European Commission

# bridge

## Analysis of Projects

### Major Achievements and R&I Gaps

R&I priorities Task Force

# Analysis of Projects

## Major Achievements and R&I Gaps

April 2021

bridge

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# INDEX

# Executive Summary

## An Integrated Energy System

As part of the European Green Deal, to encourage a smart sector integration, the Commission presented an EU strategy for energy system integration on 8 July 2020.

Sector integration means linking the various energy carriers - electricity, heat, cold, gas, solid and liquid fuels - with each other and with the end-use sectors, such as buildings, transport or industry. Linking sectors will allow the optimisation of the energy system as a whole, rather than decarbonising and making separate efficiency gains in each sector independently.

Several barriers still prevent energy system integration from fully materialising and allowing citizens and industry to embrace cleaner energy alternatives.

Key aspects to allow this integration are the availability and management of Flexibility Resources, Integrated System Operation and Control, and Integrated System Planning.

### Flexibility Resources

The increasing electrification of the energy system and the variation of the consumption patterns cause mismatches between supply and demand leading to a system increasingly difficult to plan and operate. The traditional implementation of flexibility solutions in the supply side has been evolving, although with some limitations and inefficiencies, and demand side technologies and flexibility solutions across the whole energy value chain are being developed in recent years with the support of a favourable EU framework and publications on flexibility by the European Commission (e.g., demand-side, storage, transport).

The future energy system will have to rely on much higher balancing capacities, including: (a) flexible generation units, (b) increased demand response and (c) conversion and storage technologies, together with better interconnections at all grid levels. This requires also adapting the energy system segments to provide flexibility to the system (network flexibility).

In the recent years, R&D&I work has been done in several topics to make the above possible. Based on the information collected from 29 projects, these include **demand flexibility, generation flexibility, storage flexibility, transport and energy conversion flexibility.**

On the demand-side (19 answers received from projects) several aspects were tackled such as **demand flexibility modelling, demand and supply matching and demand response optimisation, control algorithms, forecasting and aggregation.** Another dimension that has been explored was the use **of C&I customers vs. residential customers.** Other briefly explored aspects were the **coordination of TSO and DSO** in the demand-side flexibility use, **cybersecurity aspects**, **data exchange** and overall coordination of heterogeneous flexibility resources. Flexibility ranges in excess of 20% were frequently reported, strongly depending on the pilot situations.

On the generation-side (10 answers received from projects) key aspects addressed were **complementarity between different generation sources** (e.g., solar and wind), **forecasting, optimisation and control.**

Regarding storage flexibility (24 answers), aspects addressed include **interoperability between storage and heterogeneous renewable sources, provision of ancillary services, congestion management and control of customer-scale batteries.** A wide range of increase of renewables penetration and of CO2 emissions reduction was reported, depending on the pilots situations.

Finally, on transport-flexibility and other energy-conversion flexibility (14 answers), key topics tackled include flexibility usage from EVs, consideration of **public EV charging station networks** and **office buildings**

**charging stations, control of charging power** and **V2G/G2V operation. Power to Gas** technology and solutions were also briefly addressed.

Several topics were not completely covered by the previous work developed and should be considered in **further research work.** Also, many achievements were specific to a particular demo and framework. The emphasis by the European Commission on further sector integration, on the linkage between different energy vectors and on the further development of local energy communities, requires that some topics, although already addressed, require further analysis and evaluation. This has also been identified in previous publications by the ETIP-SNET and BRIDGE communities and is reinforced in the assessment now accomplished. These include the use of platforms to increase the flexibility in the system by means of better coordination, the assessment and planning of demand side flexibility by coupling local electricity sector with other networks and the increase of flexibility by improved coordination between TSO, DSO and third parties. Also, licensing and regulatory regimes are still a challenge, as well as compensation models. Particularly acute in this area is the need for refinement on data exchange, common models and standards.

Research in these areas must address the needs, solutions, and tools to ensure the adequate level of flexibility to cope with all the uncertainties and variabilities of the progressively Integrated Energy System. These and other issues are further detailed in a following dedicated chapter.

### Energy System Operation

The exploitation of the flexibility resources described in the previous section is the key for the efficient integrated energy system operation and planning, in order to achieve a carbon free, efficient and reliable energy supply. Energy system operation is the focus of RD&I activities in order to achieve wide **supervision and state estimation, short-term, medium and long-term control** ensuring the stability and security of the system, **preventive control and restoration** in order to avoid disturbances and achieve fast recovery of the system and developments in **Control Center technologies**. The new elements of efficiently integrating flexibility resources of various energy carriers and at all voltage levels of the system, requiring close collaboration between operators, energy producers and consumers pose significant RD&I challenges.

On the **supervision and state estimation** topic (12 answers received from projects) monitoring of voltages, loads, local production and storage state of charge at secondary substations was performed. State estimation tools at MV and LV level using smart meter information and limited amount of measurements were developed and advanced forecasting for RES and Load and data flow between DSOs and TSO was developed.

In **short-term control** (9 answers), the contribution of RES and storage in aggregated and disaggregated form to primary voltage and frequency control and in congestion management has been investigated. Predictive control of DER for flexibility has also been developed. For **longer term control** (8 answers), multi period optimal power flow for MV grids including medium term load and RES forecasting, DER optimisation, and day ahead topology optimisation. In addition, fully automatic frequency restoration reserves (aFRR) services by DER were developed and demonstrated. New criteria for operational planning in normal and emergency operation were developed considering the flexibility from the grid and market-based services. In **preventive control** (8 answers5 answers), restorative/self-healing control of distribution networks and islanded operation in the form of Microgrids has been achieved. R&I in **Control Centre technologies** (10 answers7 answers) has focused on the development of platforms for TSO/DSO coordination, for DER aggregation for VPPs (Virtual Power Plants), for cross-border aFRR and for island EMS (Energy Management System).

Several topics were not completely covered by the previous work developed and should be considered in **further research work**. These include optimisation algorithms at aggregator and local hub level. The lack of standardised data format for communication between the different components was reported. The topic of intended Islanding (Microgrids), i.e. transition from grid-connected to islanded operation was only partly covered. Adaptive protection and prognostic tools for grid faults need more research. Furthermore, multi-vector EMCs (Energy Management Center), integrating water and transport sector need to be developed.

## Energy System Planning

As the ETIP-SNET implementation plan well clarified, the energy transition is possible only if the traditional silos in the operation are overcome by a concept of integrated energy system and this means both sector-coupling and also inclusion of Hybrid AC/DC grids.

Projects in H2020 analysed Integrated Energy Architecture exactly according to these two directions. The emerging role of sector-coupling has been mostly considered in islanding systems, while the role of hybrid grids has been widely considered also for very large-scale systems.

Concerning **long-term planning** (9 answers received from projects), projects reported results in two main directions. A key set of activities explored innovative solutions for optimisation both for the topology definition and for network planning in general including flexibility options. Moreover, projects reported adoption of innovative technologies in support of planning such as the development of an intelligent platform with block chain-based technology for long-term capacity. Long term planning has been considered also for islanding systems.

In relation to **asset management** (5 answers), the focus has been on the direction of increasing the overall network resiliency and the following topics have been reported: evaluation of fault indicators and predictive maintenance, definition of strategies for asset management and maintenance, and weather resilience. In this area projects also reported some main achievements: development of a platform including work orders and manoeuvres for battery calibration and restoration and a smart de-icing protection of OHLs (Over-Head Lines).

Still in the area of planning work is also reported in relation to **system stability analysis** (7 answers received). In this area the topics reported do not stress much theoretical aspects while, vice versa, more approaches that can be adopted to support the overall system stability. In particular the following aspects are mentioned: different optimisation energy management systems, solutions to provide interoperability between different technologies and concepts by providing specific technical and operational requirements, approaches to deal with power oscillations and solutions for vulnerable island systems.

Also, for this topic there are **significant achievements**:

- An energy advisor and automation system were designed to increase the grid resilience by using the available flexibility and the monitored information from the distribution grid: detection of LV faults, improving LV quality, optimising LV power flow, distributed energy resources power flow, optimised power flow and fault detection, isolation and restoration
- Deployment of cloud-based control of PV-BESS (Battery Energy Storage System) in local micro-production sites (domestic and commercial) has been achieved. Two main control strategies were considered; Greedy and Forecast-based control (load and solar PV production forecast)

At component level, an intelligent converter for stability purposes has been proposed.

Looking at the **still open points**, the transition to DC network is still an open topic, as well as sector coupling. Business approach and legislation requires also more work as mentioned by more than one project. The solutions proposed in the area of asset management require further investigation mainly to increase the TRL-level; i.e. from TRL-6 to real market adoption.

For what concerns system stability, projects mentioned that several aspects have been addressed only at theoretical level requiring more practical experience. An interesting topic is also the interconnection of multiple isolated communities following a bottom-up approach.

## The Customer at the Centre

The target of at least 32% of renewable energy in gross final energy consumption in 2030 relies on the participation of citizens in the energy transition. In the process of acceptance of the integration of variable Renewable Energy Sources (vRES), social and environmental aspects must be considered at all levels. Besides, citizen behaviour is very important for the achievement of Energy Efficiency targets. RD&I activities in this are focused on **social campaigns and social studies, adaptive consumer/user behaviour including Energy Communities** and **Consumer and Prosumer Device Control**.

In recent years, in RD&I projects (15 answers received from projects) a number of social awareness raising **campaigns** have been conducted and a number of workshops was organised for the engagement of the local citizens to cleaner energy and the creation of energy communities. Also, local surveys and training seminars have been carried out and citizen engagement strategies and tools were developed. For **consumer/user behaviour** adaptation (15 answers) methods and tools to support energy adaptation and energy efficiency were developed and energy communities organisation was supported. The tools include Home Energy Management systems for residential demand response, a dedicated tool for energy communities, and EMS platforms for the integration of prosumer with DSO's SCADA and Market Place platforms to negotiate and activate consumer day ahead flexibility. Finally, the use of smart meters as efficient low-cost IoT solutions for enhancing the visibility of the grid and empowering end users has been demonstrated. For **consumer and prosumer device control** (18 answers) in-home ICT technologies for direct control of consumer demand of smart appliances and IoT-based systems for end-user engagement and management of building devices in order to support the network and increase energy efficiency were developed. This includes automatic control of building's assets. Monitoring and control of residential flexibilities and control of customer-scale and office-scale batteries was performed. DSM (Demand Side Management) for Commercial & Industrial customers and control of Distributed generation to provide aFRR ancillary services via device control was also developed.

Topics not completely covered by the previous work that should be considered in further research work include cost-benefit analysis of HEMS (Home Energy Management System) considering different types of regulatory frameworks. More efforts on the aggregation of LV prosumers for active participation in electricity markets including the development of energy communities in a multi-stakeholder network from a multi domain perspective are needed. Cost-effective solutions for the wider application of battery systems, demand response business models at the individual and aggregator level and the activation of prosumers need to be explored. Improve communication with smart meters and the use of smart meters (and other innovative technological solutions) to increase end-user engagement need to be further developed. Further research is needed for the development of more accurate user profiles for a holistic management and maintenance of buildings. Finally, development of fast demand-response units for critical processes is needed.

Despite the various tests and campaigns, more tests with larger population, wider variation in socio-demographic characteristics, over longer periods of time for impacts on electricity consumption behaviour is needed. Also, feasibility studies for replicability of smart grid solutions considering social aspects and more local social campaigns and training seminars for prosumers.

## The importance of a Market Based Energy System

To meet the EU "Green Deal" and related European national requirements targets one of the fundamental elements of an integrated energy system is related to Markets as a key enabler of the energy transition. The "Clean energy for all Europeans" package adopted by the EU Council on 22 May 2019 addresses the major changes required in the energy market structure and operation.

A significant **revision of electricity market rules** underpins the European Union's ambition to further boost penetration of renewables in the power system.

Additionally, the recent clean energy legislation requires that Electricity Markets are created with "**active customers/ consumers and citizens" and "energy communities.**" Renewables self-consumers are to be empowered to generate, consume, store, and sell electricity without facing disproportionate burdens.

Finally, the **integration of multiple energy carriers into a system of systems** requires that an enlarged multiplicity of stakeholders is considered.

In the recent years, R&D&I work has been done in several topics to make the above possible (45 answers were received from 29 projects). These include the **development and evaluation of business plans** under various business models, considering different stakeholders involved, possible market strategies, and identifying existing barriers. In particular, some projects considered business plans related to **batteries and storage usage** and to **grid flexibility and flexibility services**. Furthermore, evaluation **of business case from the use case point of view** was also performed. In some projects, the **data exchanges** needed for the implementation of the business plans were also briefly addressed.

Besides work related to Business Models (17 answers received from projects), effort was also devoted to Market Design and Governance (28 answers received from projects). These include **analysis of existing regulation and market rules** performed under multiple contexts with several recommendations provided. Furthermore, several novel **market designs, rules and options** were also tested and simulated, namely **market design for flexibility services** and **market design for ancillary services.** Finally, the **participation of demand-side in the market** was partially addressed.

In some projects, **specific results** were obtained. These include the increase of renewable generation as a result of storage deployment, the reduction of investment costs in wind offshore deployment and implications in employment generation during planning and construction phases, the deployment of operational battery-based hybrid power systems.

Many achievements allowed to validate particular technologies, explore a proof of concept or identify inefficient vs. efficient solutions. On the other hand, despite the achievements mentioned above, it should be noted that some tests, demonstration and pilots, very often concern a specific setting and context, and are, therefore, difficult to extrapolate as a general conclusion. Therefore, some topics, although already addressed, **require further analysis and evaluation**. Furthermore, dynamics in political, economic, environmental and social trends, requires the evaluation of new dimensions in the different challenges. This has been highlighted by the ETIP-SNET and BRIDGE communities and is further reinforced in the information received from finished and ongoing projects.

In particular, business models based on DER aggregation or on behavioural demand response deserve further studies, as well as the procurement of DER flexibilities through market-based mechanisms and opening data platforms to different data service providers. Additionally, Identification and establishment of remuneration schemes for storage and Demand Response ancillary services and the incentive and remuneration mechanisms for flexibility services is needed. Power-to-X topics also need further attention. Business models for prosumers providing ancillary services, including EV owners with bidirectional capabilities and storage units still need further study. On the market design side, further work on tariffs (e.g., energy communities, hybrid power systems), on demand-side participation (both on energy and ancillary services markets), on micro-grids integration, on the data flows, data models, interfaces and platforms coordination and on integration of other energy vectors to allow a market-based system of systems. These and other issues are further detailed in a following dedicated chapter.

## Digitalisation as key enabling technology

Digitalisation is one of the key elements of the energy transition as it was described in detail in a white paper released by ETIP-SNET. The white paper distinguished among three layers of digitalisation: physical layer, infrastructure, business layer.

Looking at the results of the H2020 projects, focus, in the last few years, has been provided mostly on the intermediate level, i.e. in creating the conditions for a digitalisation of the infrastructure and of the grid operation.

**Interoperability** has been addressed by a variety of projects and at different levels (13 answers). Several solutions have been proposed at the component level, while at the data level more projects have proposed both semantic enhancements and protocol solutions An additional aspect is given by the **API (Application Programming Interface) definition** which has been proposed by more than one project.

In the area of **ICT solutions** for data communication projects reported (11 answers) the adoption of wired and wireless solutions and the consideration of **5G integration.**

The area of data and information management is definitely the one with more activities where many projects addressed the definition of integrated architecture for service provision and market integration (16 answers). Even for this case we can distinguish solutions depending on what layer of the grid is considered. Some projects focused on the customer layer integration both for the creation of neighbourhood solutions and for the integration in the overall grid management while also including block chain architectures.

**Cybersecurity** is a key topic within the digitalisation process and a complete overview of challenges and available solutions have been reported in a white paper by ETIP-SNET. According to projects in this area (9 answers), analysis of threats and data anonymization have been addressed by more than one project. Block chain has been proposed as a way to increase the security of data coming from the customers and to be adopted in grid management.

Several topics have been reported as **still open challenges** in the area of digitalisation. In general, the proposed solutions do not seem to be fully comprehensive, so that many projects mentioned the need to further work in the previous directions to reach a proper level of maturity. Interoperability seems to require more work for a better coordination between Smart Grid and Smart Home and also to support cross-sectoral data exchange. Similar challenges emerged in all the aspects of digitalisation requiring further development and deeper testing. In the communication area, a better integration of the Smart Metering infrastructure seems to be one of the key points. At the platform level there is a lack of common European approach. There are several solutions available, but the open question is a further level of integration among operators.

An additional emerging topic is the application of the grid edge.

Cybersecurity is still definitely an open topic and the risk assessment should be improved. More standardisation for solutions such as block chain are also noted.

# Introduction

The European Green Deal issued by the European Commission in December 2019 reinforces the call for "mobilising research and fostering innovation". It is stressed that "new technologies, sustainable solutions and disruptive innovation are critical to achieve the objectives of the European Green Deal." This emphasises the message delivered in the Clean Energy Package of 2016 where Research and Innovation was identified as one of the five pillars and dimensions of the Energy Union. Indeed, in 2016 the Commission presented a comprehensive research, innovation and competitiveness strategy, which supports the objectives of the energy union. This strategy was outlined in the Accelerating Clean Energy Innovation Communication adopted as part of the Clean Energy for all Europeans package, where research and innovation is recognised as a driver for the three overarching goals of energy efficiency first, Europe as a global leader in renewables and a fair deal for consumers.

In line with these orientations, the European Technology & Innovation Platform (ETIP) Smart Networks for Energy Transition (SNET), in its role to guide Research, Development & Innovation (RD&I) to support Europe's energy transition, is involved in ongoing work on a Vision for 2050 (2018), a R&I Roadmap for 2020-2030 (2020) and a R&I Implementation Plan for 2021-2024 (2020). In these activities the consolidated input from the major energy stakeholder associations is collected and presented. Also, under the auspices of the European Commission, the BRIDGE initiative unites Horizon 2020 Smart Grid, Energy Storage, Islands, and Digitalisation projects to create a structured view of cross-cutting issues which are encountered in the demonstration projects and may constitute an obstacle to innovation.

In the BRIDGE General Assembly of February 2020, the Task Force Future R&I Priorities was created. The purpose was to bring together views from ETIP-SNET and BRIDGE communities on R&I priorities (including flexibility/storage, vector/sector integration and digitalisation), to look into concrete achievements from H2020 projects and highlight future R&I needs. Indeed, the dynamic nature of the energy transition and the emergence of key aspects, such as the integration of different energy vectors, the development of local energy communities and the increase of digitalisation as an enabler of these processes, requires a continuous steering of research and innovation directions. Even if the key dimensions to address are common, new challenges and complexities need to be faced. The Task Force took into consideration the Roadmap and Implementation Plan produced by the ETIP-SNET Working Groups, the four BRIDGE Permanent Working Groups, the two BRIDGE Topic workstreams and the other BRIDGE Task Forces. It also contributed and took into consideration the Clean Energy Research & Innovation Outlook (CERIO) from the European Commission. Furthermore, the Task Force collected the material produced in this report from a direct questionnaire related to R&I projects to members of the BRIDGE and ETIP-SNET communities who participated in the Task Force. As most projects work on multiple areas, 304 answers from 29 projects were received.

This report is the result of the work of the Task Force Future R&I Priorities. The aim is to provide an overview of the achievements of the identified H2020 R&I projects grouped in Research Areas and to identify gaps and those Research Areas where further efforts are needed. For this purpose, the analysis is structured into four key dimensions. A first one is dedicated to the Integrated Energy System. It is further decomposed into three aspects: Flexibility Resources, Energy Systems Operations and Energy Systems Planning. A second one addresses the Customer at the Centre. The following one is devoted to the importance of a Market Based Energy System. The final one is dedicated to Digitalisation as a key enabling technology. The above analysis is presented in two sections. The first section provides a condensed view on the four dimensions above in the form of an extensive summary, and the second section offers an extended presentation of the achievements and challenges reported in the various projects. It should be noted that the report is a trade-off between detail and synthesis, therefore additional information shall be obtained in the documents referenced. The report is supplemented by two appendices. In the first the H2020 projects that have answered the questionnaire are listed, while the second provides the structure of the questionnaire.

# 1. An Integrated Energy System

The implementation of Integrated Energy Systems is based on the availability and management of Flexibility Resources, Integrated System Operation and Control, and Integrated System Planning.

## 1.1 Flexibility Resources

The future energy system will have to rely on much higher balancing capacities, including: (a) flexible generation units, (b) increased demand response and (c) conversion and storage technologies, together with better interconnections at all grid levels. This requires adapting the energy system segments to provide flexibility to the system. Increasing system flexibility must be achieved also through policies, measures and regulations compatible with further market integration, increased competition and the achievement of climate and energy objectives.

Research in this area must address the needs, solutions, and tools to ensure the adequate level of flexibility to cope with all the uncertainties and variabilities of the progressively Integrated Energy System. These flexibility issues embrace the entire energy system, progressively across the different vectors considered.

To achieve the above, the following key areas need to be considered and are further addressed in the following sections:

- **Demand flexibility (household and industry related)**
- **Generation flexibility (flexible thermal, RES (Hydro, PV and wind generators))**
- **Storage flexibility**
- **Transport flexibility (V2G/EV) & Energy Conversion flexibility (PtG&H, PtG, GtP, PtL, LtP; PtW; WtP)**

### 1.1.1 Demand Flexibility

The present demand-related technologies, market models and integrated energy system policies do not provide sufficient features and incentives to the customer/prosumer, to engage in DSM and DR programs and market initiatives.

Below there are some recent development in these areas.

➢ Achievements

The following aspects were addressed in the mentioned recent projects. Demand Side Flexibility in general was explored in project **EU-SysFlex** and Demand Response Programs were explored in project **Ebalance-plus**. The utilisation of flexibility by customers under bi-lateral agreement schemes was studied in **InteGrid. InteGRIDy** worked in Demand and supply matching, Demand flexibility modelling and DR Optimisation. Optimal utilisation of DSR (Demand Side Response) by TSOs and DSOs and their coordination, respecting demand requirements, and required data, was explored in project **FLEXIGRID**. Project **FutureFlow** worked with C&I consumers for Enhanced forecasting, optimisation and control algorithms for provision of aggregated demand flexibility to local and regional aFRR market. In the Samsø island demonstrator in project **SMILE**, demand side flexibility was also used to shift load in time. Project **TILOS** further explored demand side flexibility with a Pool of controllable loads.

In project **INERTIA**, with work based on the integrated system tests simulating grid abnormal conditions that required demand response flexibility to be utilised at different levels, an Aggregator Control Hub managed to successfully provide the requested amounts of flexibility to the DSO. In project **InteGrid**, both at LV and MV level, flexibility (downward mainly) was used to solve local congestion issues and voltage problems. In project **FutureFlow**, 20 MW of real existing units were acquired to join the pilot and a cyberGRID's Flexibility Aggregation Platform cyberNOC (Network Operations Center) was updated and tested in real-life pilots. In the Samsø island demonstrator of project **SMILE**, demand side flexibility was remotely controlled via Internet, and in the Orkney Island demonstrator, a load controller (aggregator platform) was able to control domestic heat installs, EV smart charging and large industrial load to support the local grid in increasing the demand side management capacity and reduce levels of curtailment. In project **TILOS** Classification of integrated, controllable loads in terms of elasticity was done so as to inform different DSM strategies. Testing of DSM functionality at the end-user level and in aggregate, and load shifting to allow higher RES shares was also performed. Water pumps deemed as the most deferrable loads.

Project **INTERRFACE** is working on the Integration of all flexibility into one platform.

In the **CROSSBOW** project, demand flexibility alongside prevention of RES curtailment, constitute the TSO-DSO demo activities taking place in the island of Crete. A centralised approach involving both transmission and distribution system operators of the non-interconnected system of the island, has been demonstrated in order to provide demand flexibility through smart and effective -from the system's stability perspective- load shedding when power outages endanger the stability of the non-interconnected power system of the island. The aim of this demo is to prevent unnecessary power shedding from transformers' feeders that encapsulate significant PV production, with respect to the market framework of the island. Thus, through the appropriate coordination framework, the demand flexibility offered from DSO to TSO, takes into account and preserves the RES penetration to the maximum available extent.

Moreover, **CROSSBOW** has proposed voltage regulation and congestion mitigation with cross-border DSM application which have been carried out in simulated environment and the results have shown that the DSM actions (load curtailment and load reconnection) could lead to both increased and decreased cross-border power transfer across tie lines when suitable market framework exists.

Project **CoordiNet** will demonstrate an entire process of management of flexibility for the provision of balancing service in the Swedish demonstration campaign and for the provision of congestion management in three demonstration countries.

Project **CoordiNet** modelled the flexibility available in different types of demand and generation systems, based on the units participating in the demonstration campaigns (in Spain, Sweden and Greece). In these demonstration campaigns, different market setups are being demonstrated for the procurement of flexibility from small-scale and large-scale generation, storage and demand units for the provision of system services, including balancing, congestion management, voltage control and controlled islanding. The market setups include coordinated procurement schemes for DSOs and TSOs (in a joint market, in subsequent markets and in independent markets), coordinated data exchanges for individual procurement of services (TSO-operated central market for balancing or DSO-operated local market for congestion management at low voltage) and peer-to-peer markets for solving grid constraints.

Looking into some quantified results, in project **INERTIA**, the maximum downwards flexibility (calculated for the next 15-minute period) accounted for 18% to 24% on average. The upwards flexibility has been determined as high as 80%. Based on real-life pilot tests, compliance with aFRR quality requirements was 80%, 94% and 65% in Slovenia, Austria, Hungary respectively – on average 80%, in project **FutureFlow**. In project **InteGrid**, around 15 industrial users and more than 50 residential users have been used. Regarding the integration of multiple demand-side flexibility sources, in project **SMILE**, in the Samsø island demonstrator, 1 sauna and 1 heat pump were used as sources of flexibility; in the Orkney Island demonstrator, a number of installations to be controlled by the load controller (aggregator platform) were used: Domestic Heating Systems (including BESS, PCM (Phase Change Materials) based heat battery, Air Source Heat Pump etc.) installed in more than 40 proprieties, EV smart charging installed in 16 proprieties; in the Madeira Island demonstrator, the SMILE DMS (Distribution Management System) system was installed in 23 proprieties (21 residential and 2 commercial) named UPAC (Unit of Production for Self-Consumption) in order to maximise the self-consumption of Energy from PV. In 5 of them, a BESS was included in the system. In project **TILOS**, the estimated availability of active controllable loads was equivalent to a max of 15-20% of the appearing island load. Finally, Project **NobelGrid** showed that a Price-Based Flexibility Profiling Engine can be successfully used to organise Demand Response (DR) policies and, if final users are correctly involved in the demand response goals, aggregators can manage DR campaigns obtaining a good customer responsiveness, a good management of aggregate flexibility and a real impact on load of up to 25%

during peak periods. Also, a Context-Aware Flexibility Profiling Engine and its utilisation in Automated Demand Response trials in Flanders and Manchester achieved a high-level of accuracy regarding the estimation of flexibility that can be provided by a selected pool of assets. In all cases, the flexibility request was satisfied at levels of over 70%, while there was no override in the control strategies applied over HVAC loads which highlights that comfort preferences were respected in the assets involved.

➢ Remaining Challenges

The following topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the projects identified/mentioned below:

- Test an entire process of management of flexibility services, meaning a real process of preliminary validation of resources by DSO, as well as blocking and limitating in case of contingencies by DSOs. (**EU-SysFlex**).
- Test the flexibility activation under a competitive framework (e.g. market biding) (**InteGrid**).
- Possibility to establish some pilots with a full involvement of TSO and customers, scoping the test of flexibility market and services management. Benefits from using demand side flexibility in already operative processes. Rebound effect from including storage flexibility. Optimal operation/aggregation. (**EU-SysFlex**).
- More high-quality load flexibility analysis and experimentation is needed, and AI based Digital Twins of demand flexibility assets. (**FutureFlow**).
- Further assessment and planning on the increased demand flexibility through the coupling of the local electricity sector with the local water network, and through the expansion of electro mobility (**TILOS**).
- New market rules that may apply in the cases of islands after their interconnections with the mainland via limited capacity lines (**CROSSBOW**).
- Involvement of industrial partners with DSM capabilities and suitable market framework for demonstration purposes (**CROSSBOW**).

### 1.1.2 Generation flexibility

This aspect addresses the solutions and tools to improve the flexibility of all types of generation technologies to cope with all the uncertainties and variabilities of the progressively integrated energy system.

Suitable tools need to be developed to optimise the different flexibility resources, assessing their availability, the retrofitting technologies, the operating (and external) costs, both under a planning point of view and in a more short-term operational horizon. Developments in this topic need to address optimised coupling of the gas, heat and electricity networks and adaptation to the flexibility challenge connected to the increased penetration of variable renewables in the system.

➢ Achievements

The following developments were addressed in the below mentioned projects.

In real-life pilot tests of **FutureFlow**, compliance with aFRR quality requirements was 80%, 94% and 65% in Slovenia, Austria, Hungary respectively, 80% on average.

Project **FutureFlow** addressed enhanced forecasting and optimisation and control algorithms for provision of aggregated generation flexibility to local and regional aFRR market. Furthermore, still in project **FutureFlow**, 60 MW of real existing units were acquired to join a pilot, and cyberGRID's Flexibility Aggregation Platform cyberNOC was updated and tested in real-life pilots. Project **TILOS** used Centralised wind power and PV power (complementarity between two RES resources), two undersea interconnector cables for redundancy and back-up diesel genset. Project **Ebalance-Plus** worked on maximising the ratio of local production with flexible solutions (kWh produced vs consumed). In project **Shar-Q** a larger size of Electric Energy Storage and RES capacities was achieved by the collaboration of distributed sites and corresponding complementarity.

Some quantified results were the following. In project **INSULAE** 1 MW PV and 300 kWh battery were used. In project **FutureFlow**, based on real-life pilot tests, compliance with aFRR quality requirements was 80%, 94% and 65% in Slovenia, Austria, Hungary respectively – on average 80%. **FLEXITRANSTORE** project achieved a 10% increment in ancillary services provision, and black start capability.

**CROSSBOW** project has developed a centralised management and control platform of RES plants (WPP and PV) from 5 Balkan countries in the south east European region, able to monitor and send set points to the RES plants (where applicable).

The project **CoordiNet** is demonstrating the exploitation of flexibility in wind farms to provide balancing while avoiding congestions in the distribution grid, to provide congestion management services for both the TSO and DSOs and to improve voltage control at transmission and distribution level in the Spanish demonstration campaign. Likewise, the flexibility of hydro power plants is being demonstrated in the Swedish demonstration campaign to allow for an increased contribution from wind farms, by avoiding congestions in distribution grids.

➢ Remaining Challenges

The following topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the projects identified/mentioned below:

- The possibility to test an entire process of management of flexibilities services, meaning a real process of preliminary validation of resources by DSO, as well as blocking and limitation in case of contingencies by DSOs (**EU-SYSFlex**)
- Further work on coordinated active and reactive power provision under coordinated markets, or in a unique unified market mechanism (**EU-SYSFlex**)
- The possibility to establish some pilots with a full involvement of TSO and customers, scoping the test of flexibility market and services management (**EU-SysFlex**)
- Platform development and integration into the IEGSA (Interoperable pan-European Grid Services Architecture) system (**INTERRFACE**)
- DA, ID and real time market integration with the RES coordination platform (**CROSSBOW**)
- Use of AI based Digital Twins of generation flexibility assets (**FutureFlow**).

### 1.1.3 Storage flexibility & Energy Conversion

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Storage such as batteries appear as the more accessible technological option to guarantee to RES generation the needed flexibility; on the other side, PtX technologies are emerging as a promising option, allowing as well the desired integration with other "energy-related" networks, i.e. the gas and the heating/cooling ones.

Below there are some developments in these areas and some challenges still remaining to be addressed.

➢ Achievements

> The **Shar-Q** platform managed to cope successfully with the high load through ramp-up tests, soak and peak testing. In addition, it was able to manage enough capacity to deliver acceptable services in collaborative energy scenarios for small and medium size prosumers' infrastructures, showing potential for collaboration at regional level.

Project **Shar-Q** worked on the establishment of an interoperability network that connects the capacities of the neighbourhoods and wide regional Renewable Energy Sources (RES) and Electrical Energy Storages (EES) ecosystems into a collaboration framework that mitigates the requirement on the overall EES capacities thanks to the shared capacities among the participating actors. The **EU-SysFlex** project achieved large-scale battery operating in the FCR (Frequency Containment Reserve) market (with development on-going to include office-scale battery to FCR), customer-scale batteries control testing according to FCR rules, and validation of the activation of active power provision (TLQ-Traffic Light Quantification) for the TSO from distributed resources including storage, ensuring the execution time of TLQ process and network secure operation margins while delivering active power. **Netfficient** explored the deployment of heterogeneous storages in residential and front the meter applications. In project **INSULAE**, engineering and battery sizing was further developed. Project **FLEXITRANSTORE** worked on GT-battery (Gas-Turbine Battery) integration for flexibility provision. **InterFlex** managed to use a battery of 165 kWh to prevent local congestion. **CROSSBOW** project has investigated the topic of storage flexibility through studies for the integration of Virtual Storage Plants in the south east European region with the aim to address the intermittency of RES plants and subsequent power deviations occurring due to forecasting errors.

➢ Remaining Challenges

The following topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the projects identified/mentioned below:

- Identify where to apply local grid storage. Deeper in the grid enables better congestion management but less options for aggregators on energy markets, and vice versa, leaves open how to optimise this (**InterFlex**).
- Improved coordination in the use of the storage by the DSO and TSO (**EU-SysFlex**).
- New application of storage systems foreseeing a full integration of devices owned by third parties or directly by DSO with the operation of network processes managed by DSOs, e.g. using of storage systems like first generator for black-start applications; evaluate the rebound-effect from including storage flexibility (**EU-SysFlex**).
- Use of storage and power electronics to stabilise weak grids and micro-grids (**INSULAE**).
- Improvements on system aspects and components such as platform, the AVSs (Automatic Voltage Switchers), the adapters, usability/user interfaces, training issues, business cases, markets, additional functionalities and stakeholder involvement (**Shar-Q**).
- Integration of vehicle to grid applications (**Netfficient**).
- Lack of sufficient storage plants and national market framework in order to adopt the utilisation of storage plants under a common market framework in the south east European region (**CROSSBOW**).

### 1.1.4 Network flexibility

Transmission and Distribution networks can and should also contribute to the flexibility of the system. These can be done by means of **flexible power electronics**, such as FACTS (Flexible Alternating Current Transmission System), PSTs (Phase Shifting Transformer), HVDC (High Voltage Direct Current) links or smart transformers. These should provide an increased network observability and controllability, improving the management of power flows and voltages, therefore deepening the integration of variable renewable energy sources in the system and allowing also larger fluctuation of loads. This network flexibility should also include flexibility provided by distribution network reconfiguration, standardisation of HVDC multi-terminal networks and dynamic solutions such as Dynamic Line Rating.

➢ Achievements

**CROSSBOW** project has developed and demonstrated a Forecasted Dynamic Line Rating (DLR) solution for certain OHL in the south east European region, utilising measurements from PMUs (Phasor Measurement Units) and weather forecasts which has proven that there are significant and hidden advantages for further exploitation of the capacity of OHL, compared to the static line rating capacity.

➢ Remaining Challenges

Deployment of DLR algorithm in more HV OHLs in order to improve transfer capacity in national and regional level (**CROSSBOW**).

### 1.1.5 Transport flexibility

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. All sources of flexibility must be employed along the entire value chain, to guarantee the stability and efficiency of the system at all time and geographical scales. The transport sector, with the growing penetration of electricity, offers a valuable potential of flexibility to the grid.

There is a strong need of reliability analysis, quantification and optimisation of the impact (opportunities and constraints) of EV interaction with the grid (Smart Charging and V2G) on urban and transmission grids. Services offered to the distribution and/or transmission network (flexibility and balancing) by electricity penetration in transport sector – both V2G and urban/long-distance pubic transport – need to be quantified and demonstrated.

Below are highlighted some developments and some challenges related to these issues.

➢ Achievements

The following aspects were addressed in the below mentioned projects. Project **InterFlex** explored Flexibility usage of EVs and local batteries. Project **EU-SysFlex** worked on Public EV charging stations network. The flexibility demo is done in an office building located in Helsinki, which has 8 AC charging stations (22 kW each). In addition, one fast charger located in Helsinki is included in the demo (DC charger, 50 kW). The demo is currently on-going and the aim is to test the flexibility control (i.e. reducing charging power). Solar-based EV charging station were studied in project **TILOS**. Still in project **TILOS**, an estimated annual balance of up to 3-4MWh for EV charging (20.000km) and 3-4MWh directed to the local distribution grid was achieved. Solar installation of the local island EV charger is operated under a net metering scheme (grid-tied). As such it can cover both local grid electricity needs and EV charging. Project **Store&Go** demonstrated the maturity of Power-to-Gas. PtG technical feasibility is analysed and is found that Proton Exchange Membrane Electrolysis Cell (PEMEC) has the lowest investment costs. The greatest effects from learning and scaling effects are expected for solid oxide electrolysis cells (SOEC) in the future. A carbon footprint reduction by 85% with PtG was obtained in this project.

Over 2200 charging sessions were recorded in **INTERFLEX**, on 13 chargers. The offered EV charging flexibility was around 40% of the charging time and 5kWh per charging session.

In **FlexiGrid** transport electrification, flexibility services were used for distribution grid operation.

As a benefit from storage integration, in project **INSULAE**, final RES generation integration of 100%, 68%, 30% were achieved depending on the demo island location. CO2 emissions reduction of 362 tCO2/year, 3.994 tCO2/year, 213 tCO2/year were also achieved depending on the demo island location.

E-vehicle charging with exploitation of V2G methods where EV batteries are used as energy buffers, was also explored in project **Shar-Q**. The **FlexiGrid** project worked on Flexibility services offered by transport electrification, especially Electric Vehicles with Grid to Vehicle G2V and Vehicle to Grid V2G capabilities on distribution grid operation, in particular for load flattening, system balancing and voltage support. **INSULAE** project performed analysis of grid impact of smart EV chargers integration and development of proper control strategies.

➢ Remaining Challenges

The following topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the projects identified/mentioned below:

- Further explore the concepts around private charging stations, V2G, other CPO (Charging Point Operator)/network operators' charging points (**EU-SysFlex**).
- Integration of the EV sector for DR purposes (**TILOS**).
- Licensing and regulatory regimes are still a challenge to address (**Store&Go**).
- EV owner compensation model (**EU-SysFlex**).
- Assessment of EV DR potential (**TILOS**).

- Getting more EV drivers engaging in EV flexibility. Using EV flexibility on a specific location requires a large percentage of EV drivers to engage (**InterFlex**).

## 1.2 Energy System Operation

### 1.2.1 State Estimation and Supervision

The system supervision and state estimation is well established at higher voltage levels, while this does not apply at the MV/LV levels, that are becoming important, especially in the context of smartgrids. The following achievements and remaining challenges are noted:

➢ Achievements

Monitoring of secondary substations was performed at **Ebalance-plus** project. Phase voltages, consumption, PV production, and battery charging/discharging state were measured every 1s (for operation of microgrid and PV curtailment), stored at 1 min time resolution and some every 15min or 1h resolution (**COMPILE**).

State Estimation Tools with limited amount of measurements were developed at **EU-SysFlex** and **EUniversal** and increased Observability and State Estimation of MV and LV distribution systems using smart meter data was achieved in **INTERRFACE**. Grid monitoring of LV and MV grids and state estimation for LV grids and Load Allocation for MV grids was developed in **InteGrid**. State estimation, visualisation, GIS integration, battery management and EV management was performed in **WiseGrid**.

Advanced forecasting and data flow between DSOs and TSOs was developed in **INTERRFACE** and forecasting for load and RES was developed in **Wisegrid**. An innovative DSO platform for addressing management and maintenance activities of the distribution grid by merging operational and information technology (OT, IT) capabilities was developed in **NobelGrid**.

Quantified results are noted in the project **InteGrid**. In particular, estimation of voltage magnitudes in LV grids with 10% of smart meter measurements with real-time communication provided an error below 0.004 p.u. Reliable active and reactive power estimations on feeders by MV load allocation to the MPOPF (Multi-Period Optimal Power Flow) tool. For an entire month (January), MVLA (Medium Voltage Load Allocation) average absolute errors (0.24 KW and 0.09 kVAr) and maximum (7.76 kW and 1.77 kVAr). MAPE below 10% for secondary substations, normalised MAE below 8% for wind and solar power forecasting.

In project **InteGrid**, the voltage magnitude in LV grids has been estimated with an error below 0.004 p.u. only with 10% of the smart meters.

In **NobelGrid** an innovative DSO platform for management and maintenance has been developed by merging OT and IT capabilities.

Additional quantified results are mentioned in project **NobelGrid**, where RES forecasting modules performed well, compared to alternative tools for 2 days ahead forecasts. Load forecasting and load decomposition modules performed slightly lower than the other modules due to the large amount of missing data in the evaluation dataset (≈70%).

A phasor-measurement unit (PMU) aided state estimation in real transmission networks for monitoring the power transfer at cross border tie-lines is developed and incorporated in the WAMAS (Wide Area Monitoring and Awareness System) tool of **CROSSBOW** project. This tool is gathering transmission network real time measurements, identifying network problems such as regional oscillations, voltage phase angle mismatches, lack of inertia, etc. and react at the timeframe of millisecond. Thus, it handles the network status and topology while performing security analysis and identifying current or forecasted security problems, in case of the future contingent situations (N-1 or N-2, etc.).

The Spanish and the Greek demonstration campaigns in **CoordiNet** are developing or updating existing DSO monitoring tools in order to improve both grid observability and state estimation systems.

- Remaining Challenges

Further research is required on optimisation algorithms both in aggregator and local hub level (**INERTIA**). The lack of standardised data format for communicating between the different components makes the integration of the different modules and services more difficult (**NobelGrid**). Moreover, integration of more PMUs in the SEE region's corridors in order to provide higher accuracy in supervision of regional power flows (**CROSSBOW**).

## 1.2.1 Short Term Control

The stochastic nature of renewable energy sources requires advanced control techniques at different time scales, in order to balance production and consumption at all times. At short-term, after the imbalance the following was achieved:

- Achievements

In **COMPILE,** measurements about voltage levels at each phase, consumption and PV production and charging/discharging power of batteries can be customised/ adjusted on the use case. Data can be measured in 1s (for operation of microgrid and PV curtailment), stored at 1 min time resolution (Luče pilot site), 15min time-resolution (Rafina) or 1h resolution (Crevillent, Lisbon).

Control of renewable resources based on real-time network conditions has been developed in **COMPILE**.

The contribution of RES to primary voltage and frequency control of power grids with emphasis on weak grids has been explored in **FlexiGrid**. Short-term congestion management (50% redirection of power flows) has been achieved in FLEXITRANSTORE. Predictive control of flexibility (storage, OLTC (On-Load Tap Changer), controllable loads, capacitor banks, RES) has been developed in **InteGrid**. Short-term control strategies to manage storage in aggregated and disaggregated manner and for congestion relief with power flow controllers SSSC (Static Synchronous Series Compensator) have been developed in **Netfficient**.

Concerning quantified results, in project **INTEGRID**, technical problems (over/under voltages, overloads), have been avoided in 100% of the occurrences, by applying predictive control actions. Project **INTERFACE** managed to increase the reliability and power quality, by reducing the number and magnitude of voltage deviations of more than ≥ 2%, as required by grid codes.

An innovative demonstration of over and under frequency protection with real time control scheme using PMUs is accomplished in **CROSSBOW** project. It allows calculation of over/under-frequency protection settings and control scheme in TSO or regional level. The centralised system for the OFP (Over Frequency Protection) could be WAMPAC (Wide-Area Monitoring, Protection and Control), SCADA or hybrid solution WAMS – SCADA.

Innovative voltage control product and market have been designed and will be tested during the Spanish demonstration campaign of project **CoordiNet**. The time horizon of the market is one week, but the operation will be made every day.

- Remaining Challenges

There were no remaining challenges identified in this topic by the projects.

- The centralised system for the OFP could be WAMPAC, SCADA or hybrid solution WAMS – SCADA. As the **CROSSBOW** consortium includes only WAMS/WAMPAC vendors, only technical solutions based on this type of systems are demonstrated in this project.
- Coordination of inverters was identified in **COMPILE**.

## 1.2.2 Medium and Long Term Control

At longer time scales the following control has been achieved:

- Achievements

Multi-period optimal power flow for medium voltage grids and medium term load and renewable energy forecasting was developed in (**InteGrid**).

Forecasting and P-Q-optimisation for operational planning (real time and schedule-based) was developed in **EU-SysFlex**.

Grid Balancing and Stability and Day Ahead Topology Optimisation was achieved in **inteGRIDy**. Control strategies for Distributed Resources, like EVs, storage, residential demand, and power for desalination plants were developed in **INSULAE**. BESS site controller was developed for the Samsø island demonstrator in **SMILE**.

Network planning and operation were optimised considering the available flexibility from the grid and market-based services. New criteria for operational planning both in normal and emergency operation were developed - taxonomy, procedures and performance metrics (**EUniversal**)

Fully automatic frequency restoration reserves (aFRR) services, able to continuously drive consumption and renewables production up and down based on the needs of the Power System were developed in **FutureFlow** and demonstrated in successful field pilot tests of DR&DGs taking part in aFRR service

Concerning quantified results, project **FutureFlow** demonstrated that with 48 MW of flexible power, prosumers can deliver flexibility services to the TSOs. Simulations show the potential to save 23 % of regulating energy by the integration of flexibility markets in 4 countries.

> With 48 MW of flexible power, **FutureFlow** demonstrated that prosumers can deliver high quality flexibility services to the TSOs. FutureFlow simulations show the potential to save 23 % of regulating energy by the integration of flexibility markets in 4 countries.

- Remaining Challenges

There were no remaining challenges identified in this topic by the projects.

## 1.2.3 Preventive control/restoration

Preventive Control and Restoration become very important in order to enhance the resilience of the power system. The following has been achieved.

- Achievements

Adaptive/self-healing control for distribution networks, notably in the advent of extreme climate events was developed in **EUniversal**. Operation in island mode (Microgrid) has been achieved in **COMPILE**.

Multi-period optimal power flow to follow the predictive plan or adjust it, if necessary Predictive control of flexibility (storage, OLTC (On-Load Tap Changer), controllable loads, capacitor banks, RES) was developed in **InteGrid**. In the Samsø island demonstrator, remote shutdown/restart was tried in SMILE. A black-out recovery mechanism was tested in **TILOS**.

Tool for enhancement of transmission system resilience during emergencies in order to minimise cross-border power exchange cost between SEE countries when a major incident occurs, was developed in the **CROSSBOW** project.

A Pan-EU or multi-regional system restoration is examined in **INTERRFACE**, based on the coordination of tie lines and/or black start units, while considering system condition, system constraints, available resources and regulatory rules

The aim of **INTERRFACE** is to develop a single platform for demonstrating use cases on (a) congestion management (from TSO and/or DSO side); (b) frequency/balance management in TSO side, including mFRR, aFRR, FCR products and demonstration in cross-border usage; (c) flexible grid connectors, where both contracts and technical feasibility will be demonstrated; (d) trading between interested market participants (like BRPs-Balance Responsible Parties- or prosumers). A Pan-EU or multi-regional system restoration based on coordination of tie lines and/or black start units is also studied, while considering system condition, system constraints, available resources and regulatory rules. The project also examines the minimisation of negative impacts of switching actions from one Transmission System to the neighbouring ones.

- Remaining Challenges

Intended Islanding, i.e. transition from grid-connected to islanded operation in order to improve reliability and resilience of distribution networks (**EU-SysFlex**).

Adaptive protection, R&D in information/analyses about the needed settings for protection elements when they are operating in island mode (**COMPILE**).

Prognostic tool for grid faults (**TILOS**).

Forecasted CGM (Common Grid Model) automated input feed to the model in regular time intervals (**CROSSBOW**).

## 1.2.4 Control Center technologies

- Achievements

TSO/DSO coordination platforms for the identification of flexibility requirements to interact with local markets and with embedded functionalities were developed in **INTERRFACE**.

Development of platforms for virtual power plant, DR units aggregation, cross-border aFRR TSO co-optimisation, replica of TSO ACE management platform in **FutureFlow.**

Energy Management Centre for island Microgrid in **TILOS.**

Integrated LV/MV (Advanced Distribution Management System) with LV/MV forecasting, MPOPF (Multi Period Optimal Power Flow), MVLA (Medium Voltage Load Allocation) and LVSE (Low Voltage State Estimation) was demonstrated in **InteGrid.**

TSO/DSO coordination platforms have been developed in **INTERRFACE**, allowing the identification of flexibility requirements and the interaction with local markets, alongside with embedded functionalities.

By the **WiseGrid** cockpit outage duration was reduced from 38 to 1.75 minutes, while the voltage remained within limits 100% of the time.

Concerning quantified results, outage duration due to faults reduced from 38 to 1,75 minutes by the WG Cockpit in project **WiseGrid**, while the voltage was maintained within the desired range 100% of the time and 54.00 to 85.52% positive VPP participation was noted in flexibility requests. Moreover, the Coordinated Voltage Control module in Project **NobelGrid** successfully managed to reduce voltage deviation by an average of 4%, while reducing the network power losses by almost 3%.

Software for real time check of common grid models was developed in the **CROSSBOW** project, aiming to further improve the quality of CGMs as of major importance of the regional control and operational centres.

New TSO-DSO coordination platforms have been developed in the three demonstration campaigns in the project **CoordiNet**, which also required updating some existing operation tools on both the DSO and the TSO sides.

Moreover, a generic architecture for the platform has been proposed and the required information exchanges among the different users of the platform are being identified.

- Remaining Challenges

Development of multi-vector EMC ((Energy Management Centre), integrating water and transport sector (**TILOS**).

Minimisation of the inevitable forecast error in IGM (individual Grid Model) to CGM (Common Grid Model) conversion process (**CROSSBOW**).

# 1.3 Energy System Planning

## 1.3.1 Integrated Energy system Architectures

- Achievements

Contributions can be considered structured in two different directions.

One direction is given by innovative DC grid solutions. In this case we have two main aspects reported

- Development of interoperable, reliable and cost-effective technology of protection for meshed HVDC offshore grids (**Promotion**)
- Development of new DC grids (**INSULAE**)
- The other direction is given by results related to Sector Coupling:
- Water-energy nexus / RES-based EV charging (**TILOS**)

Correspondingly, also the results can be organised the same way. Concerning DC grids:

- HVDC circuit breaker full-scale and high-power demonstration (**Promotion**)

In **TILOS**, 65kW of water pumping has been controlled to support higher RES penetration. The water pumping system operated at a CF of 35% on annual basis, an equivalent of around 20kW of average load, equal to around 6% of the island total average load.

In **SMILE** domestic heating systems, batteries, and EV charging stations have been coordinated in Samso and Orkney Islands.

Concerning Sector coupling and multi-energy systems:

- In the Samsø island demonstrator, Electricity is coupled with heating and transport (**SMILE**)
- In the Orkney Island demonstrator, load controller (aggregator platform) able to control domestic heat installs, EV smart charging and large industrial load to support the local grid in increasing the demand side management capacity and reduce levels of curtailment (**SMILE**)
- Control of community water pumps to support higher RES penetration through load shifting / Solar-based EV charging station (**TILOS**)

In relation to **quantitative results**, the following have been reported:

- In the Samsø island demonstrator, 1 sauna; 3 heat pumps; 3 electric vehicles; up to 340 boat batteries can be charged (**SMILE**)
- In the Orkney Island demonstrator, number of installations to be controlled by the load controller (aggregator platform): Domestic Heating Systems (including BESS, PCM based heat battery, Air Source Heat Pump etc.) installed in more than 40 proprieties, EV smart charging installed in 16 proprieties (**SMILE**)
- Control of ~65kW of water pumping operated at a CF of ~35% on annual basis, or an equivalent of ~20kW of average load, equal to ~6% of the island total average load (**TILOS**)
- Blockchain-based TSO-DSO flexibility platform with 100 transactions per month (**INTERRFACE**)

- Number of aggregated sites: 45 residential and 1 Front-the-meter storage (**Netfficient**)

➢ Remaining Challenges

- Process of transition to DC grids (**INSULAE**)
- Aspects related to integration of multiple energy grids interaction still to be developed (**INSULAE**)
- Integration of the solar EV charging station at the HL-EMC (**TILOS**)
- Business model for a unified platform scalable (**inteGRIDy**)
- Integration of the heating/cooling sectors (**TILOS**)
- When creating an intelligent platform with blockchain technology - the need to harmonise GDPR guidelines - finding a solution for this situation (**SHAR-Q**).

## 1.3.2 Long-term planning

➢ Achievements

Even for this topic two main directions can be identified. On one hand, an area of research is related to optimisation. In this case the following topics are reported:

- Grid Balancing & Stability Engine, Day Ahead Topology Optimisation (**InteGRIDy**)
- Optimisation of the network planning and operation based on available flexibility both from the grid and market-based services - new criteria for network investment both in normal and emergency operation - taxonomy, procedures and performance metrics (**EUniversal**)

Another aspect is given by innovative technologies in support of planning. In this direction the following topic has been reported:

- create an intelligent platform with block chain-based technology for long-term capacity (**INTERRFACE**)
- a block chain-based peer-to-peer trading platform has been developed and is being tested in the Swedish demonstration campaign of the project **CoordiNet** to settle transactions for congestion management in two distribution grids.

In this area, results are reported indicating innovative tools in support of the planning such as:

- Simulation and planning (long term) for San Severino Pilot (**InteGRIDy**)
- Investment Planning Tool (IPT) that will support the decision maker on the selection and design of cost effective Action Plans looking for an island decarbonisation (**INSULAE**)

**INSULAE** has developed an Investment Planning Tool (IPT) to support decision makers on the selection and design of cost-effective Action Plans for decarbonisation of islands.

➢ Remaining Challenges

- In the Madeira island demonstrator, by considering the most recent changes in legislation, future work should definitely address the creation of new markets, more particularly in the context of energy communities (**SMILE**)

## 1.3.3 Asset management and maintenance

➢ Achievements

For this topic, the focus is always on the direction of increasing the overall network resiliency and the following topics have been reported:

The platform developed in **NETFFICIENT** includes work orders and maneuvers for battery calibration and restoration. 45 residential sites and one Front-the-meter storage site have been aggregated.

- Evaluation of fault indicators and predictive maintenance (**InteGrid**)
- Definition of strategies for asset management and maintenance (**Netfficient**)
- Weather resilience (**FLEXITRANSTORE**)

The following achievements were also reported:

- The platform includes work orders and manoeuvres for battery calibration and restoration (**Netfficient**)
- Smart De-icing protection of OHLs (**FLEXITRANSTORE**)

➢ Remaining Challenges

- Taking predictive maintenance from TRL 6 to market. Usefulness of fault indicators in major events. (**InteGrid**)
- Artificial intelligence for predictive maintenance to reduce costs (**Netfficient**)

## 1.3.4 System Stability analysis

➢ Achievements

In this area the topics reported do not stress much theoretical aspects while, vice versa, more approaches that can be adopted to support the overall system stability.

In particular, the following aspects are mentioned:

- Grid Balancing and Stability Engine, Optimisation-based Energy Management, Multi-Objectives Optimisation Strategies; Energy Integrated Information System, Multi-Carrier Hub Optimisation Engine, Integrated Decision and Support Supervisory System, MV Distribution Networks Management Tool, NEMO (Nominated Electricity Market Operator) tool, Intelligent Building Control and Flexibility Prediction-Forecasting, Distributed Energy Management System, Supervisory Model Predictive Control, Demand Side Energy Profiling, Integrated test environment, Zero Technology, Heat pump remote control (**inteGRIDy**)

A grid Balancing & Stability Engine has been developed in **inteGRIDy**, alongside optimisation-based Energy Management and Multi-Objectives Optimisation Strategies.

- Establish interoperability between different technologies and concepts by providing specific technical and operational requirements (**Promotion**)
- Power oscillations (**FLEXITRANSTORE**)
- Island system vulnerable to black-out events due to faults at the broader electricity system (**TILOS**)

From the system operation perspective, the following results have been reported:

- Design an energy advisor and automation system to increase the grid resilience by using the available flexibility and the monitored information from the distribution grid: detection of LV faults, improving LV quality, optimising LV power flow, distributed energy resources power flow, optimised power flow and fault detection, isolation and restoration (**Ebalanceplus**)
- In the Madeira island demonstrator, deployment of cloud-based control of PV-BESS in local micro-production sites (domestic and commercial). Two main control strategies were considered. Greedy and Forecast-based control (load and solar PV production forecast) (**SMILE**)
- Real time monitoring of grid status through data acquisition of synchro phasors using the WAMAS tool (**CROSSBOW**). The system receives the data coming from (Wide-Area Protector) WAProtector

(comprising SCADA data, PMU data and alarms eventually identified by the WAProtector). Moreover, it is capable of processing and adapt this data to extract relevant information and calculate KPIs on top of the raw received data, apart from storing the measurements and KPIs in a database that is suitable for later analysis.

At component level:

- Intelligent converters for stability purposes (**FLEXITRANSTORE**)

➢ Remaining Challenges

- In the Madeira island demonstrator, frequency control was only covered from a theoretical stand point. In practice it was not possible to assess this due to hardware limitation (this would require a high frequency smart-meter > 1 kHz) (**FLEXITRANSTORE**)
- In the Madeira island demonstrator, ultimately, one of the main conclusions is that it may be better to do voltage and frequency control at the micro-production site. This would imply the deployment of smaller batteries (less capacity), with higher ramping rates (i.e., larger inverters). (**SMILE**)
- Further automation of black-out recovery mechanism (**TILOS**)
- Prognostic tool for grid faults (**TILOS**)
- Considering the interconnection of multiple nano/micro grids to create isolated communities e.g. in developing countries following a bottom-up approach (**Ebalanceplus**)
- In the Madeira island demonstrator, frequency control was only covered from a theoretical stand point. In practice it was not possible to assess this due to hardware limitation (this would require a high frequency smart-meter > 1 kHz) (**SMILE**)
- Further automation of black-out recovery mechanism (**TILOS**).

# 2. The Customer at the centre

The target of at least 32% of renewable energy in gross final energy consumption in 2030 relies on the participation of citizen in the energy transition. In the process of acceptance of the integration of variable Renewable Energy Sources (vRES), social and environmental aspects must be considered at all levels.

## 2.1 Social campaigns and social studies

- Achievements

*Awareness and behavioural changes*

Active social awareness raising campaigns were conducted in **Compile**. In **Insulae** a number of workshops was organised for the engagement of the local citizens to cleaner energy and the creation of energy communities. Civic engagement campaigns (in the Samsø island demonstrator) and customer acceptance campaigns (in the Madeira island demonstrator) were organised in **SMILE**. Social identity theory, local social cohesion, contextualised behavioural demand response, and social network for energy communities (with individual and collective energy feedback) were topics of **Integrid**. In **MERLON** energy community engagement to support the local grid operation was advocated. A series of local surveys and training seminars on RES, energy storage, energy saving, smart metering, demand side management, electromobility, etc. and two geographical surveys across the Aegean Sea (for the replication of TILOS replication on small islands) was organised in **TILOS**.

*Tools and technologies*

In **Making City**, citizen engagement strategies and means/tools were developed and in **GreenSoul** different technologies to foster Energy Efficiency in public buildings were assessed.

In this area we have the following **quantified achievements**

In **GreenSoul**, different technologies have been assessed to foster Energy Efficiency on Public buildings, covering 5 pilots and more than 200 people. Up to 15% of energy reduction on key scenarios has been achieved.

In **GreenSoul** up to 15% of energy reduction on key scenarios for Energy Efficiency in Public Buildings was noted. Different technologies to foster Energy Efficiency in Public buildings was assessed.

In the Samsø island demonstrator social campaigns and social studies were performed by questionnaires, newspaper articles, press release, online debates, open house events, Facebook page, 100 visitors to the **SMILE** battery house. In the Madeira island demonstrator, the engagement activities were successful at recruiting the necessary participants for the different pilots. More than 70 households were contacted, 23 properties were selected to install the SMILE DMS system. In the Orkney Island demonstrator, 128 persons registered interest to participate, 20 sets of electricity and temperature monitoring equipment was installed. (SMILE)

In **TILOS** the local public engagement is estimated at 15%-20%. End-user smart metering and selected loads control reached ~100 end-users. More than 1.800 respondents (~2/3 of Aegean islanders) advocate for the adoption of the Tilos energy paradigm.

- Remaining Challenges

Testing with larger sample size (more households), wider variation in socio-demographic characteristics, over longer periods of time for impacts on electricity consumption behaviour (**InteGrid**). Testing from a multi stakeholder perspective in which citizen engagement and energy communities take a central stand. How to realise citizen engagement in practice (also changing stakeholder internal processes and key values (e.g. municipalities). (**MakingCity**). Feasibility studies for replicability of smart grid solutions considering social aspects related to the project participants and stakeholders behaviour (**NobelGrid**). More local social campaigns and training seminars for prosumers for further advancement of the existing ecosystem (**TILOS**). Anthropologic studies for acceptance among specific groups (visiting boat owners in the Samsø island demonstrator) and sustainability and eco-feedback studies to keep consumers engaged and avoid the so-called relapse phenomena (Madeira island demonstrator) (**SMILE**)

## 2.2 Adaptive consumer/user behaviour incl. energy communities

➢ Achievements

Methods and tools to support consumer and prosumer adaptation of their energy behavior were developed in **FlexiGrid** together with the definition of KPIs for customer satisfaction and rate of self-Consumption. The organisation of energy communities was supported in **Insulae**. Energy end-user behavior characterisation by a quantitative and qualitative study (**Ebalance Plus**)

*Tools*

Home Energy Management systems for residential demand response, energy use reduction, and energy consumption behaviour change through real-time energy feedback, price and environment signals, in energy community network were the topics of **InteGrid**.

A dedicated tool called WiseHome that serves as the interface with the residential electricity consumer or prosumer and a dedicated tool for energy communities called WiseCOOP were developed in **Wisegrid**. Integration of prosumer EMS platform with DSO's SCADA has been realised through FLEXICIENCY Market Place platform, to negotiate and activate day ahead flexibility (**FLEXICIENCY**). Use of IoT technology and monitoring control actions (user profiling) taking into account thermal and visual comfort of building occupants (Inertia). A grid and market hub (gm-hub) was developed to promote flexibility and data exchange between domestic prosumers and DSO. (**InteGrid**). In **NobelGrid** it has been demonstrated that smart meters provide efficient low-cost IoT solutions for both enhancing the visibility of grid and empowering end users by making their data easily available to them. Moreover, it has demonstrated the ability to use the data from the smart meters so as to monitor the power quality of the network in a cost effective way.

*Demonstrators*

Organisation of three living labs (two in Austria and one in Spain) with active participation of prosumers guiding the developments of the project (**MERLON**). The touristic harbour (Ballen Marina) was used in the Samsø island demonstrator and a DMS was installed in order to maximise the self-consumption from PVs and provide knowledge on consumption of individual appliances for load shifting in the Madeira Island demonstrator (**SMILE**).

In this area we have the following **quantified achievements**

In the **FlexiGrid** project the motives for participation in flexibility provision were investigated: energy bill reduction scored 4.30/5 and financial incentives scored 4.07/5.

In **InteGrid** pilots included an evaluation of 150 smart homes with HEMS and 150 social energy community network apartments in Sweden and similar number of residents in Portugal. Preliminary KPIs show a relative peak load reduction of 67.5% among 290 (11%) participating households and mean energy use reduction of 5.12%. Considering all apartments, a mean peak load reduction of 5.0% is achieved and all single apartments a reduction of 9.1%. 10.9% mean energy reduction in all apartments and 16.2% in single apartments.

➢ Remaining Challenges

Cost-benefit analysis of HEMS considering different types of regulatory frameworks (e.g., dynamic tariffs, provision of system services). Also, aggregation of LV prosumers for active participation in electricity markets (**InteGrid**). More research on the development and support of energy communities in a multi-stakeholder network. Consideration of a multi domain perspective, i.e. not only energy, but other aspects that affect quality of life. (**MakingCity**). Use of energy data for non-energy services (like remote health monitoring (**Insulae**). Cost-effective solutions for the wider application of battery systems in the market for the population. One solution is to rent (**SHAR-Q**). Exploration of demand response business models at the individual and aggregator level for island regions. Advancement of active consumers to PV (and storage) prosumers (**TILOS**). Wider test of the functionalities in real conditions. Improve communication with smart meters (**Wisegrid**) and use of smart meters (and other innovative technological solutions) to increase end-user engagement (**Ebalanceplus**). Technical aggregation – investigate the best way to aggregate small-scale batteries (**EUSysFlex**). Automated customer appliances connected to aggregator EMS for adaptation of the consumption to the network needs. (**FLEXICIENCY**). Solutions for demand response of the residential sector besides public buildings (**GreenSoul**). User profiling: models for the extraction of more accurate user profiles. Development of facility manager enhancement tool that includes updates on the models of the local hub environment and updates of the applications for the end users of the building to support managers towards a holistic management and maintenance tool (**Inertia**).

In project **INERTIA**, thermal discomfort was kept within acceptable levels (less than 45% discomfort) and as low as 29% discomfort (in comfort mode), on a scale where 25%-50% discomfort is considered acceptable.

## 2.3 Consumer and prosumer device control

- Achievements

**Ebalance Plus** dealt with end-user engagement and management of building devices via IoT-based systems. Monitoring and control of residential flexibilities and control of customer-scale and office-scale batteries was performed in **EUSysFlex**. In-home ICT technologies for smart appliances (for example smart load controllers) for direct control of consumer demand, incl. visualisation via in-home displays were developed in **FlexiGrid**. DSM for Commercial and Industrial customers and control of Distributed generation to provide aFRR ancillary service via device control was developed in **FutureFlow**. Automated control of building's assets (HVAC, lights, other appliances) was applied by the building subsystem (Local Control Hub holistic flexibility framework) in **Inertia**. A home energy management system for domestic prosumers was developed and demonstrated in **InteGrid**. Prosumer device control was developed in **Netfficient**.

In this area we have the following **quantified achievements**:

In the **EUSysFlex** project, 12 customer-owned batteries with average power of 3 kW, and capacities varying between 1.5 kWh and 16 kWh have been monitored in a demo. 71% of the participants have noticed some difference in the battery operation, while few noticed that the battery started to charge/discharge when normally it would not. Several customers thought that participation to flexibility provision would be beneficial and useful.

In the **EUSysFlex** project 12 customer-owned batteries with average power about 3 kW, capacities vary between 1.5 kWh and 16 kWh participated in the experiment. 58% answered to questionnaires. 71 % had noticed some difference in the battery operation during the demo (not all demo related difference). Few noticed that the battery started to charge/discharge when normally (without flexibility control) it would not; Several customers thought that participation to flexibility provision would be interesting/beneficial/useful; Some pointed out, that flexibility operation is well suited for winter time (since there is only little or no PV production to store and due to this, battery operates passively); Some pointed out that optimisation based on electricity price would be also interesting.

In **FutureFlow** fast device consumption response times, i.e. less than 5 min activation times were demonstrated. 100+ devices were connected in a virtual power plant and controlled during 1 year in a pilot installation.

In the **Inertia** project potential of 18%-28% CO2 emission savings, while keeping thermal discomfort within acceptable levels ( < 45% discomfort) and as low as 29% discomfort on a scale where 25%-50% discomfort is considered acceptable.

In **MERLON** energy savings by HVAC operation modification up to 20% during a month period within winter were estimated in a lab environment. User perceived thermal comfort up to 97% within a week of operation in a thermal comfort mode.

In **Netfficient** 45 residential and 1 front-the-meter storage device were aggregated (prosumer) and their energy consumption forecasted.

- Remaining Challenges

Development of fast demand-response units for more risky processes, such as main product production process - e.g. drinking water distribution pumps power control (**FutureFlow**).

# 3. The importance of a Market Based Energy System

To meet the EU "Green Deal" and related European national targets one of the fundamental elements is Markets as a key enabler of the energy transition.

A significant **revision of electricity market rules** underpins the European Union's ambition to further boost penetration of renewables in the power system.

Additionally, the recent clean energy legislation requires that Electricity Markets are created with "active customers/ consumers and citizens" and "energy communities". Renewables self-consumers are to be empowered to generate, consume, store, and sell electricity without facing disproportionate burdens.

Finally, the integration of multiple energy carriers into a system of systems requires that an enlarged multiplicity of stakeholders is considered.

To achieve the above, the following two key areas need to be considered:

- **Business models**
- **Market design and governance (Retail, Wholesale; Cross-border; Ancillary services; Flexibility markets; etc).**

## 3.1 Business models

Below are listed some achievements that were obtained in several projects that addressed or are addressing Business Models related issues:

➢ Achievements

Some work has been done in the areas of ***developing and evaluating business plans***. In project **InteGrid**, up to 10 business models stemming from the project functionalities identified and characterised: stakeholders involved, possible market strategies, and existing barriers (regulatory, technical, economic, stakeholder-related). In project **Wisegrid**, 7 Business models for 8 key actors were studied. In total 21 Business cases were analysed.

Some of those business plans were ***related to batteries and storage usage***. In project **FlexiTranstore**, battery storage related business models were studied. In project **TILOS**, business models for battery storage with emphasis on energy trading strategies and coupling with RES – thorough assessment of financing structures, were explored. In project **Netfficient**, the business models of the aggregated storages in residential and front the meter applications were studied.

***Business plans related to grid flexibility and flexibility services*** were also explored. Business Model Canvas for flexible grid solutions was developed in project **Ebalance-plus**. Economics of flexibility provision and acquiring were explored in project **EU-SysFlex**. The provision of DER flexibility services, data services for distribution system users, data and flexibility exchange platforms, behavioural demand response strategies were developed in project **InteGrid**. Provision of reactive power to TSO and DSO with a local reactive power market was achieved in project **EU-SysFlex**.

In some situations, an evaluation of ***business cases from the use case point of view*** was performed. Development of specific business model per each Use Case was performed in **Insulae**. **Inertia** explored and examined different business perspectives: i) Utilising Prosumer Flexibility, ii) Offering Ancillary Services to System Operators, iii) Utilising Portfolio Flexibility for Imbalance Risk Reduction Services.

Business model canvas with nine-building blocks was developed for each **CROSSBOW** product as well as other details regarding the cost evaluation and pricing mechanisms. Various insights for policy makers and actors in the power system. New services related to demand response, electric vehicles and renewable energy sources that can bring more profit and benefits to the consumers and members of the value chain.

***Data exchanges*** needed for the implementation of the business plans was also briefly addressed. DSO using DER flexibilities from different sources and a platform enabling data exchange between domestic consumers and the DSO and the retailer was achieved in **Integrid**.

Finally, some ***specific economic results*** were obtained. In the Samsø island demonstrator in project **SMILE**, BESS improved the utilisation of the PV plant to 90% (45% without BESS), with a payback period of 4 years and a loan financed with maturity of 20 years. Reduction investment cost of offshore wind was achieved in project **Promotion**. It has been estimated that the new 320 kilovolts (kV) gas-insulated switchgear requires as much as 95 percent less space compared to current air-insulated solutions. If they are used on an offshore platform, the size of the platform can thus be reduced by approximately 10 percent, which is expected to have a positive effect in the business case.

In **Promotion**, the new 320 kilovolts (kV) gas-insulated switchgear requires 95 percent less space compared to current air-insulated solutions, allowing a reduction in the size of the offshore wind platform by approximately 10 percent.

Many achievements allowed to validate particular technologies, explore a proof of concept or identify inefficient vs. efficient solutions. On the other hand, despite the achievements mentioned above, it should be noted that some tests, demonstration and pilots, very often concern a specific setting and context, and are, therefore difficult to extrapolate as a general conclusion. Therefore, some topics, although already addressed, require further analysis and evaluation. Furthermore, dynamics in political, economic, environmental and social trends, require the evaluation of new dimensions in the different challenges. The following section addresses some points identified as remaining challenges.

➢ Remaining Challenges

With an increased emphasis in moving toward a System of Systems, sector-coupling, an Integrated Energy System and the increased participation of customers and Communities and the corresponding local management issues, the business models for the different actors, products and services applicable to the energy system (electricity, gas, heating/cooling, carbon neutral fuels, water, etc.) along its value chain needs revisiting and refinement.

The following topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the projects identified/mentioned below:

- Business models based on DER aggregation or on behavioural demand response deserve further studies (**InteGrid**)
- Evaluation of DR Business models: As the implementation of DR strategies is one of the main trends on the deregulated market, it is essential to further examine the potential impact of INERTIA Aggregator platform on real life business models. (**Insulae**)
- Identification and establishment of remuneration schemes for storage and DR ancillary services (TILOS) and the incentive and remuneration mechanisms for flexibility services (**Ebalanceplus**)
- The procurement of DER flexibilities through market-based mechanisms. Opening data platforms to different data service providers (**InteGrid**)
- Very important to find solutions for cost of reactive power compensation provision to the asset owner (the reactive power market concept) (**SHAR-Q**)
- Economic viability of the proposed business models coupled with appropriate contract templates for a fair and transparent settlement and remuneration among the actors involved (i.e. aggregator - prosumers, aggregator – DSO, aggregator - TSO) – (**MERLON**)
- Economic viability of flexibility service provision (income from market vs. costs of flexibility operation); Liquidity impact, profitability of participating in such market, need of reactive power capacity

mechanisms or connection agreements, and additional issues related with the convergence of the clearing algorithm when grid constraints cannot be guaranteed (**EU-SysFlex**)

- Power to X topics (**FLEXITRANSTORE**)
- The view of the different stakeholders involved should be an integral part of the evaluation of business models (**InteGrid**).
- Include the participation in other energy services together with eletromobility (**Netfficient**)
- Finding in the future what will be the most suitable type of control methodology for intelligent EV charging (**SHAR-Q**)
- Governance and business models for local electricity markets with ad-hoc DSO coordination scheme (**Ebalanceplus**)
- Business models for prosumers providing ancillary services, including EV owners with bidirectional capabilities and storage units (**Insulae**)
- Refinement of the business models after the demonstration campaign (**Insulae**)

## 3.2 Market design and governance

➢ Achievements

***Analysis of existing regulation and market rules*** was performed under multiple contexts and several recommendations were provided. In project **Integrid**, 30+ regulatory/market barriers to the development of the project solutions and 40+ regulatory recommendations were identified. In project **FutureFlow**, the project identified that an increase of the KPI “balancing market liquidity” would be achieved with regional market creation and higher involvement of prosumers. The pilot tests demonstrated that KPI “overall cost of aFRR energy provision” would be decreased by 30% at a regional level with the introduction of the proposed cooperation. Existing regulation and market rules/design was evaluated for five target countries (Portugal, Slovenia, Sweden, Spain and Austria). Existing barriers were identified and recommendations to overcome them were provided, in project **Integrid**. In project **Promotion**, recommendations for a coherent EU and national regulatory framework regarding DC offshore grids were proposed. Analysis of the existing regulatory framework to roll out a proposed business model was performed in project **INSULAE**. Identification of gaps and proposals for regulatory harmonisation was done in **FLEXITRANSTORE**. In project **SMILE**, after the analysis of the regulatory framework related to Electricity storage and Integration of electricity and heat supply systems, a set of recommendations have been defined with respect to the following topics: electricity storage (e.g. ending double-charging), EVs (smart) charging, isolated systems, energy communities. **NobelGrid** also identified that among the main enablers and barriers for project implementation is the regulatory environment, which might vary between the different EU Member States. Many of the 18 regulatory/legal areas are based on the different local and regional regulations and national laws of the Member States; also the EU Directives are implemented with various tools nationally specific. Two clear examples are the lack of clear regulation on the use of batteries and the role of aggregator that should be solved. In project **MERLON**, existing regulation and market rules/design were evaluated for two countries (Austria and Spain). Existing barriers were identified and applicability of the proposed business models in the two pilots sites was assessed. In project **TILOS**, evaluation of local Greek regulation and associated business model for Hybrid Power Stations (HPSs) in Greek islands was studied. In project **InteGrid** it was identified that the constraints posed by existing regulation limit the ability to test certain innovative market, tariff or grid operation approaches and that barriers to engaging stakeholders not partners of the project may limit the scope of the demonstration activities. It further highlighted that exemptions to some regulatory constraints (sandboxes) are required to test some innovative aspects related to these topics. Furthermore, more mature regulations need to be put in place to further drive the adoption of smart grid technologies and solutions as highlighted in **WiseGrid**. Regulatory framework is singled out as the major obstacle with 37.5% respondents giving it the highest grade, in **Flexigrid**. **FLEXICIENCY** further identified that regulatory sandboxes or cascading funds could support the transition period, if National Authorities agree. Adaptation of local regulation for the incorporation of battery technology special features to overcome previous tailored regulation was proposed in **TILOS**. This included new regulation provisions for battery storage in Hybrid Power Systems, e.g. concerning the minimum allowed capacity in relation to RES installed capacity. **CROSSBOW** project has carried out an extensive analysis on national regulatory and market frameworks in the south east European region while investigating the arising associated barriers when aiming to adopt cross-

**CROSSBOW** has carried out an extensive analysis of national regulatory and market frameworks in the south east European region, while investigating barriers in adopting cross-border regional solutions with assets from different countries. An intraday continuous energy market (ID platform) was developed, alongside a System market platform for mFRR (mFRR platform). The intraday continuous energy trading market allows participants to trade different energy products – 15min, 30min or 1h energy products every day.

border regional solutions with respective solutions that utilise assets from different countries and subsequently legislative frameworks. The project **CoordiNet** analysed existing regulation regarding the provision of system services in order to define the business use cases that are being tested in the three demonstration campaigns and which will provide the relevant recommendations at the end of the project.

Several ***market designs, rules and options*** were also tested and simulated. Detailed analysis and quantitative comparison through simulation of the outcome of different TSO-DSO coordination schemes in three EU Countries was achieved in project **SmartNet**, together with formulation of regulatory guidelines for NRAs. In project **EUniversal** the following was achieved: Design of flexibility markets for the procurement of grid services for DSOs - Applicability of distributed market concepts to deliver grid services for DSOs - Design of dynamic distribution network tariffs to mitigate congestions - Evaluation of different market designs with various market characteristics and existing market designs. Still in **FutureFlow**, the market design for regional cooperation in terms of balancing and redispatching with four countries involved – Slovenia, Austria, Hungary and Romania – was achieved. In addition, the gap analysis of current regulations and proposals for upgrades were analysed in order to include higher involvement of prosumers on the balancing market. Starting from the TSO-DSO coordination schemes defined in the project **SmartNet**, the project **CoordiNet** further refined the definition of the coordination schemes and proposed a structured way for classifying the responsibilities of different agents under each scheme, leading to more options of coordination among TSOs and DSOs.

Analysis of the ***redispatch process*** was also particularly addressed. **EUSysFlex** and **EUniversal** addressed Market Design and the Re-dispatch process. A German demo building up process in line with Redispatch process that needs to be in operation 10/2021 was achieved in project **EU-SysFlex**.

***Market design for flexibility services*** was addressed under several perspectives. Flexibility Services, in particular with battery integration, were evaluated in project **FLEXITRANSTORE**. Spatial aggregation of Local Flexibility was studied in **INTERRFACE**. DSO revenue regulation and regulatory incentives, procurement of flexibility by DSOs, network access and connection was explored in **InteGrid**.

Also, ***market design for ancillary services*** was studied to some degree. In project **EU-SysFlex**, technical proof of concept for local reactive power market was performed. In project **FutureFlow**, the key cornerstones of potential regional aFRR energy exchange cooperation were proposed (definition of standard product, gate procurement procedures, activation mechanisms, treatment of CZC (Cross-Zonal Capacity), settlement principles). Also, the recommendations on how to facilitate higher involvement of prosumers in the balancing market were defined. Market rules and coordination mechanisms for provision of ancillary services by aggregated storage and virtual power plants, comprising RES, flexible thermal generation (small and micro-CHP), heat-pumps, EVs, were proposed in project **FlexiGrid**. In **CROSSBOW**, an intraday continuous energy market (ID platform) was developed alongside with a System market platform for mFRR (mFRR platform). The intraday continuous energy trading market allows participants to trade different energy products – 15min, 30min or 1h energy products every day. The mFRR balancing energy market allows participants to trade with balancing energy where the activation of the energy is based on the manual activation process. The platform supports 15 minute products. The project **CoordiNet** defined a new product and a new market setup for the procurement of voltage control services in the Spanish demonstration campaign, but it also proposed new market setups and rules for local and common markets to procure congestion management services in the three demonstration countries.

The ***participation of demand-side in the market*** was partially addressed. Participation of demand-side resources in balancing markets, impact of tariff structure on the end-user benefits from demand response was addressed in project **Integrid**. Energy cooperatives/communities and smart EV Charging cooperative that have still to be regulated, were studied in project **Insulae**. The three demonstration campaigns in project **CoordiNet** make use of demand-side resources for the provision of flexibility, demonstrating cutting-edge applications, e.g. the Spanish demonstrator includes, for the first time, an industrial consumer providing balancing services in the real mFRR market in Spain, and it will also test the capabilities of that consumer as well as of medium-sized consumers linked to municipalities to provide congestion management services (which is not allowed to happen in real markets yet). In the Swedish demo, a wide variety of demand-side resources have been actively participating in the flexibility market including heating systems, aggregated consumer loads, storage and residential building blocks.

Other ***new market related developments*** were the following:

- In project **SMILE**, in the Samsø island demonstrator, in the touristic harbour consumers are billed by their actual consumption, instead of a fixed lump sum. Based on the results, the boat owners seem to be unconcerned about the electricity price.
- In project **TILOS**, a ~1MW/2.88MWh-scale, RES & battery-based HPS in full operation paved the way for the issuance, early in 2020, of more than 100 production licenses for battery-based HPSs in Greek islands. The first PPA for an Hybrid Power System (HPS) in Greece was achieved. It was also the first battery-based Hybrid Power System in Greece, with impact in the Greek island energy market, unlocking the potential for new HPSs in Greek islands. The complexity of HPSs tariff scheme was identified.
- Coupling of markets in South East Europe putting the focus on Intraday Market, Capacity Reserve Market, bilateral continuous trading and Guarantees of Origin was performed in project **Trinity**.

➢ Remaining Challenges

Despite the achievements mentioned above, the following particular topics were not completely covered by the previous work developed and should be considered in further research work, as highlighted by the mentioned projects:

Related to **tariffs**:

- Experimental tariffs for the customers, to get them more involved in consumption habits' change: this kind of awarding tariffs should be linked to the need of system operators to solve congestions on certain areas in certain moment (**FLEXICIENCY**)
- Simplification of tariff scheme for Hybrid Power Systems (**TILOS**)
- Electric market role and potential contractual arrangements/tariffs of the energy communities still to be defined (**Insulae**)

Related to **Demand Side** participation:

- Actual participation of demand-side resources in balancing markets, as well as TSO-DSO coordination schemes, were left outside the scope of the project. Alternative network tariff designs, including dynamic tariffs, could not be extensively tested within the scope of the project (**InteGrid**)
- DER flexibility procurement through market-based mechanisms was not tested (**InteGrid**)
- Energy cooperatives/communities and smart EV Charging cooperative have still to be regulate (**Insulae**)
- Regulation on DR at the end-user level (**TILOS**).
- Integrating load (including energy conversion) in the re-dispatch process and identification of benefit from including load (including energy conversion) in re-dispatch process could not be covered due to regulatory framework (**EU-SysFlex**)

Related to **micro-grids integration**:

- Introduction of microgrids as an integrated market entity practicing energy trading (**TILOS**)
- Micro-grids and balancing of Balancing Local Grids (**SMILE**)

Related to **new regulations**:

- Examination for a new RES and storage regulation (exceptions) framework for small-scale islands / Electricity market framework for battery storage integration (bundle of services) (**TILOS**)
- Adding market competition aspects: replace cost-based bids with competitive bids and perform an analysis of market power potentials in ancillary services markets with flexibility offered from distribution (**SmartNet**)
- The constraints posed by existing regulation limit the ability to test certain innovative market, tariff or grid operation approaches Barriers to engaging stakeholders not partners of the project may limit the scope of the demonstration activities (**InteGrid**)

***Other topics*** needing further research:

- Evaluation of the cost of reactive power compensation provision to the asset owner (the reactive power market concept is not economically feasible in the current situation in some countries) (**EU-SysFlex**)
- Detail assessment of cooperation impact on the balancing responsible parties and overall cost of imbalances in the local markets after introduction of the regional market (**FutureFlow**)
- Power to X topics (**FLEXITRANSTORE**)

# 4. Digitalisation as key enabling technology

## 4.1 Protocols, standardisation and interoperability

➢ Achievements

Projects reported significant results in this field and in different directions. Interoperability has been considered as a major topic for many of the projects in H2020. Challenges are considered both at data level and at data exchange level and corresponding activities of harmonisation are reported by different projects. The work performed should be also distinguished between technical coordination and market related services.

At the **component level** the following activities are reported:

- Intelligent controllers for balancing services, DLR technology, FACTS (**FLEXITRANSTORE**)
- Component interoperability at the HPS and island microgrid level (**TILOS**)

Intelligent controllers for balancing have been developed in **FLEXITRANSTORE**. A congestion relief equal to 50% has been achieved, while DLR sensor standardisation improvement, voltage regulation, power oscillation damping and reserve emulation were examined.

When we look strictly at the **data level** we can mention:

- Standardised data format for flexibility exchange based on ENTSO-E "Reserve Resources Processes" for flexibilities (**InteGrid**)
- Semantically Enhanced Middleware for the integration of the DERs and sensors in the building. The Semantic Based Middleware (based on the Hydra/ LinkSmart Middleware) establishes a seamless, transparent and homogeneous interface to all sensor/actuator/metering cloud components. (**INERTIA**)
- EUMED-CIM (European Union Metering Exchange Data – Common Information Model) data model (Ontology) has been created as an extension of CIM to cover all BUC of the project (**FLEXICIENCY**)
- Interoperability among flexibility sources (load, storage, generation), optimization framework and relevant software platforms as well as the involved market actors and further extending OpenADR (Open Automated Demand Response) (**MERLON**)
- Adoption of MQTTT (Message Queuing Telemetry Transport) protocol for the creation of a data bus at the centre of data platform architecture (**SOGNO, Platone**)
- Utilisation of MQTTT protocol for data exchange between network assets (**CROSSBOW**)
- Project CoordiNet is identifying the data exchange requirements between TSOs, DSOs, managers of markets for system services (in general, TSOs or DSOs, but it could also be an independent agent) and flexibility providers for the procurement of system services. Although it is an ongoing work, the results are expected to be an evolution of the CIM.

The third aspect in data harmonisation is given by **interfaces and API**. At this level we can identify:

- Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms (**Flexigrid**)
- Standardised interface for flexibility exchange in LV and MV grids (**Integrid**)
- Universal, open, adaptable and modular approach to interlink active system management with electricity markets and foster the provision of flexibility services, also acknowledging the activation needs of and the coordination requirements with other commercial parties and TSOs (**EUniversal**)
- API layer and Reference Knowledge Warehouse for Cross Modular Platform (**inteGRIDy**)

More in **general** other results are reported in terms of several demos for cross-border interoperability (**EU-SysFlex**) and also new products for flexibility in intraday markets (**FLEXITRANSTORE**)

Some quantified results are also reported:

- Congestion relief equal to 50%, DLR sensor standardisation improvement, voltage regulation, power oscillation damping, reserve emulation and others (**FLEXITRANSTORE**)

➢ Remaining Challenges

- Readiness level of commercially available aggregation platforms (constantly developing, new features needed, must be tailored to be suitable for each market/country/asset type) (**EU-SysFlex**)
- Cost reflective market design enabling profitable flexibility business models (**InterFlex**)
- Interoperability between systems and smart home appliances (**InteGrid**)
- Real time markets (**FLEXITRANSTORE**)
- Use of grid/market-hub at a whole national level as virtual data and service hub (multi-DSO), instead of single DSO. (**InteGrid**)
- Cross-sectoral data exchange at European level (**SHAR-Q**).

## 4.2 Data Communication (ICT)

➢ Achievements

ICT solutions for data communications are reported in two different directions**:**

- Communication between assets and aggregation platform, trading systems, TSO markets (**EU-SysFlex**, **CROSSBOW**)
- Communication infrastructures for smart meter data for close to real-time monitoring in critical zones at critical moments (**Flexigrid**)

The projects did not report special achievements in this area apart from:

- Communication layer has been developed using SOAP (Simple Object Access Protocol) /RESTful (Representative State Transfer) API, that perfectly integrates with the Data Model. An integration test feature has been developed to reduce integration test on Platform users side. (**FLEXICIENCY**)
- Both wired and wireless technologies (GSM, Wifi, PLC (Programmable Logic Controller), Fiber optics, Ethernet) – Networks: HAN/WAN (Home Area Network/Wider Area Network) – HPS (Hybrid Power System) & HL-EMC (High Level Energy Management Centre) SCADAs (**TILOS**)

A communication layer has been developed in **FLEXICIENCY** using SOAP/RESTful API that perfectly integrates with the Data Model, alongside an integration test feature that can reduce integration test on Platform user side.

➢ Remaining Challenges

- Use of grid/market-hub at a whole national level as virtual data and service hub (multi-DSO), instead of single DSO. (**InteGrid**)
- Use of the grid/market-hub for "classic" retail market communication, e.g. meter data for billing, change of supplier, balancing (**Integrid**)
- Testing of the Narrowband (Nb) Internet of Things (NB-IoT) LPWAN radio technology for the Smart metering & DSM network (**TILOS**)

## 4.3 Data and Information Management

➢ Achievements

Platforms solutions have been developed and proposed at different level of the energy infrastructure and the results can be structure in this way. Starting from the top level and going down in the infrastructure, we can distinguish:

Grid infrastructure management. This category deals with the grid operators and their interaction. The following are reported:

- Development of a reference architecture (**InteGridy, SOGNO, Platone**)
- Implementation of cross border data exchange (**EU-SysFlex, CROSSBOW**)
- Intraday actors cooperation (**InterFlex**)

Customer/User Level has provided rich and diverse results. The different achievements are summarised in the following:

- Local ICT-based Energy Management Systems to interface the storage with building's EMS or with the distribution grid (**Elsa**)
- A multi-sensorial cloud was implemented at building level, providing real-time information required to extract the current building context, further allowing the collection of historical data, along with control access to actuators. Information collected: -Environmental conditions -Occupancy-related Information, such as door counting using infrared beams and pressure mats installed at room's entrances, motion/sound/CO2 sensors and depth image cameras. -Consumption related information - User profiling information, related to the interaction of building occupants with devices, such as lights and air-conditioning -Operational status of devices, in particular HVAC and lights. (**INERTIA**)
- Use of standard proven cloud services for Identity management, authentication, API-management, cloud-connector, database integration, security, privacy (e.g. oauth 2.0), development environment, showing that the development effort could be significantly reduced. (**InteGrid**)
- Setting-up of an IoT platform (**Compile**) DSM for Commercial & Industrial customers and control of Distributed generation to provide aFRR ancillary service via device control was developed in **FutureFlow**.
- Prosumer device control was developed in **Netfficient**.
- Integration of customers through block chain layer (**Platone**)

A multi-sensorial cloud was implemented at building level in **INERTIA**, providing real-time information required to extract the current building context, further allowing the collection of historical data. The collected information comprises environ-mental conditions and operational status of devices, occupancy-related, consumption-related and user-profiling.

A category on its own are also the market level solutions that are mentioned in more than one project while a complete market platform is reported by **FLEXITRANSTORE.** Link between market and operation are reported in **Platone.**

*Also for this area we have some **quantified achievements***

- 37 devices connected in an IoT platform (PV, EV chargers, home batteries) (**Compile**)
- Number of aggregated sites: 45 residential and 1 Front-the-meter storage (**Netfficient**)

➢ Remaining Challenges

- Business model for a unified platform scalable (**inteGRIDy**)
- Actual integration of platforms, data sources, etc. to enable European level cross-border and cross-sector exchange of any type of data. (**EU-SysFlex**)
- How can a less complex system still achieve most of the objectives (**InterFlex**)
- Further research on building's occupancy estimation: Incorporate new privacy-preserving sensors and technology, performing the corresponding analysis and research so as to increase accuracy, lower even more the cost, or both. (**INERTIA**)
- Direct connection with devices at the grid edge. (IoT was handled via the demonstrators at demo-sites) (**InteGrid**)
- Transposition of the reference architecture in a modular SW platform. Just instantiation on pilot sites and requirement check was performed (**InteGRIDy**)
- Migration activities/effort to transfer to other hyperscalers (**InteGrid**)
- Interoperability between bidirectional sync-switch at the point of common coupling of the island with subsea interconnector to the island of Kos, with rest of microgrid elements in the sequence of actions for black-starting the island (**TILOS**)
- A unique data platform, not only energy data but also social, economic and environmental data in order to perform correlation analysis and therefore better target energy choices. (**Ebalanceplus**)
- Development of aggregation platforms (**SHAR-Q**)
- Extension of the set of services and standard API (**SOGNO, Platone**)

## 4.4 Cybersecurity and data privacy

➢ Achievements

It is possible to identify some results that can be connected to this topic:

- Based on a risk assessment 16 threats were identified and mitigation measures defined (incl. GDPR) and monitored for vulnerabilities and measures for findings. (**InteGrid**)
- Privacy has been ensured in several ways: - by anonymization of data to be elaborated by third parties, - by asking for authorisation to the data owner, - by aggregating consumption data per area, implicitly removing any reference to final customers (**FLEXICIENCY**)
- Compliance with end-user data anonymity. Restricted integration between HAN and DSM panels (**TILOS**).
- Integration of customers data in system operation thanks to block chain interface (**Platone**)
- Implementation of cybersecurity frameworks, improvement recommendations and practices in utilities focusing on transmission system operators and power plants and implementation of procedures for incident notification (**CROSSBOW**)

In **InteGrid**, based on the gm-hub concept, a thread-modelling approach for cyber-security was applied, which lead to a detailed implementation of security measures. Based on a risk assessment, 16 threads were identified and mitigation measures defined (incl. GDPR as one of them).

➢ Remaining Challenges

- Further security hardening for a market product based on the risk assessment. Analysing coming e-privacy - regulation has to be assessed for impact on communication and consent (**InteGrid**)
- Penetration tests for cyber security (**TILOS**).
- Standardisation of block chain solutions for energy (**Platone**, **CROSSBOW**)

# 5. Conclusions-Recommendations

The analysis of H2020 projects confirmed the significant advances achieved in all aspects of the energy systems.

It is also clear however that there is still need for further research to bring the TRL to the appropriate level for full application.

By considering the results of the questionnaire and taking into account both the recent legislation such as the Green Deal and the Clean Energy Package for all Europeans, and the ETIP-SNET implementation plan, recent developments are driving the need for further research efforts beyond what was defined for Horizon 2020 in the period 2014-2020. Examples of such developments from the recent years are Sector Coupling or Integrated Energy Systems and Citizen Energy Communities.

Indeed, Integrated Energy Systems allow the efficient cross-coupling of the various energy carriers that together with the local Distributed Resources offered by prosumers through Citizen Energy Communities can provide secure, cost-effective and decarbonised energy of the future. These two horizontal topics affect but also drive the evolution of the main research areas of H2020 in a very transversal manner.

For example, a really integrated Energy System together with conversion and all forms of storage technologies will significantly affect all the market aspects, in order to accommodate gas, heat and cooling, transportation, hydrogen and others, requiring further research on roles, market design and interactions, business models or data exchange. It will also affect planning and operation, bringing significant changes in the standard procedures investigated so far. Research on production and use of Hydrogen, as an energy carrier is of particular relevance. The diversity of Flexibility Resources to be considered and coordinated is also increased, raising new challenges to evaluate and test.

The same is true for the Citizen or Local Energy Communities, which play a disruptive role in the markets. They also introduce new challenges not only in the market related aspects, but also in the planning dimension, the operational procedures, the flexibility considerations and all the interactions needed.

Furthermore, none of the above and foreseen changes are possible without an increase in digitalisation, as the interaction between all actors, the needed monitoring and control and the dynamic nature of the processes increases. So, while digitalisation per se may sound like an abstract and too wide topic, the determination of the key horizontal applications for digitalisation of the energy sector will help prioritisation of the research topics and, in general, of the digitalisation agenda. On the other hand, digitalisation is only relevant in this aspect if it serves as an enabling technology, that together with other technologies can solve the great challenges of future Integrated Energy Systems.

Overall, the projects showed very significant achievements in line with the objectives set for the 2014-2020 period, although increased research and innovation efforts are needed for EU to maintain its leadership role and enhance its competitiveness during the energy transition. Furthermore, an optimal Energy System remains always a moving target, as new technological, economical, societal and political developments occur. The two mentioned above are examples of such developments. This requires a continuous research, development and innovation effort, often in similar domains (planning, operation, markets, digitalisation, etc) but with additional requirements, challenges and constraints.

The Task Force thinks that by appropriately focusing the efforts of Horizon Europe in this direction it will be able to offer Europe an energy system ready to support the transformation envisioned by the Green Deal.

# 6. Further Reading

- ETIP SNET Vision 2050
- ETIP SNET R&I Roadmap 2020-2030
- ETIP SNET R&I Implementation Plan 2021-2024
- BRIDGE Business Models WG
- BRIDGE Regulations WG
- BRIDGE Customer Engagement WG
- BRIDGE Data Management WG
- Virtual Workshop “Connecting R&I priorities of ETIPs and PPPs for a common path to achieve the Energy Transition by 2050”
- ETIP-SNET Coverage analysis of the present roadmap (2017-2026)

# Annex I – questionnaire

The following questionnaire has been distributed to the project representatives:

| RESEARCH AREA | TOPIC | ANY PARTICULAR SUB-TOPIC TO HIGHLIGHT? | PROJECT | START DATE | END DATE | WHAT WAS ACHIEVED? | WHAT QUANTIFICATION ELEMENTS CAN BE STATED? KPI, KER, ...? | WHAT WAS NOT COVERED? (ASPECTS IN THE TOPIC NOT COVERED BY PROJECT) | REMAINING CHALLENGES IDENTIFIED FOR FURTHER STUDY? | OTHERS OBSERVATIONS |
|---|---|---|---|---|---|---|---|---|---|---|
| **Consumer** | ***Social campaigns and social studies*** | | | | | | | | | |
| | ***Adaptive consumer/user behaviour incl. energy communities*** | | | | | | | | | |
| | ***Consumer and prosumer device control*** | | | | | | | | | |
| **System Economics** | ***Business models*** | | | | | | | | | |
| | ***Market design, governance and tariffs*** | *(Pan-European) Wholesale markets* | | | | | | | | |
| | | *Local / retail markets* | | | | | | | | |
| | ***Energy System Regulation*** | | | | | | | | | |
| **Digitalisation** | ***Protocols, standardisation and interoperability*** | | | | | | | | | |
| | ***Data Communication (ICT)*** | | | | | | | | | |
| | ***Data and Information Management (Platforms, IoT, etc.)*** | | | | | | | | | |
| | ***Cybersecurity and Privacy*** | | | | | | | | | |

| RESEARCH AREA | TOPIC | ANY PARTICULAR SUB-TOPIC TO HIGHLIGHT? | PROJECT | START DATE | END DATE | WHAT WAS ACHIEVED? | WHAT QUANTIFICATION ELEMENTS CAN BE STATED? KPI, KER, ...? | WHAT WAS NOT COVERED? (ASPECTS IN THE TOPIC NOT COVERED BY PROJECT) | REMAINING CHALLENGES IDENTIFIED FOR FURTHER STUDY? | OTHERS OBSERVATIONS |
|---|---|---|---|---|---|---|---|---|---|---|
| Planning | ***Cross-sector integration*** | | | | | | | | | |
| | ***Integrated Energy System Architectures*** | | | | | | | | | |
| | ***Long-term planning*** | | | | | | | | | |
| | ***Asset management and maintenance*** | | | | | | | | | |
| | ***System Stability analysis*** | | | | | | | | | |
| Flexibility | ***Demand Flexibility*** | | | | | | | | | |
| | ***Generation Flexibility*** | | | | | | | | | |
| | ***Energy Conversion flexibility*** | | | | | | | | | |
| | ***Storage Flexibility*** | | | | | | | | | |
| | ***Transport Flexibility*** | | | | | | | | | |
| System Operation and Control | ***State estimation and State supervision*** | | | | | | | | | |
| | ***Short-term control*** | | | | | | | | | |
| | ***Medium and long-term control*** | | | | | | | | | |
| | ***Preventive control/restoration*** | | | | | | | | | |

# Annex II – Projects in the Report

| Project name | Project's starting date | Project's ending date | Respondent | |
|---|---|---|---|---|
| | | | First Name | Last Name |
| ***inteGRIDy*** | 1/1/2017 | 31/12/2020 | Javier | Valiño |
| ***GreenSoul*** | 1/4/2016 | 31/10/2019 | Cruz E. | Borges |
| ***Promotion*** | 1/1/2016 | 30/9/2020 | Mahboubeh | Hortamani |
| ***TRINITY*** | 1/10/2019 | 30/9/2023 | Álvaro | Nofuentes |
| ***Ebalance-plus*** | 1/2/2020 | 31/7/2023 | Anna | Pinnarelli |
| ***EU-SysFlex*** | 1/11/2017 | 31/10/2021 | Kalle | Kukk |
| ***COMPILE*** | 1/11/2018 | 31/10/2022 | Tomi | Medved |
| ***Making City*** | 1/10/2018 | 30/9/2023 | Joke | Kort |
| ***INSULAE*** | 1/4/2019 | 31/3/2023 | Paola | Mazzucchelli |
| | | | Stefano | Barberis |
| ***FLEXIGRID*** | 1/10/2019 | 30/9/2023 | Paola | Mazzucchelli |
| ***CryoHub*** | 1/4/2016 | 31/3/2021 | Jonathan | Radcliffe |
| ***INTERRFACE*** | 1/1/2019 | 31/12/2022 | Athanasios | Dagoumas |
| ***CoordiNet*** | 1/1/2019 | 30/06/2022 | Carlos | Madina |
| ***Elsa*** | 1/1/2015 | 31/12/2018 | Mahboubeh | Hortamani |
| ***InterFlex*** | 1/1/2017 | 31/12/2019 | Joost | Laarakkers |
| ***INERTIA*** | 1/10/2012 | 30/9/2015 | Stelios | Zikos |
| ***Store & Go*** | 1/1/2016 | 28/2/2020 | Mahboubeh | Hortamani |
| ***SHAR-Q*** | 1/11/2016 | 31/10/2019 | Dagmar | Jarásová |
| ***InteGrid*** | 1/1/2017 | 31/10/2020 | Jorge | Moreira |
| ***EUniversal*** | 1/2/2020 | 31/7/2023 | Pedro | Marques |
| ***SmartNet*** | 1/1/2016 | 30/6/2019 | Gianluigi | Migliavacca |
| ***Wisegrid*** | 1/11/2016 | 20/4/2020 | Aris | Dimeas |
| ***NobelGrid*** | 1/1/2015 | 31/7/2018 | Aris | Dimeas |
| ***MERLON*** | 1/1/2019 | 31/12/2021 | Antonis | Papanikolaou |
| ***Netfficient*** | 1/1/2015 | 31/12/2018 | Alicia | Arce |
| ***FLEXICIENCY*** | 1/2/2015 | 31/1/2019 | Daniele | Porcu |
| ***FutureFlow*** | 1/1/2016 | 31/12/2019 | Rok | Lacko |
| | | | Nadja | Novak |
| ***FLEXITRANSTORE*** | 1/11/2017 | 31/10/2021 | George | Boultadakis |
| ***SMILE*** | 1/5/2017 | 30/4/2021 | Giannicola | Loriga |
| ***TILOS*** | 1/2/2015 | 31/1/2019 | Takis | Ktenidis |
| ***CROSSBOW*** | 1/11/2017 | 30/10/2021 | Athanasios | Botsis |
| ***GRIDSOL*** | 26/1/2017 | 26/1/2020 | Rebekka | Goggou |
| ***SOGNO*** | 1/1/2018 | 30/06/2020 | Antonello | Monti |
| ***PLATONE*** | 1/9/2019 | 31/08/2023 | Antonello | Monti |

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