features of project results

The figure below illustrates the functional interactions between the prototype flexibility aggregation platforms and the prototype regional balancing and redispatching platform as the central point for the cross-border and other transmission system operators (TSO) oriented businesses. The field tests with real energy customers and distributed generation owners aim show the synergetic benefits from the collaboration of such commercial and industrial (C&I) consumers, prosumers and distributed generators in frequency restoration reserve markets combined with the cross-border integration of such markets. FutureFlow has also analysed the scalability and replicability potential at European level of the most promising tested use cases as designed for the four involved countries.

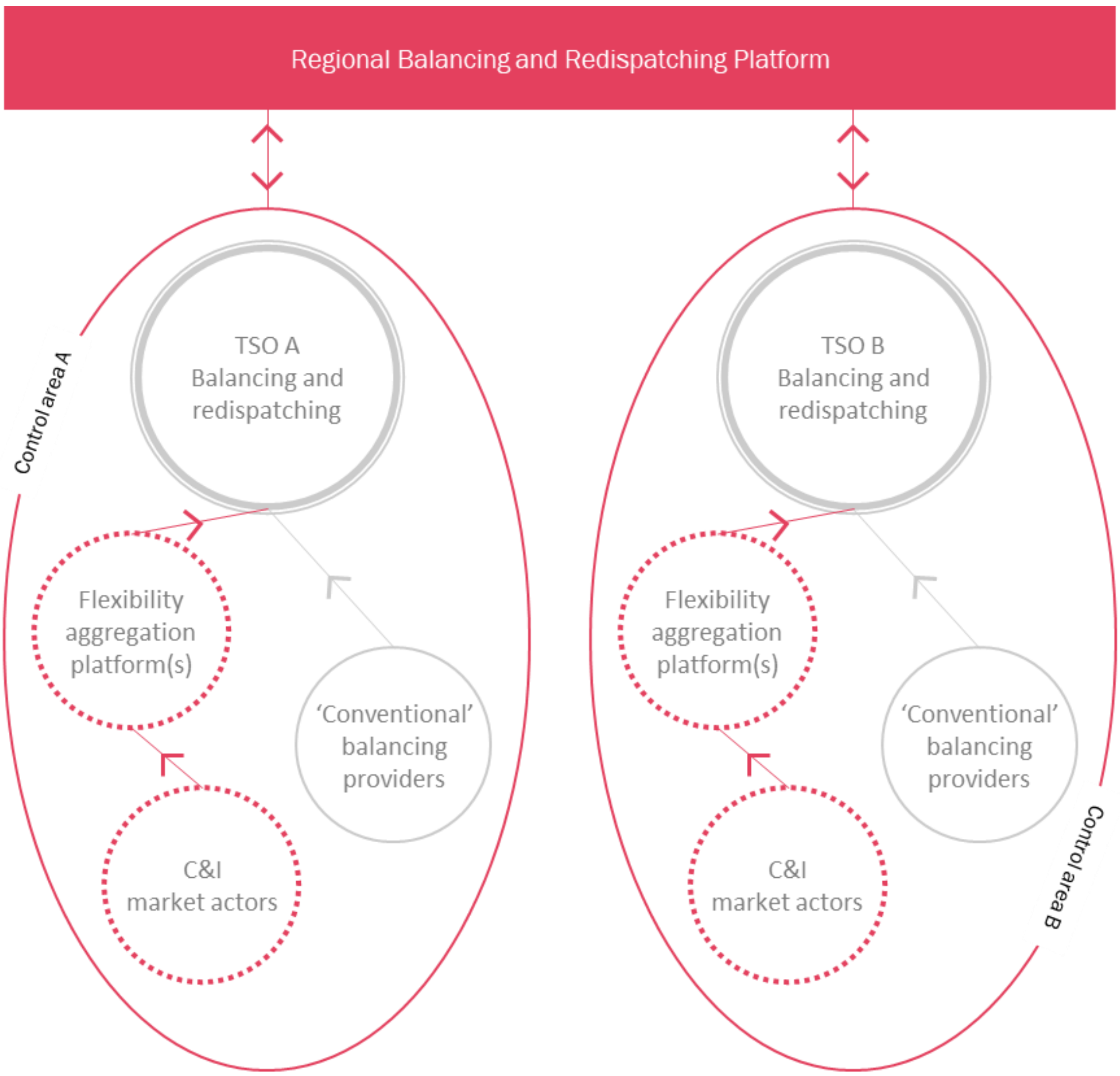

Figure 7: the high-level concept of FutureFlow

6 Value addition to the energy sector

The value addition of FutureFlow spreads all over the electricity market value chain:

- Generators of all sizes have a tool allowing them to offer their balancing energy in market areas different that (or those) where their power plants are installed, thus enhancing their market potential and their opportunities in areas where their flexibility might be more valuable.
- Once their operations are thoroughly understood in terms of thermal inertias and their relation to electricity consumption, industrial prosumers can also leverage on their system flexibility to deliver flexibility to the system, switching off or increasing their electrical consumption according to system needs, thus optimizing their capital turnover and increasing their sales margins.
- System operators can access a much deeper market for balancing and redispatching resources, becoming able to leverage on previously unexploited resources niched at lower voltage level but as valuable as those directly connected to the transmission system for system balancing, congestion resolution and voltage regulation.

7 Conclusions: the strength and the potential of the FutureFlow scenario

FutureFlow has proven to have may merits to the lead to the target model for the internal electricity market to cross the finish line. These credits have been gathered by an extensive theoretical and practical application of the required extensions that TSO have to implement in their system operation processes to embed the response from distributed energy resources (DG and DR) and be able to coordinate their market participation at cross border level and across voltage levels. The project has not only formulated several business cases which can be concretely used in practice but has come to the implementation of the devices and the platforms required for the deployment of the solution at the regional scale, much beyond the overall control zone covered by the four TSOs cooperating into this project.

Notably, FutureFlow has been able to reach five sizeable results:

1. TSOs have conformed their central role for mastering the system frequency: with this project, the high voltage transmission system operators have proven the capability to adapt in concrete their control

scheme on the ACE, integrating their responses to system frequency deviations with a simple logic and leveraging on other, effective solutions adopted at continental scale (PICASSO, IGCC imbalance netting above all). This solution leads the TSOs to reach the ultimate goal to grant direct market access to all balancing resources[5] and, by this, it can confirm its position as the most reliable "frequency manager" also for the future (here: an issue we might be willing to analyse a bit more into details concerns the potential role of the DSOs in the game, if we might be willing to export the model beyond the FF perimeter - I recover the point more below).

2. The electrical energy market would hit the finish line of the proposed target model. The FutureFlow solution can deliver the full visibility on real-time balancing resources, bringing two until now unachieved dimensions of the energy real time delivery to its most advanced state: the almost complete view of the system frequency modulation capability (i.e. its flexibility) for each control area and its integration with the same resources at cross border level. The economic optimization at a geographical scale larger than that of a single TSO by the selection of the most economic bids serving balancing needs on a regional scale delivers the maximum possible "balancing market depth", unlocking the view on the real volume of the available flexibility on the grid and on their pricing.

3. As a direct consequence, the flexibility price becomes the price of electricity reflecting the real value of the commodity. If unconstrained marginal pricing for balancing and imbalances - with no caps and floors - is chosen, the view on the real volume of generation and demand available to modulate the frequency signal allows sending clear market prices about how much and what generation is needed. Few price spikes in a year would indicate a healthy system, while an increasing number of spikes are denouncing a structural lack of generation as their overshoot on the mean prices increases, therefore the need to invest. This might not mean that long term signals for investments are needed, since distortions in market pricing took too long to be removed from the market[6], but wasn't this the energy market economists had been designing 25 years ago?

4. All possible kinds of VPP structures have been modelled and tested. This has created a vast library of business cases and solutions that can be further industrialized for applications in areas where the flexibility potential of e.g. small hydro has been remaining largely untapped, thus allowing the fast and quick inclusion of the VPP flexibility into the market. The tool might also result extremely valuable to all those market actors who have been staying out of the market until now, but might be interested in seizing new opportunities and value pools offered by a further disclosure of the market aces also to providers of limited volumes by the comprehensive and easy-to-access features of FutureFlow.

5. FutureFlow creates the base to eliminate other “elephants in the room” of the electricity market. This project lays down a powerful tool not only for marketing flexibility more efficiently but also to solve other

[5] If all available VPPs will participate regardless the hedging of their production via incentive schemes, together with those loads who might have a specific and intrinsic inertia making the participation to balancing attractive, the real volume of system flexibility would then be revealed, contributing to reach the (almost) complete view of the real frequency modulation potential available within TSO a control area.

[6] It must be recalled that the Clean Energy Package has been completely approved few weeks before the end of this project, in November 2019.

issues which have been part of the workflow of the Regional Coordination Centres, but which have been proving dramatically difficult to solve until now. The definition of the operational security perimeter, a reliable calculation of the cross zonal capacity at high refresh rates and of the system adequacy at mid-term are all problems which require tools working at the same time as magnifying loop to see the system balancing resources in their finest granularity and, at the same time, embrace the largest possible geographical scale for their procurement. These are exactly the core features of FutureFlow, which might help the TSO to identify with extremely higher precision their operating point at extremely high refresh rates, thus raising the potential to increase significantly the cross-border capacity available for the market. The tool might indeed be the ideal platform for launching a precise price zone calculations - with border adapting flexibly to the congestions (no matter if internal or cross-border) for each 10-minutes market terms, the tool for calculating well-rounded cross-border cost allocations for PCI - including also valuation on balancing markets... and many more could come!

Appendix 1 – List of Exploitable results

We recap here below the fifteen major exploitable results reached by the project:

1	**Prequalification test for DR&DG pool (EIMV)**	
	Description	The FutureFlow project is enabling the organization to expand the competence and knowledge in testing and qualifications of the pool of demand response and distributed generation for providing balancing services. The project has been preparing test cases and signals for prequalification of pools of demand response and distributed generation units. The project has been testing this at pilot test level. Furthermore, for the evaluation of activation responses EIMV has developed a balancing energy envelope which has characteristics defined according to the requirements of TSO and aggregator. Test cases, signals and evaluation are adjustable to market needs or requirements. This service would mostly serve TSOs and BSPs. It would verify and demonstrate the potential and ability of small units (DR/DG) or mix of different units to participate in the respective markets.
	Validation BO	The validation of the business opportunity is based on its replication potential. Replication potential is the possibility of realizing a service for testing and qualifying DR/DG across EU member states for aFRR delivery. The service has already been implemented in four different control zones, meaning under four different aFRR regulatory constraints. The service can be adjusted to different market needs and requirements, such as: • signal complexity or/and requirements from TSO/BSP side; • different regulatory constraints for FAT (Full Activation Time); • communication standards requirements. Furthermore, aiming to connect all EU markets, this service can provide recommendations for standardization bodies (possible inclusion into selected ENTSO-E documents) to unify procedures for integrating new balancing resources into energy markets (balancing, AS and energy). The contractors are providing prequalification services for some TSOs, other TSOs provide this service themselves."

	Overcome risks and barriers	The main factor of resistance was offered by the TSO skepticism of integrate additional balancing services by adopting the testing and validation service with measurable benefits in reducing the burden on employees. Another risk which has been overcome was related to the incorrect or/and uncertified measurement technology on loads, also depending on Cooperation with regulators on the field of unification of criteria for measuring devices. Privacy of transmitted data => GDPR, EU legislation Communication failure (one or more generators) => If communication failure occurs during testing period, the testing process is interrupted and restarted after the failure is eliminated

2	**Calculation of the envelope**	
	Description	A novel approach with an envelope (interval of variations during time) of acceptable power (lower and upper bound) around set points, which is computed at all points in time where set points are sent to BSP — at every optimization cycle, usually every 2 seconds. The algorithm is considering general tolerance (depicted in Figure 2.1), maximal response time, full activation time (FAT) and overswing tolerance at every change of a set point which may be completely arbitrary at every optimization cycle. All considering quantities are parametric. In particular use case, we have used 5% general tolerance, 1 minute of maximal response time, 5 minutes of full activation time and 10 % of change of overswing tolerance. With this envelope, it is possible to validate if a BSP is inside of an envelope or to precisely evaluate violation of product delivery (when measured P arrives outside the area bounded by the envelope). Violation is defined as a difference between measured active power and calculated envelope.
	Validation BO	Main users of developed methods are all TSOs and producers of SCADA systems for TSOs. Using such accurate evaluation would also enable a potential for fine grained BSPs awarding what will motivate BSPs to follow set points more precisely which will result in much better frequency stability.
	Risks and barriers	A method is founded on real-time measurements and its accuracy depends on measurements' accuracy and data quality as well. For example, some

		repeated values are received (bad data quality), which introduces a risk that violations can't be detected.

3	**Modelling VPP**	
	Description	Modeling VPP: In FutureFlow the chosen approach is based on VPP modelling using machine learning and statistical models. These models rely on measured real-world data that were obtained during prequalification tests. This data is further used to compute models, which will express similar behaviour that real VPPs did when tested, however models must be carefully trained and validated, so they are not overfitted on the measured VPP data.
	Validation BO	Main users of developed models are: • TSO grid operators of SCADA systems: For the planning of DR/DG activations based on model predictions, with which they can assess the response of activated flexibility units. • Producers of SCADA systems: Can include produced models into their systems. The models can be pre-learned and re-learned at TSO site when data is available. This enables smooth integration of the models into TSO system, since this solution would already be offered in SCADAs and not as an external plugin. • Financial analysts: Based on model predictions and responses, the financial analysts can assess the costs of activations for different DR/DG simulated scenarios. From simulations, they can see which DR/DG activation produces the fastest response times and costs as little as possible. The models enable to simulate different technical and economic conditions on the aFRR markets, which produces input for cost optimization and smoother integration of DR/DGs.
	Risks and barriers	Models are based on recorded measurements of multiple types of DR/DGs. The models have always good response performance as outages of DR/DGs can't be predicted which is where models are different from real world units. Some DR/DGs (PV, wind) also have production that is highly dependent on weather conditions and forecasted weather which should be further modelled to encapsulate all the imposing factors.

4	CAFx module (with DEMOx)	
	Description	The Matlab/Simulink module CAFx is one of the five main parts constituting the DEMOx model. CAFx module is a marketplace where the upward and downward balancing bids (the supply) are confronted with the current value of the zonal error that is reflected in the current value of variable demand for regulating power. The CAFx Simulink block is represented as a Matlab function having a certain list of input parameters such as the bid sizes and the respective prices etc. and a certain list of output parameters such as the correction signal indicating the total amount of balancing energy that is crossing the inter-zonal borders. This correction signal is, in turn, in the following time frame (in the next 2 sec) used as an input into the four TSO blocks.
	Validation BO	Main users of the CAFx Matlab/Simulink model may be commercial and non-commercial research institutions, including the faculty, conducting studies and case studies in the framework of the new overall European balancing market.
	Risks and barriers	The model CAFx is an implementation of the Common Activation Function equations from Deliverable D1.2 [5] using the Matlab/Simulink programming tools. However, as the scalability analysis shows, if the number of participating TSOs should increase significantly, it would be advisable to translate the whole code into a numerically more efficient programming language as for example C or C++.

5	Concept for the CAFx	
	Description	EKAC has been preparing and the mathematical model to be implemented first in the DEMO platform and then in the operational architecture.
	Validation BO	The understanding and development of aFRR target model, development of methodological approach and know-how used to assist the programming teams to develop the CAFx software solution, could further be used as a knowledge and experience database to support similar processes across Europe and in other regions.
		Every region bears its specifics, which in addition evolve over time. In case of larger time gaps between the projects, applied approach and solutions

		might become outdated; therefore, constant upgrades and improvements need to be done.

6	**Power Flow Colouring (PFC) method**	
	Description	Power Flow Colouring (PFC). The main idea behind the PFC was to determine total flow components (loop flows, internal flows, exchange flows, transit flows, and PST flows) with the essential information on their sources, not only on a control area level but with much higher resolution comprising even generator-load pairs. The PFC methodology can be very useful, in the first place for Regulators, TSOs, and RSCs. It represents the basis for creating the framework of the whole cost-sharing process, which can later be used for implementing the best model for redispatching cost compensation.
	Validation BO	The PFC methodology can be very useful, on the first place for Regulators, TSOs, and RSCs. It represents the basis for creating the framework of the whole cost-sharing process, which can later be used for implementing the best model for redispatching cost compensation.
	Risks and barriers	Because of its features, PFC methodology is applicable only to zonal market design, which represents a kind of constraint to its broad use.

7	**A method for empirical analysis and tuning of the target model for cross-border aFRR exchange**	
	Description	The main objective of the analysis of balancing aFRR energy exchange integration options is to decide which model of cooperation among the available Integration Cases analyzed, should be implemented within the Future Flow project by analyzing the impact of all FF models on ACE control quality performance and other relevant KPIs. During the selection of a target model, the technical performances (such as ACE quality) are evaluated numerically, while also other indicators are considered qualitatively, such as aFRR market liquidity, complexity of implementation, volatility, etc. The concrete case analyzed in Deliverable D1.4 of the FutureFlow assumes three potential integration cases, and two definitions of Cross Zonal Capacity.

	Validation BO	The methodological approach for empirical analysis and tuning of the target model for cross-border aFRR exchange, exercised within FutureFlow project, partially already correlated with the actual defining the European target aFRR model (PICASSO), and possibly contributed to it in an early stage. Since aFRR exchange and target model are alive processes and further fine tunings can be expected after more experience take place, the simulation approach exercised within the FutureFlow can further contribute to the stakeholders (TSOs, ENTSOE, RSCs, NRA, ACER, BSPs) in continuation of these processes.
	Risks and barriers	The analysis is based on four involved systems, and although made as replicable, its scalability to the application to e.g. entire Continental Europe, still needs to be exercised and proven in practice.

8	**Redispatch optimization models**	
	Description	Redispatching common optimization function (RCOF), developed within the Future Flow project is based on optimal power flow (OPF), where the optimal solution is the one that resolves overloading, gives the minimum of costs and at the same time satisfies all predefined constraints. However, what makes it stand out is the fact it is tailored to regional cooperation and is carried out as a common platform that communicates with other markets, regarding the bidding list and XB capacity. On top of it, RCOF includes DR and DGs in redispatching, providing that way higher overall efficiency to the process.
	Validation BO	This common platform could be very useful to TSOs and RSCs. Regional cooperation and the inclusion of DR and DGs in redispatching process, as the highlights of this platform, are expected to enable a number of benefits, such as lower redispatching costs, greater liquidity, flexibility and efficiency.
	Risks and barriers	It is important that RCOF fulfils very high requirements, including fastness and robustness, which are obtained through the usage of PTDF matrix. This, however, has a downside - it misses to capture losses and therefore potentially represents a risk, although very small, of determining insufficient congestion relief in the first iteration. This issue has been solved by calculating AC LF, after the application of the results from RCOF as a sort

		of a check, but still it requires some additional time (of the order of seconds).

9	**Aggregation DR&DG for aFRR (GEN-I)**	
	Description	GEN-I has been mainly involved in securing the participation of external flex providers, as distributed generators and industrial providers. In this sense, several actions were undertaken to identify the most interesting segments in the distributed generation and on the demand response side to be involved in the experimentation.
	Validation BO	In order to do so, GEN-I has been going through a thorough analysis of the potential business partners screening through the four countries the sector of distributed generation and each most likely concerned industrial sectors, talking with energy managers, maintenance managers, purchasing officers and other roles involved in supply and operations. Tools to support the identification process have been classical surveys via phone, email and online research so to collect the broadest possible volume of data to define the respective flexibility volume potential and the type of flexibility which could be offered.
	Risks and barriers	Companies on the market were not looking at the project as research, but what they can extract from it financially. Funds available were not too motivating to participation. They said that the upside they would have been paying was related to the possibility of having the unit work more automatically (i.e. supported by a sort of artificial intelligence). For manufacturing companies, energy is a cost and not a revenue stream, they are not concerned too much by energy cost, and all improvements to be made in terms of energy were always the last one to be accounted. It has been extremely difficult to keep motivation high. Loads such as major consumers in the manufacturing industry (steel makers and other similar commodity producers) have been proving to be too challenging in terms of risk related to interruption of the manufacturing process, so even if these loads could deliver flexibility, they were resistant to stop the process for avoiding issues related to then quality of their final products. It will take more time to manage these processes to make the processes more automated, since a firm of artificial intelligence shall be embedded

		into the production stream to support a more appreciable reaction from demand side.

10	Platform for the Common Activation Function operation (SAP)	
	Description	SAP integrated the FutureFlow platforms covering three main areas: 1. Operational real time balancing platform, 2. Redispatch simulation and 3. Datawarehouse. The work done has been mainly consisting in creating the operational framework for all sub-systems created in the project to make them interact according to the designed business model.
	Validation BO	The validation of the business objectives has been carried out with an extensive set of tests on the selection of bids according to the criteria fixed by the mathematical model implemented by EKC and the prototype business model designed by EIMV by Simulink.
	Risks and barriers	Risks were mainly related to the potential difficulties to integrate the sub-systems with each other to achieve the expected time-response and to an insufficient definition of all possible cyberattacks to which the platform might be exposed.

11	aFRR activation control module	
	Description	The objective of activation control module (ACM) is to provide reliable aFRR service to the TSO from the aggregated (pool) information from DR&DG units. Every activation signal (set-point) received from the local TSO (periodically in 2s-intervals) is checked against several conditions before de-aggregation of the set-point to the DR&DG units inside the aggregated pool. Internally, the de-aggregation process is also called "unit commitment module" which provides the information which DR&DG unit is to be activated, so to reduce the overall costs of activated aFRR energy. The unit commitment module holds an internal merit order list which is continuously updated with live data from DR&DGs in the pool. The merit order will list the units based on their cost for activation and pass it to the

		control module. In case any deviation between the realized activation and the requested activation (set-point) is detected, the incoming set point (from TSO) to the de-aggregation process is adapted by the PID algorithm. ACM results in a combination of a fast open-loop control to follow changed set points and a closed loop control for minimizing the deviations.
	Validation BO	cyberGRID is focused on development and deployment of Flexibility aggregations ICT platforms which enable electricity retailers, aggregators to efficiently aggregate and manage different types of flexibility assets and offer the flexibility to the market (e.g. aFRR services). The activation control module is the part of cyberGRIDs flexibility platform and will be offered to cyberGRID's consumers via different business plans, such as one-time license payment or monthly subscription.
	Risks and barriers	The flexibility markets are currently under development. In the future, it might happen that certain functionalities will have to be adopted to meet the new rules on the EU scale or on country to country basis.

12	**aFRR real-time communication module**	
	Description	Offering reliable aFRR service to the TSOs also includes DR&DG data exchange. If this is not fast enough or unreliable then overall aFRR service is no longer viable. To achieve this, flexibility platform introduced microservice architecture to load balance all the data-exchange from DR&DGs. This results in supporting plethora of DR&DG and fast process of all incoming and outgoing data between Flexibility platform and the DR&DG.
	Validation BO	cyberGRID is focused on development and deployment of Flexibility aggregations ICT platforms which enable electricity retailers, aggregators to efficiently aggregate and manage different types of flexibility assets and offer the flexibility to the market (e.g. aFRR services). The real-time communication module is the part of cyberGRIDs flexibility platform and will be offered to cyberGRID's consumers via different business plans, such as one-time license payment or monthly subscription.

	Risks and barriers	The flexibility markets are currently under development. In the future it might happen that certain functionalities will have to be adopted to meet the new rules on the EU scale or on country to country basis.

13	**Automatic marginal bidding based on the pool data**	
	Description	The bidding module enables platform traders to create, visualize and submit the bids to the market (aFRR). Traders can manually prepare aFRR bids or parameterize the auto-bid generator which automatically builds bids and send them to the market. In the past, there were only large conventional units which were able to provide flexibility for balancing services. Nowadays, the trend is to introduce many smaller DR&DG powered by renewable energy sources, where availability is frequently changing due to the changing weather conditions. Because of the high number of units and frequent changes of availabilities, traders cannot rely solely on their experience. Therefore, the bid-creator supports them by generating feasible bids from their pool of different types of loads or generators (conventional or renewable). The automatic marginal bidding module enables users to automatically generate bids and send them to the market. Furthermore, it regularly calculates the pool availabilities and build bids based on the module settings and send them for approval (acceptance) to the market. In case of the FutureFlow target model, the BSPs should calculate energy bids for a specific one-hour timeframe in the future. The BSP can decide when he would like to start the calculation but must meet the gate closure (GC) time, which is 30 minutes before the start of delivery. After GC time, bids are not accepted in the tender. When the market receives all the bids from various BSPs, the merit order list of received bids is calculated and BSPs are informed whether their bids were accepted or rejected. If the bids are accepted this means that the BSP has a binding contract to reserve the capacity and follow the requested set point received from the TSO.
	Validation BO	cyberGRID is focused on development and deployment of Flexibility aggregations ICT platforms which enable electricity retailers, aggregators to efficiently aggregate and manage different types of flexibility assets and offer the flexibility to the market (e.g. aFRR services).

		The automatic marginal bidding module is the part of cyberGRIDs flexibility platform and will be offered to cyberGRID's consumers via different business plans, such as one-time license payment or monthly subscription.
	Risks and barriers	The flexibility markets are currently under the development. In the future it might happen that certain functionalities will have to be adopted to meet the new rules on the EU scale or on country to country basis. Further, when such markets will become common practice in EU, the module will need to be upgraded with more advanced algorithms to check e.g. the current market price and adopt the bids accordingly.

14	**Trustful ICT connection using block chain technology**	
	Description	Gemalto has been leading the work to evaluate where the introduction of a blockchain based encryption was necessary to grant the adequate level of security to the communication. In principle a blockchain protocolled communication can be introduced across all platforms, but in the end, this resulted necessarily only where it makes the most impact (i.e. between the outside world and aggregation platform, and where the signal access the TSOs control loop). The other three platforms are in SAP domain and were less significant since they were in the last mile and less relevant for communication with the real world.
	Validation BO	The business objectives were validated by an extensive analysis of the possible application ground of the blockchain technology so to identify the areas where a particular security level of the information was required to prevent attacks from the external world.
	Risks and barriers	The potential hard-to-overcome barrier stands in the need of adapting traditionally closed systems as the control loop of TSOs is to the need of integrating exogenous signals, coming from third party systems. Not all TSOs project partners declared themselves ready to open their area control error loop to additional correcting signals, coming from external systems.

15	**Forecasting and baseline algorithms for RES**

	Description	The forecasting module delivers production forecasts with improved accuracy, thanks to the implementation of new training algorithms, continuous training and intraday corrections with adapted time-series models, the incorporation of horizon shading and the use of satellite data.
	Validation BO	Accurate production forecasts of renewable assets are requested by grid operators, asset managers, balance responsible parties and traders. They are pivotal for efficient, cost-effective and reliable operation of production assets and the grid under the presence of a high share of renewable generation. 3E provides historical and (near) real-time satellite-based solar resource data for asset managers through its website and through an API. The new forecasting module allows 3E to complement its current data services offer with state-of-the-art forecasting of energy production from solar and wind parks.
	Risks and barriers	Markets and technologies are continually evolving. For grid operators, asset managers and traders, having a slightly more accurate forecast than others may prove to be very lucrative. Therefore, forecasting technologies are continuously being improved and benchmarking of forecast accuracy from different providers is a common practice in the industry. For 3E, in order to be and remain successful, it is important to keep on providing the most accurate forecasts in a flexible and reliable way.