FLEXIGRID

Interoperable solutions for implementing holistic **FLEXI**bility services in the distribution **GRID**

Business Model Development

Deliverable 8.1

WP8

Grant agreement: 864579

From 1st October 2019 to 30th September 2023

Prepared by: CAPENERGIES

Date: October 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under service agreement No 864579

DELIVERABLE FACTSHEET

Deliverable no.	**D8.1**
Responsible Partner	CAPENERGIES
WP no. and title	WP8 Business cases and exploitation strategies
Version	V3
Version Date	09/11/2020

Dissemination level	
X	**PU**→ Public
	PP → Restricted to other programme participants (including the EC)
	RE → Restricted to a group specified by the consortium (including the EC)
	CO → Confidential, only for members of the consortium (including the EC)

Approvals

	Company
Author/s	CAPENERGIES
Task Leader	CAPENERGIES
WP Leader	CAPENERGIES

Documents History

Revision	Date	Main Modification	Author
1	28/09/2020	Laurine Moreau	CAPENERGIES
2	07/10/2020	Raphaël Rinaldi, Enrico Mazzon	CAPENERGIES
3	14/10/2020	Clara Lorente Almenara	CIRCE
4	15/10/2020	Abdon Alejandro Vivas Imparato	ATOS
5	15/10/2020	Inés Villa Martinez	CIRCE
6	23/10/2020	Laurine Moreau	CAPENERGIES
7	06/11/2020	Clara Lorente Almenara, Aleida Lostale Caparroso	CIRCE
8	09/11/2020	Laurine Moreau	CAPENERGIES

ABBREVIATIONS

BESS: Battery Energy Storage System
BRP: Balance Responsible Party
DER: Distributed Energy Resources
DG: Distributed Generation
DG&S: Distributed Generation and Storage
DR: Demand Response
DSO: Distribution System Operator
EC: European Commission
ER: Exploitable result
ESCo: Energy Service Company
EU: European Union
EV: Electric Vehicle
FiT: Feed-in-Tariff
FiP: Feed-in-Premium
GHG: Greenhouse Gases
HV: High Voltage
HVAC: Heating, Ventilation, Air Conditioning
IEA: International Energy Agency
IED: Intelligent Electronic Device
LV: Low Voltage
M: Month
MV: Medium Voltage
P2H: Power-to-Heat
PSH: Pumped Storage Hydropower
R&D: Research and Development
RD&I: Research, Development and Innovation
RES: Renewable energy sources
TES: Thermal Energy Storage
TRL: Technology Readiness Level
TSO: Transmission System Operator
UC: Use Case
VPP: Virtual Power Plant
VTES: Virtual Thermal Energy Storage
WP: Work Package

DISCLAIMER OF WARRANTIES

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 864579".

This document has been prepared by FLEXIGRID project partners as an account of work carried out within the framework of the EC-GA contract no 864579.

Neither Project Coordinator, nor any signatory party of FLEXIGRID Project Consortium Agreement, nor any person acting on behalf of any of them:

(a) makes any warranty or representation whatsoever, express or implied,
   (i). with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or
   (ii). that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or
   (iii). that this document is suitable to any particular user's circumstance; or

(b) assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if Project Coordinator or any representative of a signatory party of the FLEXIGRID Project Consortium Agreement, has been advised of the possibility of such damages) resulting from your selection or use of this document or any information, apparatus, method, process, or similar item disclosed in this document.

EXECUTIVE SUMMARY

This Deliverable, intervening after the first twelve months of the FLEXIGRID project, constitutes a first step in the FLEXIGRID solutions' business model development process.

It provides an analysis of key market trends and of the challenges that they create for stakeholders of the electricity value chain. The rising penetration of variable renewable energy sources (RES), the electrification of end-use sectors such as transport, buildings and industry, and the development of energy storage systems create new requirements and opportunities regarding power system flexibility. In this evolving market environment, existing stakeholders (transmission and distribution system operators, energy retailers and renewable energy producers) are taking on new roles and responsibilities and new actors (aggregators and energy service companies) are emerging. Consumers and prosumers, individually or within the framework of energy communities, are at the centre of this transformation of the power system, in which they are expected to play an active role. Smart grid solutions are key enablers for these evolutions, with developments focusing on three main fields: smart management of electricity networks, demand-side management, and integration of distributed generation and storage.

This analysis of the new roles, challenges and needs of stakeholders across the energy system value chain paves the way for the identification of the business cases for the main customer segments addressed by the FLEXIGRID solutions and for a first vision of the Value Proposition of the FLEXIGRID approach, which rests on:

- assets and services optimization for DSOs;
- an optimized management of and value extraction from the energy resources (generation, demand and/or storage assets) of industrial, commercial and residential end-users, as well as energy communities, which can be operated directly by these actors, or within the framework of services provided by aggregators/ESCos.

The choices that have been made in FLEXIGRID solutions' design and development, especially in terms of interoperability, replicability, and modularity/scalability, are also key for their market positioning and aim to foster a swift uptake.

In order to start paving the way towards this market deployment, a first value proposition and business model design exercise has been conducted for the individual solutions constituting the FLEXIGRID approach. All the partners intervening in their development have been involved in this interactive process, using a common methodological framework: the Business Model Canvas. The resulting exploratory business models are presented in this deliverable; they will be refined over the course of the project and complemented by a reflection at the level of the use cases, for which they will constitute technological bricks.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Presentation of the FLEXIGRID project

Elements of context

In the context of the transition towards a decarbonized energy system, renewable energy sources (RES) relying on wind and solar photovoltaic energy are playing a growing role in electricity generation. The development of distributed, small or medium-sized, and variable sources able to inject electricity in a bidirectional power flow grid is creating many challenges for the energy system, which used to rest on large-sized, centralized power plants. In addition to these supply-related challenges, energy demand is also registering many changes, linked to the electrification of new uses, especially in the field of mobility with the development of electric vehicles (EV) and in the residential and industrial sectors. Besides, the increasing competitiveness of battery energy storage is likely to impact both electricity supply and demand.

Faced with these challenges, the actors intervening in the electricity value chain, especially at distribution level, must ensure the reliability, stability and security of supply to end-users. The latter are also increasingly expecting and willing to play a more active role in the energy system (JRC, 2020).

The development of the power system's flexibility is key to reinforce its ability to address these challenges. Flexibility has been defined by the International Energy Agency (IEA) as "*the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply*" (IEA, 2019a). While flexibility has long rested on conventional power plants and pumped storage hydropower (PSH), with electricity networks as a "*critical enabler*", the development of distributed resources (RES, storage, EV) paves the way for new flexibility solutions and services (IEA, 2019a). As underlined by the IEA, "*these flexibility resources can work together in concert to enhance system flexibility in a cost-effective, reliable and environmental sound manner*" (IEA, 2019a).

Objectives of the FLEXIGRID project

FLEXIGRID is an innovation action project funded by Horizon 2020. It is part of the European projects which have the potential to contribute to a successful, digitally-supported energy transition. It aims to provide hardware and software tools for grid observation, control and operation allowing to ensure flexibility, reliability, economic efficiency and security in scenarios where a large share of RES is connected to low and medium voltage (LV and MV) grids. Demonstration activities will take place in four European distribution grids with very different characteristics, in order to assess the applicability of the project results in distinct environments.

In addition to pursuing its own objectives, FLEXIGRID will make special efforts to exploit synergies and share knowledge and experience with other projects participating in the BRIDGE Initiative of the European Commission, which gathers all the smart grids and energy storage demonstration projects. A specific task (task 9.3) of the FLEXIGRID project is dedicated to this aim.

Key characteristics of the FLEXIGRID project

15 partners, from 5 countries

The FLEXIGRID consortium gathers fifteen best-in-class partners with multidisciplinary expertise, representing the entire energy system value chain:

- two research and technology organizations (CIRCE, LINKS);
- two universities (UNIZG-FER, UNICAN);
- five technology providers: three large companies (ATOS, ORMAZABAL, ZIV) and two SMEs (HYPERTECH, SELTA);
- three distribution system operators (VIESGO, HEP-ODS, EDYNA);
- one aggregator/ESCo (VERD);
- a commercial end-user in the sector of tourism (IOSA);
- one association (CAP).

Among them, technology developers will focus on the development of the FLEXIGRID hardware and software solutions and on the information and communication technology (ICT) framework in which they are designed to be integrated. Partners representing the demonstration sites will provide data and support and play a key role in the testing of the developed solutions. Other partners, in charge of exploitation and dissemination activities, will provide a transversal support to them.

8 solutions and 1 platform to ensure interoperability

The FLEXIGRID approach comprises four hardware solutions:

- (S1) the secondary substation of the future;
- (S2) a new generation of smart meters with improved feeder-mapping capabilities;
- (S3) protections dealing with high RES penetration;
- and (S4) a multi-purpose concentrator able to control grid assets, called the Energy Box.

It also consists of four software modules, addressing:

- (S5) fault location and self-healing;
- (S6) forecasting and grid operation;
- (S7) grid congestion management;
- and (S8) virtual thermal energy storage (VTES) optimization.

Furthermore, an open source platform (S9) is being upgraded to enable the integration of the hardware and software solutions and ensure full exploitation of the data.

8 use cases

The FLEXIGRID approach has been designed around eight use cases, which aim to address the most common distribution grid challenges in the European Union (EU):

- (UC1) secondary substation upgrading for higher grid automation and control;
- (UC2) protections functions operating with large RES share penetration in the distribution grid;
- (UC3) holistic energy system optimization and emulation for commercial and residential customers;
- (UC4) microgrid congestion management and peak shaving;
- (UC5) coordinating distribution network flexibility assets and protections schemes in urban districts;
- (UC6) Virtual Energy Storage (VES) for urban buildings;
- (UC7) dispatching platform for MV generation;
- (UC8) isolated valley grid operating in islanding mode.

4 demonstration sites

In line with these use cases, four demonstration sites with different topologies have been chosen for the deployment and upgrade of FLEXIGRID solutions, in order to reach complete and qualified systems:

- a rural and peri-urban network in Spain, with a RES share of 39%;
- a hotel resort in the Greek island of Thasos, only able to integrate 10% of RES;

- an urban grid in the city of Zagreb, which counts congested areas;
- an isolated valley in the region of South-Tyrol, in Italy, with more than 50% of hydro power.

1.2. Presentation of deliverable 8.1

Objectives of deliverable 8.1

The notion of business model refers to "*the rationale of how an organization creates, delivers, and captures value*" by means of the solutions (products and/or services) that it offers to its customers (A. Osterwalder and Y. Pigneur, 2010). It is therefore key to support the exploitation of the results of a project such as FLEXIGRID.

A reflection on the business models of the FLEXIGRID solutions and of the related use cases is carried out over the course of their development, within the framework of the Work Package number 8 (WP8). Deliverable 8.1 (D8.1), "Business model development", aims to take stock of the advances made in this reflection and lay the foundations for the definition of a business plan to support the deployment of the FLEXIGRID solutions in the market.

Positioning within the project

Stage of the project at which this deliverable intervenes

This Deliverable (D8.1) intervenes at the early stages of the project (after the first 12 months) and builds upon a reflection conducted within working groups gathering all the partners involved in the development of each solution. As a consequence, the *ex-ante* business models that have been defined for each solution should be considered as exploratory.

These exploratory business models are intended to be continuously updated and adjusted, in coordination with the partners, throughout the duration of the FLEXIGRID project. The next two yearly reports will be key milestones in this regard, before business model finalization in the fourth yearly report.

Articulation with other tasks and work packages

The business models developed within the framework of task 8.1 – "Business models and plan validation and refinement" – will be a critical component of the FLEXIGRID approach business plan. They will be complemented by:

i) the market analysis: the market's current state and prospects, as well as the key actors intervening in it, are described in this document. This will contribute to an in-depth understanding of the market context, together with the tasks of Work Package number 7 (WP7 – "Guarantees of replication"); the latter will notably focus on the regulatory framework (task 7.3), a dimension which is especially significant regarding electricity networks. The market analysis will help ensure that the proposed strategy meets market requirements and addresses the needs and expectations of potential customers and users while taking into account the competitive situation;

ii) the cost-benefit analysis (CBA) of FLEXIGRID developments (task 8.2), which will include a CBA of the individual solutions and aggregated CBA of the use cases;

iii) the exploitation strategy (task 8.5), with which the proposed business models will have to be consistent.

These elements will in turn contribute to the identification of the market opportunities triggered by FLEXIGRID (task 8.4).

The development of the FLEXIGRID approach business plan through the articulation of these analyses and strategies will pave the way towards the deployment of the FLEXIGRID solutions on the market. It may also be instrumental in the search for additional funding or external investment to reach the first sales, should this need arise.

1.3. Key characteristics of the methodology used for business model development

The business model creation process

A gradual and evolutionary process, spanning the entire duration of the project

In an innovation project such as FLEXIGRID, business model creation is a gradual process: it evolves as the different steps of the project (technological solutions development, demonstration campaigns, analysis of the replication potential…) unfold, and builds on their findings and outcomes.

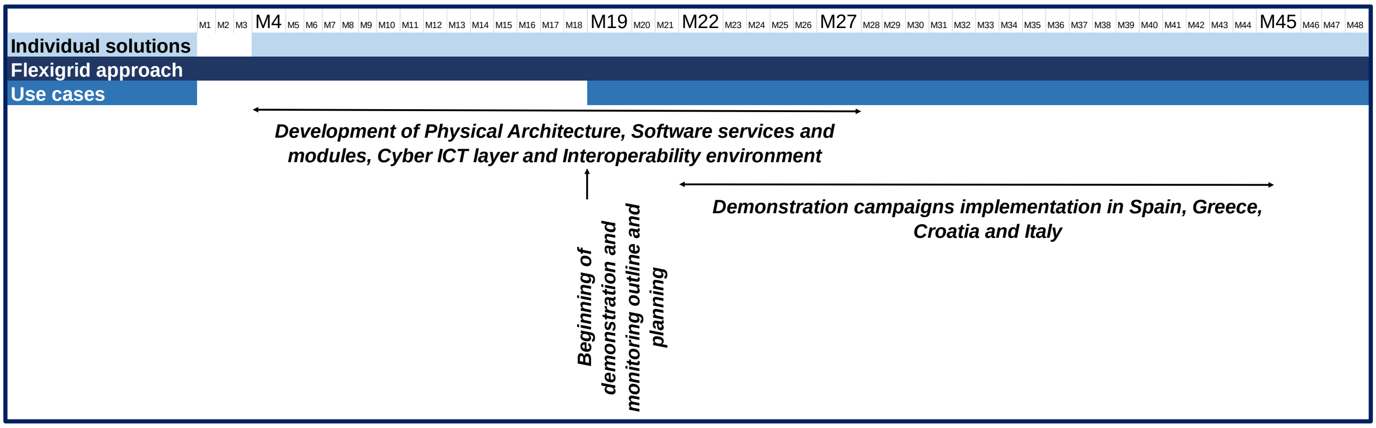
FLEXIGRID's business model development process involves several steps, corresponding to the different levels of analysis to be adopted over the course of the project (Figure 1):

i) the individual solutions;

ii) the whole FLEXIGRID approach, which refers to the value proposition of the hardware and software solutions that are being developed, considered jointly;

iii) the use cases, which will be represented in the demonstration sites, and imply the deployment of several of the FLEXIGRID solutions.

Figure 1. The FLEXIGRID business model development process: different levels of analysis



Due to the gradual approach described above, the business model creation process is by nature evolutionary: the exploratory business models and value propositions designed *ex ante* are intended to be updated as the different steps of the project unfold.

Throughout this process, alternative business models may arise for a given solution or use case. Their advantages and drawbacks for each stakeholder will in this case be highlighted. SWOT (Strengths, Weaknesses, Opportunities, Threats) analyses may be used to facilitate their comparison.

An interactive process

All partners are participating in the business model creation process, following a common formal procedure proposed by Capenergies. The reflection on each solution's exploratory business model has been coordinated by its lead partner and has taken place in working groups gathering all of the involved partners. This has been achieved through an iterative process and/or by organizing one or several dedicated workshop(s) (e.g. brainstorming sessions).

The subsequent updates and adjustments of the business models will also be enriched by the insights of all partners, whose expertise covers the entire energy system value chain, and by the activities and results of the other work packages (see above).

A common methodological framework: the Business Model Canvas

Even though the FLEXIGRID project involves the development of both hardware and software solutions, a common approach has been retained for the business model creation process. It rests on the Business Model Canvas designed by A. Osterwalder and Y. Pigneur (*Business Model Generation*, 2010). Appendix 1 provides a detailed description of this tool and of the methodology retained for its application within the framework of the FLEXIGRID project.

2. MARKET ANALYSIS

2.1. Key market trends

An increasing share of (variable) renewable energy sources (RES)

RES, especially wind and solar energy, have registered a strong development in the European Union (EU) over the past decade, as investments were spurred by supportive European and national policies and by the rising competitiveness of these technologies. This trend is expected to continue in the coming years, with new objectives for their deployment defined at the 2030 horizon.

2020: towards the achievement of the EU's 20% RES target

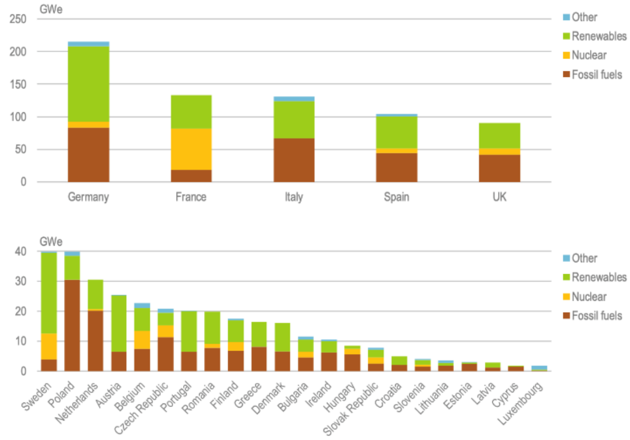
The climate and energy package enacted by the EU in 2009 defined three key targets at the 2020 horizon: a reduction of greenhouse gas (GHG) emissions by 20% from their 1990 levels, an improvement in energy efficiency ensuring a 20% reduction of total primary energy consumption, and an increase to 20% of the share of RES in gross final energy consumption. This latter objective was specified by the Renewable Energy Directive (RED) 2009/28/EC, which set binding targets at the level of EU member States, ranging from 10% for Malta to 49% in the case of Sweden.

EU member States have implemented supportive policy frameworks and mechanisms in order to reach these national objectives. In many countries, they initially took the form of Feed-in-Tariffs (FiT). The FiT were gradually replaced by market-based mechanisms such as Feed-in-Premiums (FiP) and competitive bidding processes, in accordance with the Guidelines on State aid for environmental protection and energy (2014-2020) adopted by the European Commission in 2014. The IEA underlines that "*this has led to a spectacular reduction in the level of state aid required per megawatt-hour (MWh) in a very short period of time. Since auctions were introduced in Germany, an almost 50% reduction was observed for solar and zero-subsidy bids for offshore wind in Germany and the Netherlands (even if the public authorities/TSOs still shoulder part of the grid connection costs)*" (IEA, 2020a). These evolutions took place in a context of improvements in RES technologies and decreasing costs, which fostered their competitiveness.

As a result, the penetration of RES has registered a significant rise, bringing the EU close to its 2020 target: as of 2019, RES represented 18% of gross final energy consumption (IEA, 2020a).

The installed electricity generating capacity of RES in the EU28 (including hydro) rose from 22% of total installed capacity in 2000 to 43% in 2017 (IEA, 2020a). The installed capacity for wind energy increased from 12,709 MW (c. 2% of total installed capacity) in 2000 to 168,933 MW (c. 17%) in 2017, and for solar energy it grew from 177 MW (c. 0.03% of total installed capacity) in 2000 to 109,014 MW (c. 11%) in 2017 (IEA, 2020a). The RES share of total installed capacity is especially significant in certain European countries (Figure 2).

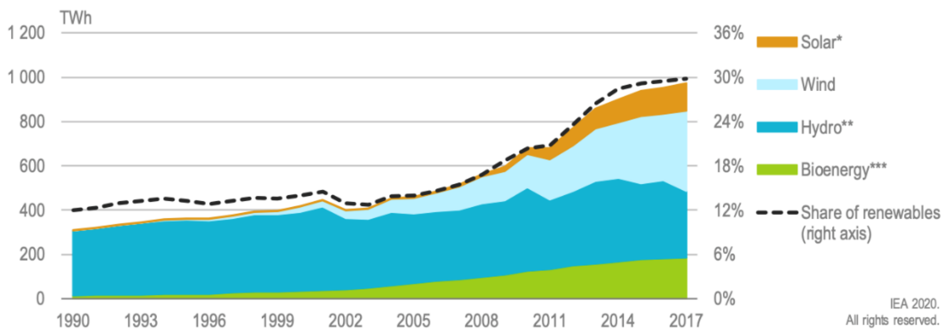
Figure 2. Installed electricity generating capacity by source in EU member States (2017)



Source: IEA, 2020a

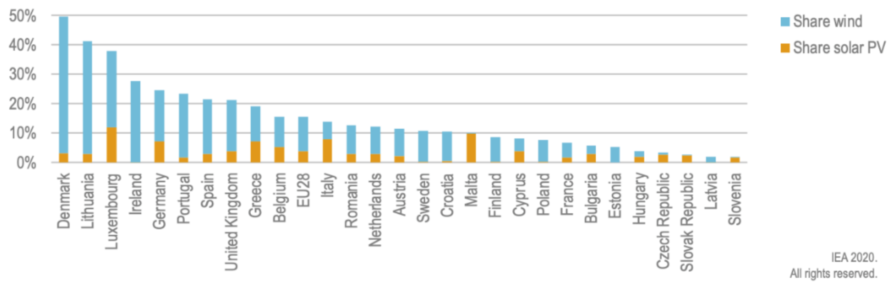
The share of RES in electricity generation in the EU has been increasing in parallel: it doubled in ten years to reach 30% in 2017, with 975 TWh generated (Figure 3) (IEA, 2020a). The share of wind power has become the largest among these renewable sources (11%), and solar power has also registered a strong growth, to reach 4% of electricity generation (IEA, 2020a). Therefore, variable RES account for more than 15% of electricity generation today, up from c. 10% in 2013 (IEA, 2020a). The share of these two RES is however variable among EU member States (Figure 4): in the case of wind power, it is especially high in Ireland and Denmark, while for solar power it is relatively large in Italy and Greece (IEA, 2020a). The IEA notes that "*some EU member States, notably Denmark, Ireland and Spain, operate some of the highest combined wind and solar shares anywhere in the world*" (IEA, 2020a).

Figure 3. Electricity generation by RES in the EU (1990-2017)



Source: IEA, 2020a

Figure 4. Share of wind and solar PV in EU member States (2018)



Source: IEA, 2020a

European objectives at the 2030 and 2050 horizon

a) Objectives for 2030

The EU has defined in 2014 a 2030 climate and energy framework which sets new targets: it states that the reduction of GHG emissions should reach at least 40% from 1990 levels at this horizon. In September 2020, within the framework of the European Green Deal, the European Commission proposed to increase this target to at least 55%.

A target concerning the share of RES in gross final energy consumption in 2030 was also defined at 27% and raised to 32% by the Renewable Energy Directive 2018/2001/EU in 2018, within the framework of the Clean Energy Package. The Directive contains a review clause allowing further upwards revisions by 2023.

The 32% target implies that more than 50% of electricity will be generated from RES. Variable RES are expected to play a significant role to achieve it; in particular, the IEA forecasts that "*wind power [will] become the leading fuel of electricity ahead of gas and nuclear well before 2025*" (IEA, 2020a).

In line with these objectives defined at the EU level, member States must set RES development targets at the national level for the 2021-2030 period, within the framework of National Energy and Climate Plans (NECPs). The objectives that had been set for each member State at the 2020 horizon are considered as the baseline for the definition of these new targets. Member States had to provide draft NECPs to the European Commission by the end of 2018, and final NECPs by the end of 2019. An assessment of these Plans by the European Commission is expected to be published in the fall of 2020. Member States will then provide a progress report every two years for the European Commission to monitor progress towards the EU-level targets.

While member States can define the objectives and the policies to be implemented to achieve them, the Renewable Energy Directive 2018/2001/EU contains some provisions regarding the design of national support schemes and the streamlining of permit-granting processes.

b) A vision for 2050

In the 2018 communication "A Clean Planet for All", the European Commission proposed a "*strategic long-term vision for a prosperous, modern, competitive and climate neutral economy*" (EC, 2018). It rests on the analysis of eight scenarios in line with the Paris Agreement, which achieve GHG emission reductions superior to 80% at the 2050 horizon (EC, 2018). One of the "*strategic buildings blocks*" that are considered implies to "*maximize the deployment of renewables and the use of electricity to fully decarbonize Europe's energy supply*" (EC, 2018). In this context, the scenarios forecast that "*by 2050, more than 80% of electricity will be coming from renewable energy sources (increasingly located off-shore)*" (EC, 2018).

The European Commission presented in December 2018 a roadmap in line with this vision of a climate-neutral European Union at the 2050 horizon: the European Green Deal. One of the areas for action identified within its framework is the development of "*a power sector […] that is based largely on renewable sources*" (EC, 2019a).

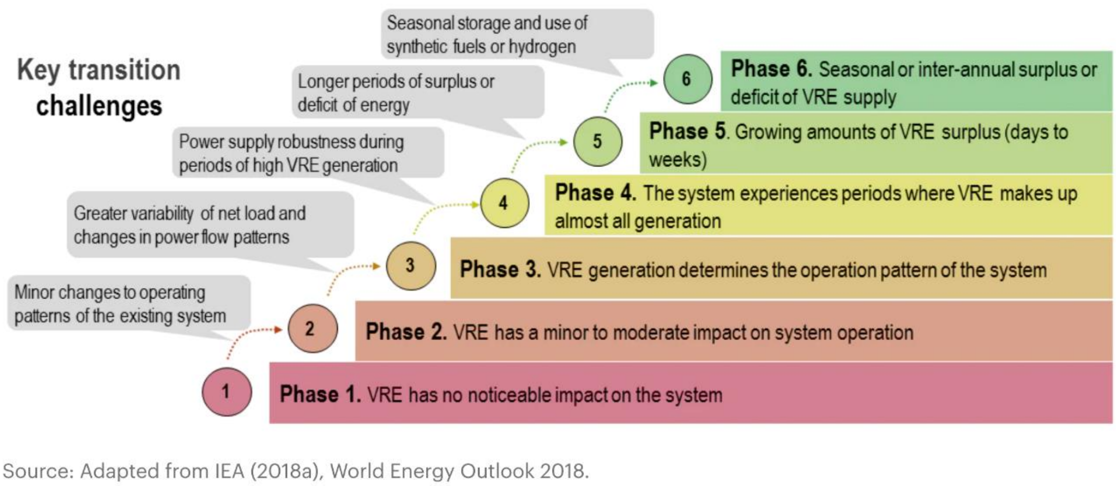
In this context, the European Technology & Innovation Platform (ETIP) Smart Networks for Energy Transition (SNET), which aims to guide research, development and innovation (RD&I) in this domain, developed and presented in June 2018 a Vision for 2050 (ETIP SNET, 2018). It "*advances a more unified Europe based on a low-carbon, secure, reliable, resilient, accessible, cost-efficient, and market-based pan-European integrated energy system supplying the whole economy and paving the way for a fully*

CO_2-neutral and circular economy by the year 2050, while maintaining and extending global industrial leadership in energy systems during the energy transition" (ETIP SNET, 2018). ETIP SNET's report highlights the "*RD&I challenges*" arising from this vision of an integrated energy system "*with the electricity system as its backbone*", and especially sheds light on the role that flexibility solutions could play in it (ETIP SNET, 2018).

Implications for power system flexibility

The rising share of RES entails significant consequences for the energy system, which needs to integrate both large-scale (e.g. offshore wind) and smaller-scale, distributed installations. It especially creates requirements in terms of flexibility, which are a function of the level of RES – especially variable RES – penetration. The IEA has classified these requirements in six phases, which depend on the share of variable RES generation, and range from an initial phase where "*[variable RES] has no noticeable impact on the system*" to a stage of "*seasonal or inter-annual surplus or deficit of [variable RES] supply*" (Figure 5) (IEA, 2019a; IEA, 2020a). The Agency underlines that "*this framework can be used to prioritise different measures to support system flexibility, identify relevant challenges and implement appropriate measures to support the system integration of [variable RES]*" (IEA, 2019a).

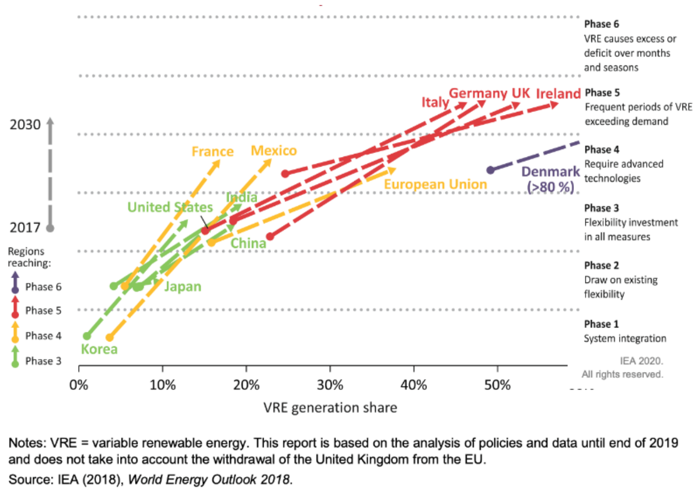
Figure 5. Phases of variable RES integration: IEA classification



Source: IEA, 2019a

The IEA forecasts that at the 2030 horizon, the EU will "*require advanced technologies*" corresponding to phase 4, which is currently the highest level of variable RES integration observed at the global level (reached notably by Denmark and Ireland) (Figure 6) (IEA, 2019a; IEA, 2020a). Some of its member States – especially Germany, Italy and Ireland – will reach phase 5, characterized by "*frequent periods of [variable RES] exceeding demand*", and Denmark will even be in phase 6, with a share of variable RES generation exceeding 80% (Figure 6) (IEA, 2020a).

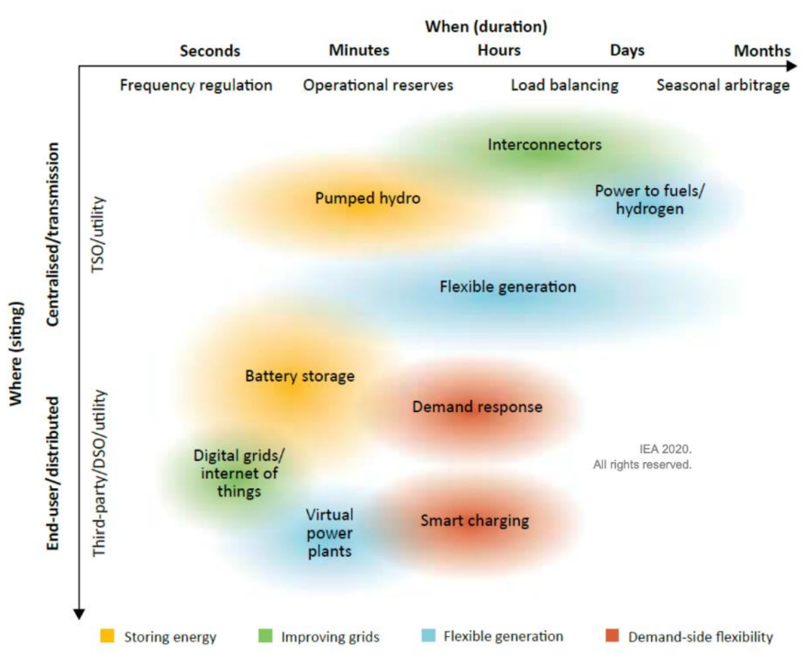
Figure 6. Phases of variable RES integration in EU member States and other countries, in 2017 and 2030



Source: IEA, 2020a

The increasing flexibility requirements corresponding to these different phases can be addressed by means of various sources and services, relying on the generation and demand side, but also on electricity networks (including interconnections) and storage solutions (Figure 7).

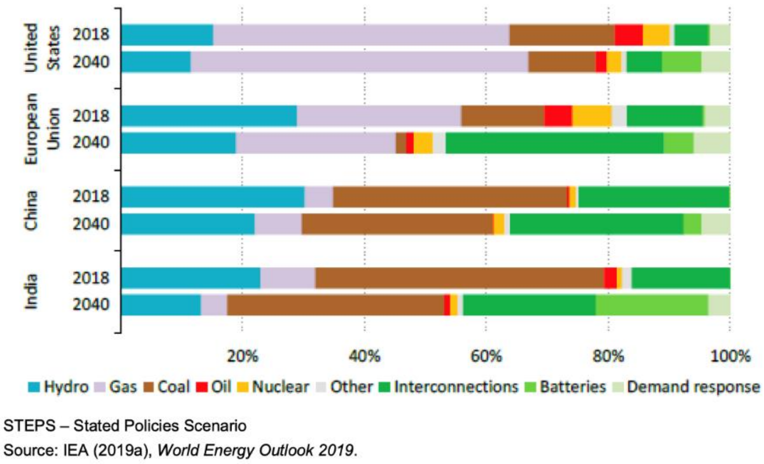
Figure 7. Flexibility sources and services: a typology



Source: IEA, 2020a

As of today, dispatchable generation (notably hydropower and gas plants) is the main source of flexibility in the European Union, as in other regions of the world (Figure 8). The IEA notes that "*in all systems, […] an increase of flexible resources will become a cost-effective integration strategy at some point, requiring additional investments in systematic expansion of the grid, ensuring an appropriate power plant fleet, unlocking demand response potential and storage*" (IEA, 2020a). In the specific case of the EU, interconnections are also expected to play an important role at the 2040 horizon (Figure 8).

Figure 8. Flexibility sources and services in 2018 and 2040, according to the IEA's "Stated Policies Scenario"



Source: IEA, 2020a

The expected development of new uses that will have an impact on the power system

Electrification of end-use sectors

In the context of their decarbonization efforts, many end-use sectors, among which the industrial, residential and transportation sectors, are expected to resort more and more intensively to electricity. As a consequence, electricity could represent 40% of final consumption in the EU in 2040 and 46% in 2050, according to the IEA's Sustainable Development Scenario (IEA, 2020a). In its communication "A Clean Planet for All", the European Commission estimates that "*by 2050, the share of electricity in final energy demand will at least double, bringing it up to 53%*", up from c. 20% in 2018 and 29% in 2030 (EC, 2018; IEA, 2020a). The final electricity consumption of the transport sector could be multiplied by up to 10 between 2015 and 2050, according to some of its scenarios, while that of the residential sector and industry could increase by up to c. 60% over the same period (EC, 2018).

The electrification of transport, for instance, will depend on the uptake of electric vehicles (EV), which were estimated to be about 1.3 million in the EU in 2018 (IEA, 2020a). Their performances and competitiveness are expected to continue to increase: the abatement cost associated with an investment in an EV could be brought to 37 euro per avoided ton of CO_2 by 2025, down from 214 euro in 2018, thanks to a diminution in the cost of batteries (Carbone 4, 2018).

The electrification of end-use sectors can contribute to reaching GHG emissions reduction targets if electricity supply is itself decarbonized, which reinforces the stakes of RES development and integration. Yet, electrification also creates new challenges for the management of the power system, especially due to the associated variations of the consumption profiles which can generate mismatches between supply and demand and result in higher peak loads or increased network congestion.

Power system flexibility is key to address these challenges. Conversely, the electrification of end-use sectors creates new opportunities in this domain. They are sometimes designated by the concept of "sector coupling", which is defined by the IEA as "*the intelligent linkage between the power sector and other energy-consuming sectors (e.g. industry, mobility and buildings), often through advanced sensing, communication and control technologies, that flexibly utilizes demand to integrate [variable RES] and lower power system operational costs*" (IEA, 2019a). Smart charging strategies for EV, or the use of buildings' thermal storage capacities to shift the peak loads resulting from the development of heat pumps, are examples of the demand-side flexibility opportunities derived from the electrification of end-use sectors.

Electricity storage

Technologies for energy storage are also undergoing significant evolutions, as the rising penetration of variable RES and the electrification of new uses create increasing needs in this domain. Indeed, in its communication "A Clean Planet for All", the European Commission underlines that "*pathways that focus more on electrification in end-use sectors see also need for high deployment of storage (6 times today's levels) to deal with variability in the electricity system*" (EC, 2018).

a) Batteries

The development of EV relying on battery systems is expected to create new opportunities in terms of electricity storage, notably through vehicle-to-grid solutions. More generally, the advantages of battery energy storage systems (BESS) – i.e. their fast response times and their modularity – explain the rising interest for grid-scale battery projects. Their competitiveness is increasing, even though "*further reducing costs and improving the technology's performance characteristics remain important*" (IEA, 2019a).

Battery energy storage can have various applications in the power system, which give many opportunities for value creation. They range from individual uses by customers to congestion management in the distribution and transmission systems, and include the provision of energy and ancillary services, the contribution to reserve requirements, and the association with power plants to reinforce their flexibility (IEA, 2019a).

b) Power-to-X

Power-to-X technologies allow the transformation of electricity into heat, synthetic gases (e.g. hydrogen or methane) or liquids, which can then be used notably for heating, transportation or industrial purposes.

Power-to-X technologies are considered as a useful complement to BESS, inasmuch as they could address longer-term storage needs and flexibility requirements (see Figure 7 above). They could especially help to manage the seasonal variations that characterize electricity generation from variable RES.

The association of these technologies with electricity generation from decarbonized sources, notably RES, is therefore seen as very promising. Nonetheless, they are energy-intensive, and their cost-competitiveness will have to be reinforced. Two elements could contribute to this objective, according to the IEA: supporting pilots in this domain, and remunerating flexibility services on a technology-neutral basis (IEA, 2019a).

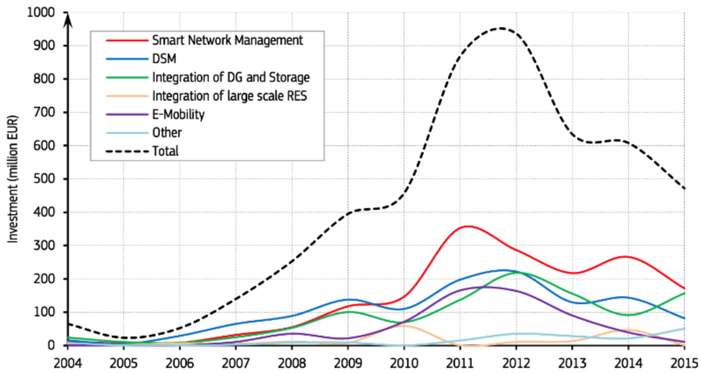
Adapting to these evolutions in generation, demand and storage: the advent of smart grids

The increasing penetration of RES – especially variable ones –, the electrification of end-use sectors and the new opportunities associated with storage deployment will require a parallel evolution towards a more digital, interconnected and flexible power system, relying especially on smart grids. The latter will act as an enabler of the development of these various technologies and will therefore be key to foster a smooth transition towards a low-carbon, decentralized electricity system. They are defined by the European Commission's Joint Research Centre (JRC) as "*an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers* *and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety*" (JRC, 2017).

Smart grid solutions rely on several types of intelligent electronic devices (IEDs), the intelligence of which rests on forecast and optimization algorithms, behavioural modelling, implementation of artificial intelligence tools, and cooperative mutual negotiations of utility-independent entities. Smart grids thus leverage cloud computing (at remote level) and edge computing (at local level), as well as their combination, fog computing.

The JRC distinguishes between six potential domains of application of smart grids, among which "*smart network management*", "*demand-side management*", and "*integration of distributed generation and storage*" (JRC, 2017). These three domains concentrate the largest shares of investments in smart grids in Europe (Figure 9) (JRC, 2017).

Figure 9. Investments in smart grid domains of application in Europe (per starting year)



Source: JRC, 2017

Smart management of electricity networks

The smart management of electricity networks aims to reinforce flexibility in their operations, at the transmission and distribution levels. It consists of solutions improving the measurement, control, protection and monitoring systems, and solutions allowing fast (or real-time) data communication (Table 1) (JRC, 2017).

Table 1. Key applications in the smart management of electricity networks

Smart network management
- Wide area monitoring systems (WAMS) at transmission network level - Fine-grained measuring devices and advanced prosumer grid interfaces at distribution network level to cope with volatile grid states - Tools for pan-European network observability - Tools for pan-European network reliability assessment - Advanced sensors on network equipment to identify anomalies and communicate with nearby devices when a fault or another issue occurs - Tools for self-controlling and healing grids i.e. the ability of a power system to automatically prevent, detect, counteract and repair itself - New capabilities for frequency control, reactive control and power-flow control - Controllable distribution substations, smart inverters, smart protection selectivity (smart relays) - Dynamic line rating - Deployment of leading-edge transformers, capacitors, VAR-control devices for reduced losses and voltage control

Source: JRC, 2017

These evolutions create new opportunities for Transmission System Operators (TSOs) and Distribution System Operators (DSOs) to manage their networks in a more efficient and flexible way; they also favour a higher involvement of end-users in the management of their energy resources.

Integration of larger shares of RES and storage

Smart grid solutions can facilitate both the development of distributed generation and storage (DG&S) in distribution networks and the integration of large-scale RES (especially wind power) in transmission or high-voltage (HV) distribution networks (Table 2) (JRC, 2017).

Table 2. Key applications in the integration of larger shares of RES and storage

Integration of DG and storage
- Network planning and analysis tool for assessment of network capacity for DG connections - Active grid support (power-frequency control, voltage control) through smart inverters to facilitate DG connection - Centralized vs decentralized (e.g. agent-based) control architectures - Integration of storage systems as key enablers for future renewable energy supply - Integration of distributed energy storage to increase the distribution network operational flexibility - Development of open and interoperable information and automation solutions for integration of DG&S - Aggregation of controllable DG and storage into virtual power plants and microgrids
Integration of large-scale RES
- Development and testing of new grid technologies that will allow for increased grid capacity and flexibility at pan-European level while maintaining system reliability - Offshore networks for wind power integration - Development of numerical test platform for testing and validating new market designs for integration of massive flexible generation dispersed in several regional power markets - Development of novel technologies coupled with innovative system management approaches for provision of system services (voltage and frequency control) by aggregated wind farms - Forecasting tools for RES production - Integration of DSM for provision of ancillary services by DSOs to support TSO operation

Source: JRC, 2017

These evolutions pave the way for new interactions between the stakeholders of the energy system, especially DSOs and DG customers, as DSOs can enable – and benefit from – network services provided by DG units; they also create opportunities for new energy actors and structures, such as aggregators and energy communities.

Demand-side management

Demand-side management is defined by the JRC as "*a global or integrated approach aimed at influencing the amount and timing of electricity consumption in order to reduce primary energy consumption and peak loads*" (JRC, 2017). It therefore covers both energy efficiency improvements and demand response (DR) services, which aim at changing the load profile of electricity-consuming assets. The IEA considers that "*the vast majority of demand-side response potential lies in large industrial thermal loads and processes, thermal comfort in buildings (i.e. heating and cooling), EV charging and behind-the-meter storage and generation*" (IEA, 2020b). It especially underlines that "*if demand response from EVs were enabled for the full EV fleet today, 2 GW of flexibility would be immediately available to the system – similar to the total amount of non-pumped hydro storage capacity*" (IEA, 2020b).

Table 3. Key applications in demand-side management

Demand-side management
- Development of ICT solutions and services for demand response and energy efficiency - Implementation of initiatives and solutions to encourage residential, commercial and industrial consumers to modify their level and pattern of energy usage - Empowerment of energy consumers (including vulnerable consumers) through the implementation of smart metering enabled services and awareness-raising initiatives - Demand response and energy management within energy communities

Source: JRC, 2017

Demand-side management solutions imply a more active role for end-users in the energy system, as consumers but also, potentially, as prosumers; the USEF framework indeed integrates the control of local generation and storage within the scope of demand response and refers to "*Active Demand and Supply (ADS)*" applications (USEF, 2015). The uptake of demand-side management solutions can also have significant consequences for DSOs' network planning and management.

2.2. Challenges for stakeholders across the energy system value chain

The increasing penetration of RES, the electrification of end-use sectors and the growing competitiveness of BESS (see part 2.1. above) are expected to lead to a rising-scale deployment of distributed energy resources (DER), including generation and storage units and loads. The USEF framework points out that "*although it is currently unclear how commercially successful each individual technology will be, taken jointly they are a disruptive development for the energy system*" (USEF, 2015). The deployment of these technologies, together with the reinforcement of the grid intelligence that is necessary to accompany them (see part 2.1. above), is giving rise to new business opportunities. To seize them, existing stakeholders are redefining their position and role in the energy system, while new players are emerging.

Challenges for existing stakeholders

Transmission system operators (TSOs)

Transmission system operators (TSOs) are in charge of operating, maintaining and developing the high-voltage (HV) transmission network, as well as its interconnections with other systems, which are especially important in Europe: the IEA underlines that "*Europe is perhaps the most advanced region for cross-border power system integration*" (IEA, 2019a).

The TSOs' main objectives consist in ensuring the safety and security of supply, as well as grid stability, by maintaining system balance and managing capacity. In their planning decisions, TSOs must consider long-term horizons: electricity grids have a long lifetime, and their construction entails significant capital expenditures. Besides, transmission infrastructure projects require long timeframes for development and implementation, and "*tend to face delays and social acceptance barriers*" (IEA, 2019a; IEA, 2020a). In this regard, the IEA stresses that "*today, significant flexibility resources are still being underutilized due to transmission and interconnection bottlenecks*" (IEA, 2019a).

New challenges for the optimization of dispatching and the management of transmission capacity and system balance are arising in the context of an increasing penetration of variable RES, due to their intermittency. They create rising flexibility needs, while reducing TSOs' ability to rely on large-scale generation units to cover them.

In this context, the USEF framework highlights the wide range of flexibility services that TSOs could obtain from aggregators, through balance responsible parties (BRPs), and the diversity of their time horizons (Table 4) (USEF, 2015).

Table 4. Flexibility services that could benefit TSOs

Flexibility service	Benefit for TSOs
Primary control **Secondary control** **Tertiary control**	Maintain system stability and reliability
National capacity market	Reduce requirement for peak generation capacity
Congestion management	Delay grid reinforcements, avoid grid reinforcements
Grid capacity management	Optimize asset use, reduce grid losses
Controlled islanding **Redundancy (n-1) support**	Reduce frequency and duration of outage

Source: USEF, 2015

Balance Responsible Parties (BRPs)

Balance Responsible Parties (BRPs) are electricity market participants in charge of ensuring that imbalances between supply and demand within their portfolio do not exceed specific limits, in order to minimize imbalance costs. The USEF framework identifies four flexibility services that can help them minimize their electricity sourcing and balancing costs: "*day-ahead optimization*", "*intraday optimization*", "*self-/passive balancing*" and "*generation optimization*" (USEF, 2015).

Advances in the construction of "*a strong transmission grid throughout Europe*", with further integration of electricity markets and cross-border flexibility transfers, could also help to address the identified challenges (USEF, 2015). The IEA underlines that this evolution constitutes a "*paradigm shift*" for the EU, as the reinforcement of integration in the field of electricity is now less driven by security of supply concerns than by the willingness to facilitate the deployment of large shares of RES (IEA, 2020a).

Distribution System Operators (DSOs)

a) Ensuring quality, reliability, stability and security of supply

Distribution System Operators (DSOs) are in charge of ensuring an efficient, reliable and safe delivery of electricity to end-users, as well as power quality. The minimization of distribution network losses and of the number of (un)planned interruptions in electricity supply are among their objectives. DSOs are also responsible for measurement and metering activities.

To achieve these objectives, DSOs operate, maintain and develop the medium-voltage (MV) and low-voltage (LV) distribution network. Like TSOs, DSOs must consider long-term horizons in their planning decisions. A precise knowledge of the grid's status, in real time, is also key to their activities.

The distribution network has traditionally been planned and operated as a centralized and passive system. The development of smart grids is expected to increasingly transform the way the distribution system is managed, with widely distributed intelligence and two-way information flows. These evolutions create new opportunities for DSOs to manage their network in a more active, efficient and flexible way, and offer them new options beyond traditional grid reinforcement investments.

Besides, the digitalization of the distribution grid allows massive data acquisition, which could be leveraged to develop advanced applications aiming for instance at proactive network maintenance, increased operational efficiency and improved service quality (USEF, 2015). However, the integration of information directly related to grid status appears to lag behind other technical applications, such as client consumption measurements. S. Sagiroglu et al. explain this by specific issues regarding data collection and integration, namely the necessary upgrade of the underlying IT infrastructure (deployment of sensors, controllers and associated IT resources in the MV-LV grids) and the lack of global strategies for data management focusing on its quality, integrity and maintenance (issues of data silos, low standardization) (S. Sagiroglu et al., 2016).

The uptake by DSOs of smart network management tools may be limited by several concerns and hurdles. First and foremost, the power grid infrastructure being critical, its security and reliability are of paramount importance. An in-depth experimentation of innovative solutions has to be carried out before their deployment in order to make sure that they do not negatively affect grid performances (USEF, 2015). Besides, the increasing complexity of the grid calls for new, sophisticated security mechanisms, in order to avoid any vulnerability due to a large number of geographically spread, interconnected components. Secondly, the adoption and implementation of smart grid solutions may be hampered by the significant investments required for the fine-tuning necessary to adapt them to specific grid requirements and energy services characteristics and to deploy them. The JRC notes that these investments "*cannot always be recovered through the revenues allowed by national regulatory schemes*", as "*in most countries R&D and demonstration projects are treated like any other cost, without any specific compensation for the risks involved in testing new processes and technologies (Eurelectric, 2014)*" (JRC, 2017). The difficulty of benefit quantification and the emphasis put by many regulatory regimes on cost savings are other challenges to investments in smart grid solutions (IEA, 2020b).

b) Strengthening the distribution grid's ability to integrate larger shares of variable RES and to manage an increasing amount of distributed loads

Many of the new RES installations are connected to the distribution network. The bidirectional, distributed and (mainly) variable system emerging with their deployment represents a significant change of paradigm for distribution systems, which were designed for unidirectional power flows from centralized and mainly fossil-based sources towards loads.

The increasing penetration of RES, and especially variable ones, is paving the way towards more dynamic energy systems. It however creates many challenges for DSOs. In their operations, they must be careful that the design limits of grid components (lines, transformers) are not exceeded in each operational condition, in order to avoid congestion or over/under voltages. Increasing shares of RES may also result in more frequent imbalances and trigger voltage issues in the grid, which can prompt to curtail RES to keep voltage levels within limits (USEF, 2015). Besides, the protection algorithms currently applied to distribution systems may no longer be adequate, due to the current supplied by RES during short circuits (which differs from classical fault current contribution from synchronous generators), and to the bidirectional power flows associated with distributed generation.

In addition to the challenges arising from the rising penetration of RES, distribution systems also have to integrate an increasing amount of distributed loads, in the context of the electrification of end-use sectors like transport and buildings. This may make the energy system more difficult to manage, due to the variation of consumption profiles and the possible mismatches between energy demand and supply, as well as the risk of increased peak loads. Yet, many of these applications – including EV charging or heating systems – can also be flexibility sources for the power system: load shifting and EV batteries' storage capabilities, for instance, can contribute to the limitation of local peak loads. The impact of their deployment on the system will therefore especially depend on the incentives provided to end-users.

DSOs must adapt their planning and operations to take into account the expected developments in RES capacity and the electrification of new uses. The reinforcement of existing grid infrastructures is a first option for them to address the ensuing challenges and ensure stable and secure grid operation. It may however entail significant costs and require time, as many distribution grids in Europe are facing ageing and saturation issues. In addition, the efficiency of such investments may be limited, as the local and system-wide peaks that they would aim to address occur only during a small number of hours per year. Leveraging the flexibility potential of DER, especially through demand response solutions, may enable DSOs to defer or avoid some grid reinforcement investments. The USEF framework provides a description of such flexibility services that could benefit DSOs (Table 5) (USEF, 2015).

Table 5. Flexibility services that could benefit DSOs

Flexibility service	Benefit for DSOs
Congestion management	Delay grid reinforcement, avoid grid reinforcement
Voltage control	Avoid grid reinforcement
Grid capacity management	Optimize asset use, reduce grid losses
Controlled islanding **Redundancy (n-1) support**	Reduce frequency and duration of outage
Power quality support	Avoid grid investments

Source: USEF, 2015

To exploit this possibility, DSOs have to be confident that enough flexibility will be available when needed, on the one hand, and that the regulatory framework will not limit their ability to consider this option, on the other hand (USEF, 2015; IEA, 2019a). The IEA underlines that this is not always the case, as "*utilities typically earn a fixed return on their approved capital expenditures (CAPEX)*", while "*the deployment of aggregated DER to provide localized flexibility services […] would generally be classified as an operational expenditures (OPEX), which is typically not considered as part of the revenues utilities are allowed to receive*" (IEA, 2019a). To avoid this bias, in the United Kingdom, the regulation by Ofgem is evolving towards a "*total expenditure [TOTEX] framework*" (IEA, 2019a).

The use of flexibility solutions and services will confer a more active role to DSOs: relying on their knowledge and anticipations of the operation status of the grid and of the electricity flows in it, which can be enriched by forecasting tools, they can identify potential congestion points, calculate flexibility requirements and source this flexibility from aggregators, or directly from industrial, commercial or residential customers. DSOs can develop new roles "*as data manager and neutral market facilitator in deployment of novel services in the electricity retail markets (ranging from advanced monitoring to local energy control [(demand response)] and flexibility services)*" (JRC, 2017). In this new position, DSOs can especially make "*relevant meter data […] available […] in a non-discriminatory way to third market players, under customer consent, through advanced interoperable platforms*" (JRC, 2017). This evolution could foster a transformation of the traditional DSO business model from wires-based to platform-based.

The need for a strong TSO-DSO cooperation

The rising penetration of RES and the provision of ancillary services to TSOs by some of them which are connected to distribution networks reinforce the need for coordination between TSOs and DSOs (JRC, 2017).

The JRC notes that "*nearly 30% of the investment allocated to [smart network management] projects includes TSO-DSO collaboration. Such collaboration includes exchange of necessary information and data with respect to daily operation of their networks and long-term planning of network investment, performance of generation assets and demand response, etc.*" (JRC, 2017).

The Clean Energy Package adopted by the EU in 2019 (see part 2.3. below), and more specifically Regulation EU/2019/943 on the Internal Market for Electricity, include provisions for "*cooperation between distribution system operators and transmission system operators*", both "*in planning and operating their networks*", and in the objective of "*[achieving] coordinated access to resources such as distributed generation, energy storage or demand response that may support the particular needs of both the [DSOs] and the [TSOs]*". At the EU level, this Regulation provides for the establishment of a "*European entity for distribution system operators*", which notably aims to "*ensure close cooperation with transmission system operators and the ENTSO for Electricity*".

Energy retailers

Energy retailers source and supply electricity to end-users, and charge them for their energy use, implementing energy tariffs. Their role is evolving as some of these end-users are becoming prosumers, able to inject electricity back into the grid.

Data acquisition and analysis will be more and more essential to energy retailers' activities: the USEF framework underlines that "*suppliers with the most accurate prediction models and the algorithms to efficiently dispatch the right assets will gain the most competitive position in the market and make the most efficient use of the available flexibility to optimize their portfolios*" (USEF, 2015).

Renewable energy producers

Renewable energy producers use their generating assets to feed electricity into the network. In order to operate them as efficiently as possible, these actors have an interest in forecasting variable RES production, and they are also willing to minimize curtailment.

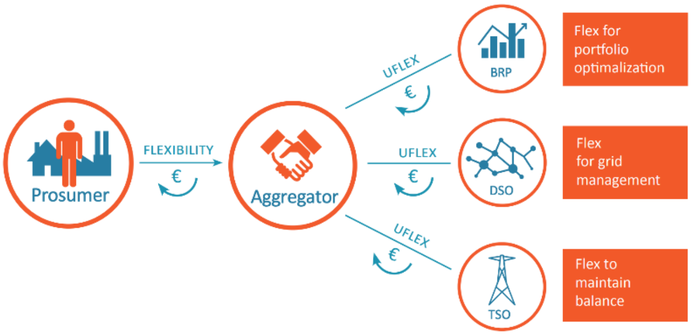
While the increasing penetration of RES creates new flexibility needs (see part 2.1. above), RES can also be sources of flexibility, by being dispatched upward or downward (IEA, 2019a). The IEA underlines that "*given that [variable RES] resources are commonly remunerated on a volumetric basis for the energy they produce, and may in some cases provide flexibility services, which in turn require reductions in energy production, it may be necessary to ensure that [variable RES] generators are remunerated fairly for providing flexibility services, just as conventional power plants are*" (IEA, 2019a).

Appearance of new players

Aggregators and Energy service companies (ESCos)

Aggregators provide energy services to industrial, commercial and residential end-users, leveraging their portfolio of DER – including generation, storage and demand-response capabilities – and acting as intermediaries between grid operators and them. The aggregation of consumers' assets into virtual power plants (VPPs) indeed enables these actors to engage in the energy wholesale market (in the case of generation assets), and to provide flexibility services to TSOs, BRPs and DSOs. Aggregators can then schedule and/or adjust the electricity generation and consumption of the assets in their portfolio in function of grid operators' flexibility requests and tariffs and consumers' preferences. The USEF framework proposes a classification of the flexibility services provided by aggregators based on customer segments (Figure 10) (USEF, 2015).

Figure 10. Flexibility services provided by aggregators to the different customer segments



Source: USEF, 2015

Energy Service Companies (ESCos) also act as service providers to end-users, notably in the field of energy efficiency and RES projects. Their offers can consist for instance in "*insight services, energy optimization services, and services such as the remote maintenance of ADS assets*" (USEF, 2015).

More generally, the JRC identifies as "*emerging stakeholders*" the "*actors providing bundled services (e.g. energy management service providers offering demand management as part of an energy service contract), or services enabling higher consumer participation (e.g. aggregators, energy-management service providers). These actors aim to promote and facilitate customer participation, thus allowing consumers to engage with energy in new ways (e.g. remotely operated and controlled energy-management platforms, smart appliances or peer-to-peer energy trading)*" (JRC, 2017).

Aggregators' activities create value for both grid operators and consumers. The scale of their flexibility pool ensures the reliability of their services to answer grid operators' needs, by "*[cancelling] out the uncertainties of non-delivery from a single Prosumer*" (USEF, 2015). End-users also benefit from aggregators' ability to optimize the value of the flexibility drawn from their assets and manage the associated complexity and market risks (USEF, 2015).

Aggregators need to have an in-depth knowledge of their customers' DER, behaviour and preferences, as well as accurate forecasting capabilities, notably for the management of price risks (USEF, 2015). They may therefore choose to address only certain customer segments (e.g. residential, industrial or commercial) or certain categories of DER (USEF, 2015).

Aggregators and ESCos tend to have smaller customer bases than existing stakeholders (e.g. energy retailers). The USEF framework underlines the necessity to ensure that "*market access conditions are standardized and certifiable*" for these "*new market players [to be able to] seamlessly participate in the market, without the prerequisite of complex market integration testing with all existing market players*" (USEF, 2015). They indeed face significant transaction costs in their activities, which can create challenges in terms of profitability. The aggregation of DER and their qualification for market participation and flexibility service provision may entail such costs, notably when requirements are designed for large-scale resources (IEA, 2019a). In the case of ESCos, the energy savings achieved for customers also have to be weighed against the level of energy prices, and low prices may make it difficult to guarantee short-term returns on investments.

These actors have to take these challenges into account when conceiving their business model. The USEF framework distinguishes between *"six main business models for the Aggregator emerging in Europe: Combined Aggregator-Supplier […], Combined Aggregator-BRP […], Aggregator as service provider […], Delegated Aggregator […], Prosumer as Aggregator […], [and] E-mobility role (CSO[1] or EmSP[2]) as Aggregator"* (USEF, 2015).

Industrial, commercial and residential consumers

Industrial, commercial and residential consumers can own loads, but also production (especially from RES) and storage assets ("behind-the-meter" assets), turning them into "prosumers". This evolution, which used to concern mainly industrial and commercial end-users, increasingly involves residential end-users as well. They are indeed more and more energy aware and willing to contribute to the energy transition. The USEF framework provides a typology of the ADS assets that consumers/prosumers can hold and of the associated flexibility services (Table 6) (USEF, 2015).

Table 6. ADS assets of consumers/prosumers and related flexibility services

Type	Flexibility	Examples
Controllable load	Load shifting, on/off switching, variable power	Heat pumps, air conditioning, HVAC systems, cold stores, heating or cooling processes, industrial production processes
Local generation	Controllable, variable power generation	Solar PV, CHP and micro-CHP systems, fuel cells, gas turbines, UPSes
Storage	Charge and discharge. The sole task of storage is to introduce flexibility in the energy chain	Residential storage units (e.g. batteries), district storage
Electric vehicles	Smart charging and discharging plus the ability to move to another location	Cars, trucks, forklifts, watercraft

Source: USEF, 2015

Increased digitalization and advances in communication technologies provide end-users owning such assets with opportunities to play a more active role in the energy system. The increased information and monitoring of energy consumption (and generation) that they allow, especially thanks to the deployment of smart meters, act as an enabler in this regard.

ADS assets can be dispatched in function of their owners' needs. End-users may opt for solutions for energy management (e.g. in buildings) and coordination of DER (e.g. RES production and storage assets), in order to optimize the operations of behind-the-meter assets (with the objective, for instance, to maximize self-consumption) and to achieve energy and cost savings (notably thanks to a minimization of energy and network charges). The USEF framework identifies several services that could benefit end-users for in-home optimization purposes (Table 7) (USEF, 2015).

[1] Charging Station Operator
[2] E-mobility Service Provider

Table 7. Flexibility services that could benefit end-users for in-home optimization purposes

Flexibility service	Benefit for end-users
ToU[3] Optimization	Reduce energy costs
KWmax Control[4]	Reduce grid connection costs
Self-Balancing	Reduce energy costs
Controlled Islanding	Increase availability

Source: USEF, 2015

However, end-users may also be willing to exploit more fully the economic potential of these ADS assets (USEF, 2015). This can prompt them to participate in energy markets and provide flexibility services (especially DR services), either directly (in the case of commercial and industrial end-users) or through an intermediary (e.g. an aggregator). "*Empowering consumers and providing them with the tools to participate more in the energy market, including participating in new ways*", is one of the key objectives set by Directive (EU) 2019/944 on common rules for the internal market for electricity, which is part of the Clean Energy Package adopted by the EU in 2019 (see part 2.3. below).

These evolutions are paving the way towards a smart, citizen-centred energy system. However, some challenges have to be addressed in order to enable a more active role of end-users in the energy system and markets and foster their engagement. In addition to the elimination of technical barriers (e.g. by enabling standards-based two-way communication, plug-and-play installation and data exchange and integration across brands and protocols), specific attention will have to be paid to data protection, security and privacy.

The specific challenges of energy communities

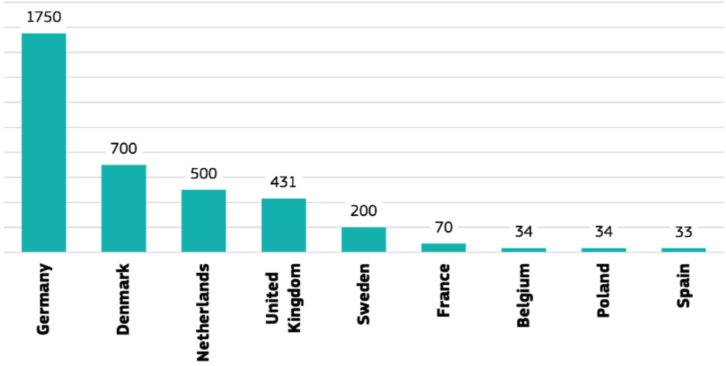
An energy community is a legal entity which enables citizens, possibly with other stakeholders (e.g. local authorities, SMEs), to cooperate in the generation, consumption, and/or storage of energy, mostly from RES (notably solar and wind power). Some energy communities are also involved in energy supply, aggregation, and/or in energy services (e.g. energy efficiency services).

Energy communities are often organized as cooperatives, which aim to provide services to their members and reinvest profits in their common benefit (JRC, 2020). However, energy communities can adopt various other legal forms, among which limited partnerships, community trusts and foundations, housing associations, non-profit customer-owned enterprises, public-private partnerships, or public utility companies (JRC, 2020).

Europe currently counts around 3500 renewable energy cooperatives (Figure 11) (JRC, 2020). The JRC observes that "*energy communities are more prevalent in the Northern-Western European countries with higher levels of welfare and longer traditions of community ownership*", notably Germany and Denmark (JRC, 2020).

[3] Time-of-Use
[4] Control of the maximum load

Figure 11. Number of community energy initiatives in nine European countries



Source: JRC, 2020

Energy communities are viewed as a lever to foster investments in green assets, as participants can co-own them and jointly retrieve the related benefits. Such organizations can therefore ease the transition towards decarbonized energy systems, by facilitating RES uptake and acceptance. Energy communities can also become important actors in the provision of flexibility services (e.g. reducing congestion and limiting demand peaks, by aggregating DER) (JRC, 2020). Depending on their uptake, they may contribute to the decentralization of the power system.

To foster this uptake, the European Commission has adopted enabling legislative measures within the framework of the Clean Energy Package (JRC, 2020). Two of the related Directives provide for "citizen energy communities" (Internal Electricity Market Directive EU/2019/944) and "renewable energy communities" (Renewable Energy Directive EU/2018/2001) and have to be transposed into national law.

Energy communities could play a significant role in RES generation in the coming decades: according to some estimates, their share of installed capacity could represent c. 17% for wind power and 21% for solar power at the 2030 horizon (JRC, 2020). Nonetheless, the JRC underlines that "*more research is needed to clarify and quantify their potential at local, regional and/or the national levels, and analyse their economic, environmental and social effects. This should also investigate the barriers preventing people and communities from participating in energy projects*" (JRC, 2020).

Some of the barriers that would need to be addressed may include remaining technical issues, as well as the challenges related to financing and to the development of sustainable business models. While the policy frameworks and mechanisms supporting RES investments, notably FiT (see part 2.1. above), have fostered the emergence of energy communities, market-based remuneration schemes like auctions and tenders may prove more challenging to access for them (JRC, 2020).

2.3. Market opportunities

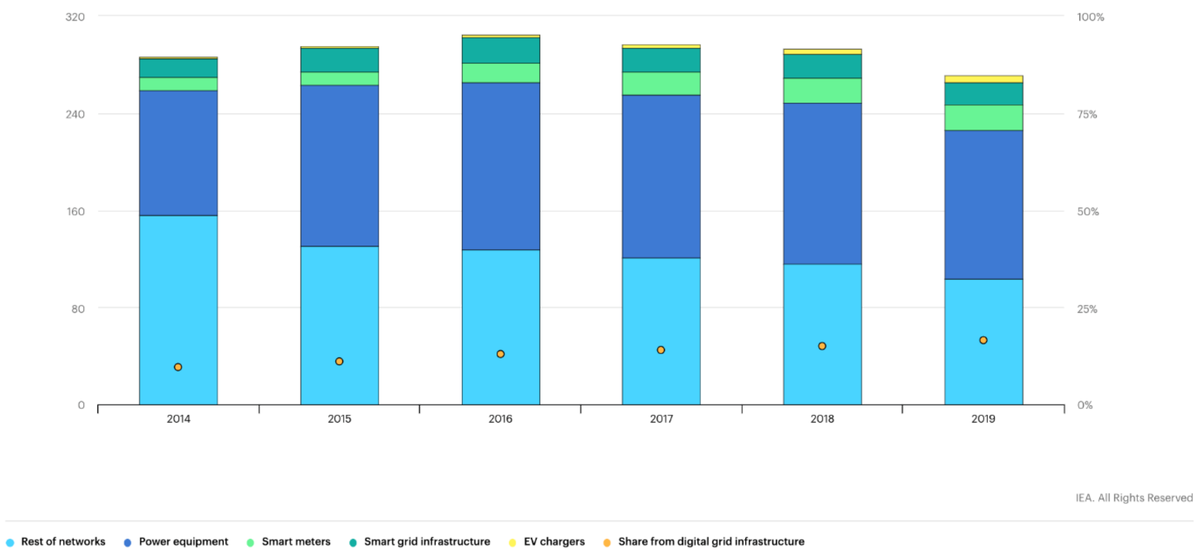
A market with strong development prospects

Market outlook at the global and EU level

Flexibility is becoming a more and more widespread challenge, as the share of variable RES is increasing in power systems all over the world: according to the IEA, "*in 2015, there were just over 30 countries with an annual generation share of [variable RES] greater than 5%; by 2018, this number had risen to nearly 50 countries*" (IEA, 2019a).

In parallel, investments in the smartening of network infrastructures are expanding, accounting for more than 15% of total investments in electricity grids in 2019 (Figure 12) (IEA, 2020b). This trend is observable in Europe, where the IEA notes "*rising expenditures allocated to upgrading and refurbishing the existing grid as variable renewables and electrification become more important*" (IEA, 2020b).

Figure 12. Investments in electricity grids and digital grid infrastructure (USD bn and % from digital grid infrastructure)

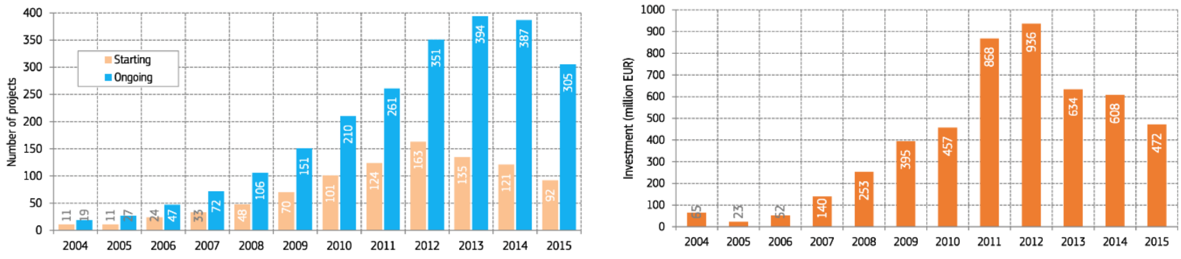


Source: IEA, 2020b

Smart grid solutions such as smart meters, sensors, actuators and control systems are indeed being deployed in various EU member States (JRC, 2017). As regards smart meters, in particular, the Electricity Directive 2009/72/EC had set an objective for their deployment in EU member States: it had to reach 80% of end-users at the 2020 horizon, conditional upon the results of a cost/benefit analysis. As of end-2017, nine EU countries had reached a coverage superior to half of residential end-users (IEA, 2020a).

The JRC however underlines that "*the high number of R&D projects suggests that even if some smart grid solutions are getting close to the commercialization phase, R&D efforts are still required in many fields to investigate new options and features as well as their integration and interoperability within the grid*" (JRC, 2017). The JRC's study highlights the dynamism of such R&D efforts in Europe: its database evidences 950 projects – 540 R&D projects and 410 demonstration projects – in this field in the 50 countries that it covers, representing a total investment of 4.97 billion euro (JRC, 2017). The number of new projects and the related investments have strongly increased between 2005 and 2012 and registered a slight decrease since then (Figure 13) (JRC, 2017). The JRC explains it by "*the cautiousness of private investors in financing projects which develop and test more advanced solutions*", notably due to "*uncertainties related to the regulatory environment and to the possibility of getting a fair return on investment*"; it however notes that "*smart grid stakeholders still see the need and potential of investing in R&D and of more advanced, integrated and interoperable solutions*" (JRC, 2017).

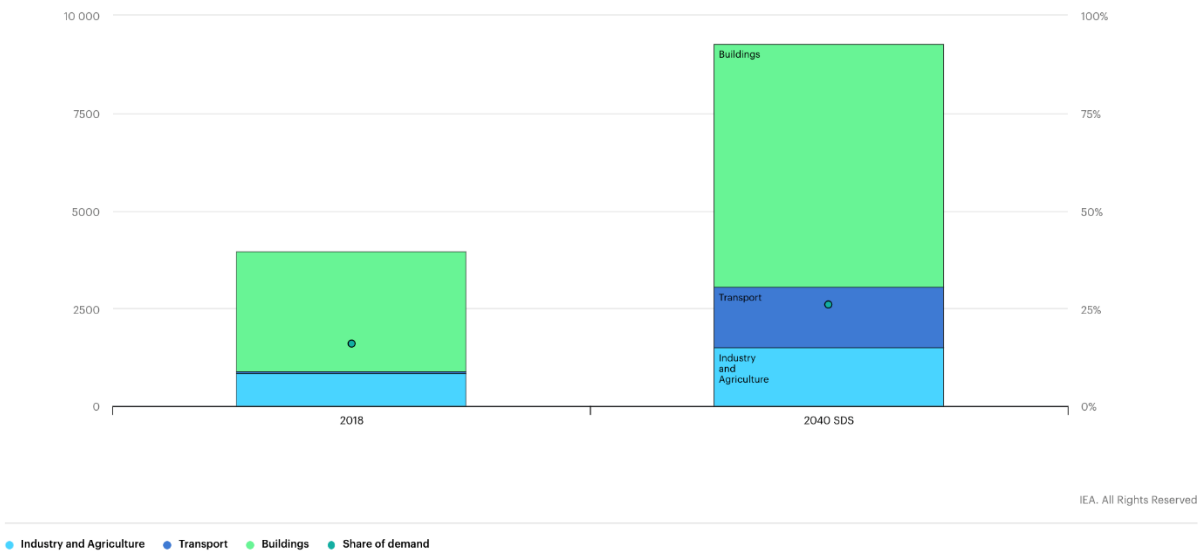
Figure 13. Smart grid R&D and demonstration projects (left) and related investments (right) in Europe



Source: JRC, 2017

As regards demand-side flexibility, the IEA observes that capacity increased by 5% year-on-year in 2019 at the global level, driven notably by the United States, Australia and Europe (IEA, 2020b). It stresses that "*the demand response base is small relative to the magnitude of effort needed in the [Sustainable Development Scenario]: by 2050, the global inventory of flexible assets in the residential, commercial and industrial sectors needs to be ten times higher than it is today. Less than 2% of the global potential for demand-side flexibility is currently being utilized*" (IEA, 2020b). These estimates however point to an "*enormous potential*" in this domain (Figure 14), calling for current barriers – notably "*regulatory uncertainty*" – to be addressed and for an extension of DR to services beyond load reduction, especially through an exploitation of "*local flexibility*" (IEA, 2020b).

Figure 14. DR potential in the IEA's Sustainable Development Scenario in 2018 and at the 2040 horizon (TWh and % of demand)



Source: IEA, 2020b

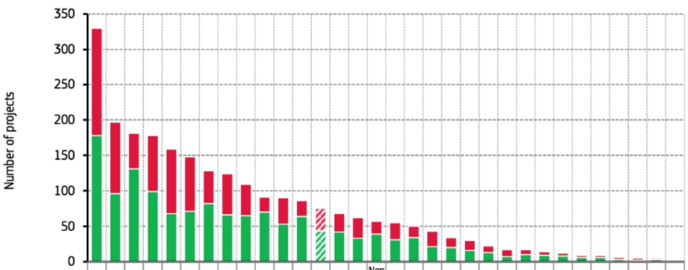
In the EU, DR participation in the market represented c. 21 GW in 2016, most of which (15 GW) from industrial end-users (IEA, 2020a). The leading markets include France, Germany, Italy, Spain and the United Kingdom (IEA, 2020a). The EU's theoretical potential in this domain has been estimated to 100 GW by the European Commission; it could rise to 160 GW by 2030 (IEA, 2020a).

Key criteria to be taken into account when assessing a given geographical market's potential

The JRC observes a significant heterogeneity between EU member States in smart grid projects development (JRC, 2017). The number of projects, considered by the JRC as "*an indication of the* *intention to invest in smart grid solutions in each country*", is very high in Germany, and also significant in the United Kingdom, Denmark, Spain, France and Italy (Figure 15) (JRC, 2017). Investment is also concentrated in these countries (Figure 15), and some of them (notably France and the United Kingdom) "*pioneered large investments earlier than others*" (JRC, 2017).

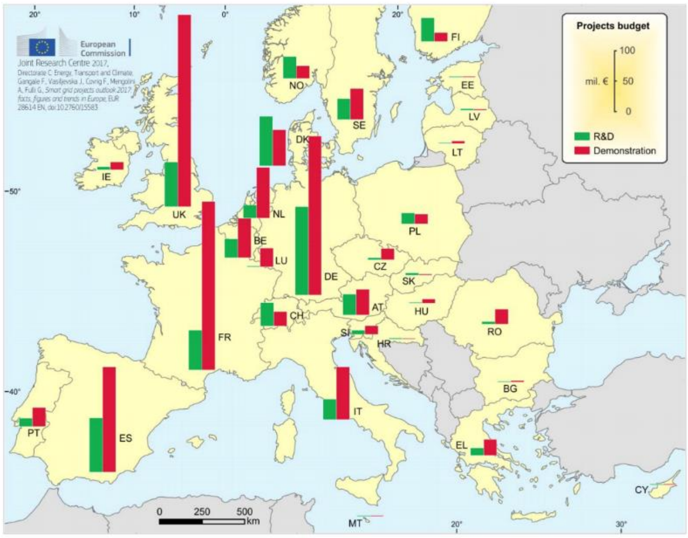
Figure 15. Smart grid projects in the EU: number of projects and investment

Number of projects[5]



	DE	UK	DK	ES	FR	IT	AT	NL	BE	CH	SE	NO	Avg	PT	EL	Non-EU	FI	PL	SI	IE	RO	CZ	HU	BG	HR	SK	LV	CY	EE	LT	MT	LU
Demonstration	152	101	50	79	91	77	46	58	44	21	37	22	32	26	29	18	24	16	22	14	14	9	10	7	5	4	3	3	3	3	2	2
R&D	178	96	131	99	68	71	82	66	65	70	53	64	43	42	33	39	31	34	21	20	16	13	7	10	9	8	6	6	3	2	3	0

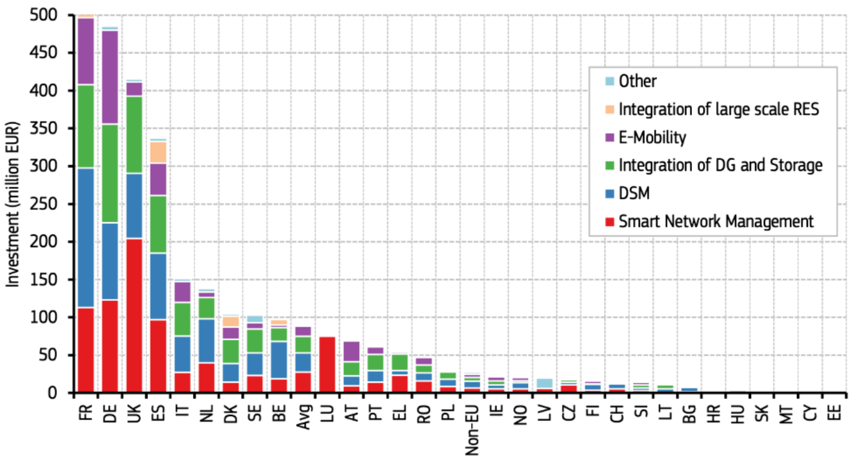
Investment



Source: JRC, 2017

The JRC also considers another indicator: the location of the sites chosen for the implementation of demonstration projects, which can "*shed some light on the national and regional interest for the development of specific smart grid solutions*" (JRC, 2017). Germany and Spain are the countries with the most implementation sites (140 and 95 respectively, out of 800), and the related investment is also significant in France and the United Kingdom (Figure 16) (JRC, 2017).

Figure 16. Investments in implementation sites of smart grid demonstration projects in European countries

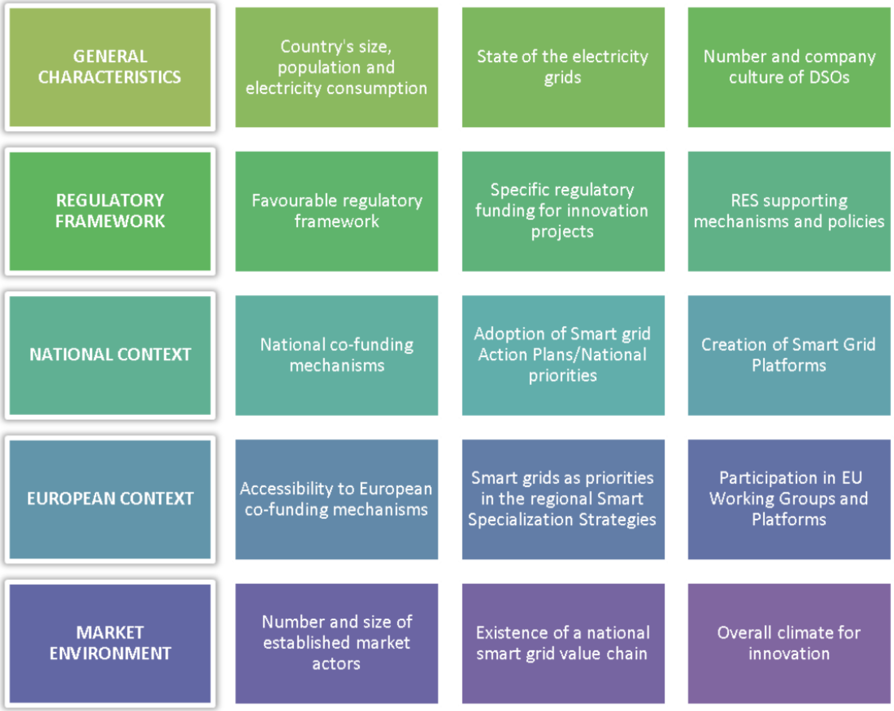


Source: JRC, 2017

[5] It must be noted that the JRC's "*project count assigns projects to the countries where the participating organizations are based*" (JRC, 2017).

The JRC provides a framework of analysis of the factors that may explain the differences in smart grid projects development among member States (Figure 17) (JRC, 2017). These factors evidence the main criteria to be taken into account in order to assess a given geographical market's potential in the field of smart grid development.

Figure 17. The JRC's framework of analysis of the "main factors affecting the number of projects and the level of investment" in smart grid projects (JRC, 2017)



Source: JRC, 2017

Beyond the general characteristics of a country and of its power system (especially the importance of electricity consumption and the state of the grid), the regulatory framework and the instruments available to address financing challenges play a significant role in enabling investments in smart grid projects, which involve the development and experimentation of innovative technological solutions as well as new business models (JRC, 2017).

Regulatory frameworks, market designs and their possible evolutions will play a key role in shaping the smart grid and flexibility solutions development prospects. The IEA highlights the "*importance of […] developing rules for the evolution of power markets that enable and reward system flexibility*": "*all power system assets can provide flexibility services if enabled by proper policy, market and regulatory frameworks. […] Moving forward, efforts to modify connection codes and market rules will be key for all assets – including power plants, electricity networks, DER and energy storage – to receive fair remuneration for their flexibility services*" (IEA, 2019a).

Several EU member States, in particular Denmark, Germany and the United Kingdom, have adopted regulatory frameworks supportive of smart grid projects (JRC, 2017). The IEA also gives some examples of "*innovative regulations*" which have acted as enablers or even goads for the development of flexibility services, such as the feasibility study realized by the Italian publicly-funded research agency

RSE on Virtual Storage Systems in Lombardy, or the "*regulatory sandboxes*" allowing experimentations in Germany (IEA, 2019a).

More generally, the EU adopted in 2019 a new energy rulebook, the Clean Energy for all Europeans Package, which provides for evolutions in the electricity market design. They especially aim to facilitate the integration of rising shares of variable RES and the deployment of DER, and to foster flexibility services from generation, DR and storage resources. They specify the new roles that the various stakeholders, especially DSOs, aggregators and consumers, can play in this regard, and especially encourage the introduction of dynamic, time-differentiated distribution network tariffs. The IEA underlines that "*the full implementation of the CEP has only just started*" and that it "*will have to be the main focus of the European Commission and the EU member states in the coming years*" (IEA, 2020a).

A specific task of the FLEXIGRID project (task 7.3) will be dedicated to the analysis of the regulatory framework in Europe, taking into account these developments. It will especially lead to the identification of potential legislative barriers and to the formulation of recommendations to foster the deployment of innovative solutions and business models.

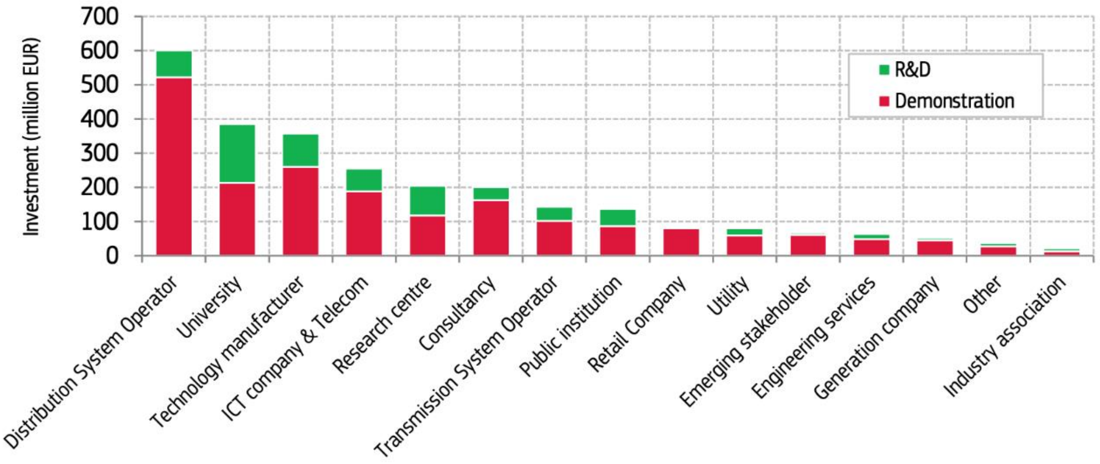
In addition to the regulatory framework and market design, financing can create other challenges for the development of smart grid projects, which often require significant investments. The JRC notes that "*a barrier that seems to be encountered by all smart grid actors is the difficulty in finding sufficient resources to finance the projects exclusively by their own means*"; it observes that "*in [its] database, […] only 15% of the projects are financed exclusively by own/private resources*" (JRC, 2017). The availability of national – and, in the case of EU member States, European – funding programs can therefore play a key role in enabling smart grid development. The ForskEL program in Denmark, the "Future-Proof Power Grids" initiative launched by federal ministries in Germany, the "Investment for the Future" program in France, or the funding provided by the Tekes agency for innovation in Finland provide examples of supportive mechanisms in this domain (JRC, 2017). In total, almost half of the projects studied by the JRC benefited from national funding, and 30% from EU funding (JRC, 2017).

The JRC also raises the issue of the compensation for the costs of innovation projects provided for in the regulation of DSOs' activities, and mentions the existence of "*ad hoc regulatory schemes*" in some countries, such as the Low Carbon Networks Fund (LCNF) established by Ofgem in the United Kingdom, or the supplementary remuneration of capital cost attributed for certain demonstration projects by the Italian regulator AEEG (JRC, 2017).

A range of actors positioning themselves on the market

The JRC's study identifies a significant range of actors intervening in smart grid development, with a total of 2930 organizations involved in the 950 projects considered (JRC, 2017). The most active are DSOs, universities, and technology manufacturers (Figure 18).

Figure 18. Stakeholders' private investments in smart grid R&D and demonstration projects



Source: JRC, 2017

DSOs are the actors investing the most in smart grid R&D and demonstration projects: they are "*proactively investigating and testing new solutions, as well as new roles and business models, in order to get ready to take up the new tasks, responsibilities and opportunities that are shaping up in the evolving power system*" (JRC, 2017).

Technology manufacturers (especially hardware solutions providers) and ICT companies (including software developers) are collaborating to develop digital solutions to smarten the power system, and investing "*to develop and test their solutions in real life environments and gain technology leadership that can be exported globally*" (JRC, 2017).

In addition to these long-standing actors in the smart grid domain, "*emerging stakeholders*" (a category which includes aggregators, energy-management service providers and housing associations) are playing a growing role, notably in France, the United Kingdom and Germany, and collaborating with other actors, especially with DSOs, in the field of flexibility services (JRC, 2017). The IEA also observes that oil companies are increasingly diversifying in flexibility and demand-side management technologies, citing as examples the acquisitions of Saft (battery manufacturer) and Go Electric (microgrid developer) by Total, that of Ampere (residential storage developer) by Repsol, and that of Limejump (aggregator) by Shell (IEA, 2020b).

While the emphasis has for a long time been put on hardware solutions, such as digital substations and smart meters, the IEA observes that "*utilities […] have indicated they are increasingly adopting sophisticated software tools*", notably in the United States and in Europe (IEA, 2020b). It cites as an example the development of software platforms, including digital twins, for the monitoring and control of grid infrastructure and substations, or the use of artificial intelligence for predictive maintenance (IEA, 2020b).

The JRC also points out that "*a growing number of projects investigate and test the systemic integration of different smart grid solutions*" (JRC, 2017). Interoperability is indeed expected to become a growing concern as the continuous development and deployment of a wide range of solutions create strong needs for seamless interaction and operation between the devices on which they rely and other equipment, both in the power system and in other sectors (e.g. EV charging infrastructure) (IEA, 2020b). In this context, the IEA stresses that "*technical roadmaps will be required that lay out the* *necessary evolution of standards and interoperability of both digital and traditional electricity infrastructure as the energy system continues to evolve*" (IEA, 2020b). Particular attention also has to be paid to cybersecurity risks and concerns around privacy and data management, in order to ensure grid infrastructure availability and integrity and confidentiality of energy information (USEF, 2015). To this end, the European Commission adopted in April 2019 a "Recommendation on Cybersecurity in the Energy Sector" to "*provide non-exhaustive guidance to member States and relevant stakeholders, in particular network operators and technology suppliers, for achieving a higher level of cybersecurity in view of the specific real-time requirements identified for the energy sector, cascading effects and the combination of legacy and state-of-the-art technologies*" (EC, 2019b).

3. THE FLEXIGRID APPROACH

3.1. Key components of the FLEXIGRID approach

4 hardware solutions

FLEXIGRID hardware solutions aim to build a new physical architecture and advanced integrated communications infrastructure that will allow the development and provision of services that are currently constrained by technical limitations.

Secondary Substation of the future

Medium Voltage (MV) to Low Voltage (LV) transformer substations are a key link in the smart grid chain, to leverage the opportunities offered by Intelligent Electronic Devices (IEDs) for the acquisition and treatment of data.

The Secondary Substation of the future transforms the classical LV distribution switchgear into a smart LV switchgear and control gear assembly, with advanced functionalities in terms of automation, intelligent operation, fault detection, and meter infrastructure. It especially includes a compact smart distribution transformer with an On-Load Tap Changer (OLTC) able to automatically regulate the voltage in order to face the fluctuations generated by new loads (e.g. EV) and variable distributed generation in the LV grid, while compensating voltage instabilities in the MV network. Electronic equipment and sensors to acquire measurements are integrated into a smart low-voltage board (LVB), which avoids the necessity to install a new control box in the MV transformer substation.

An alternative version of the Secondary Substation of the future will be developed for remote isolated areas, with modifications to the Plant Central Regulator (PCR) and the Medium Voltage Regulator.

In addition to these new generations of Secondary Substations, FLEXIGRID provides a solution for the refurbishment and upgrading of existing Secondary Substations. It requires some hardware and software modifications in these Secondary Substations, and rests on Energy Boxes.

Energy Box

The Energy Box is a multi-purpose concentrator for smart grid and micro-grid management. It has versatile real-time communication capabilities, which are expected to be developed to turn it into a global adaptor able to communicate with all the relevant standards used in the energy sector. Besides, it contains an embedded computer that provides processing capacity to implement distributed computing (especially for capture and storage of information, execution of algorithms, and control of the installation), thanks to state-of-the-art, interoperable microprocessors.

The deployment of the Energy Box allows to smarten the grid architecture: it enhances the capacity of the system to obtain information about field devices (e.g. smart meters, grid analysers, renewable electronic controllers, sensors and actuators) and to provide flexibility services in an edge computing paradigm. The Energy Box will be able to retrofit and smarten existing Secondary Substations, providing upper-level automation and communication interfaces to monitor the facility and enhance the assets control capacity. Beyond this integration in Secondary Substations, the Energy Box will also be placed in domestic and industrial environments over the course of the project.

Smart meters with feeder-mapping capabilities

Smart energy meters are key components of intelligent energy networks. Within the framework of FLEXIGRID, the functionalities and intelligence of meters will be enhanced to propose a new generation of smart meters able to take advantage of the possibilities offered by new advanced metering infrastructures (AMI). The developed interface will provide end-users with real-time information about their electric power consumption. It will rest on power line communications (PLC) technology. Besides, the potential applications that could leverage the data exchanged between the data concentrators and the meters to improve network operation will be analysed. An innovative mechanism will allow the identification of the LV feeders of the connected smart meters at the Secondary Substations. It will rely on inducer-receiver sensors arranged on one phase of the lines that are in contact with the final meters.

Protections for high RES penetration

Innovative protective systems will be developed in order to strengthen the MV grid's ability to address the challenges resulting from the increasing penetration of RES (bidirectional current flow direction, variations in fault current dynamics). They will include both a hardware architecture and software algorithms creating an adjustable set of protection schemes and reconfiguration tools able to recognize changes in network layouts or in power flow directions and magnitude due to DER.

4 software solutions

FLEXIGRID software solutions aim to develop innovative operation, control and management strategies for the distribution grid.

Software module for fault location and self-healing

This software module, resting on advanced fault detection/location and energy supply restoration (self-healing) algorithms, aims to provide information and control for the operation of the MV and LV networks in real time. In the advent that it detects a fault in the distribution grid, it will be able to send orders to open and close the relevant breakers and disconnectors in order to isolate the affected area in a milliseconds range, limiting it as much as possible and taking reconfiguration steps to restore the service.

Software module for forecasting and grid operation

This software module will comprise a set of forecasting algorithms to accurately predict RES generation, demand, and electricity price. It will leverage the measurements registered by sensors and other intelligent electronic devices (IEDs) installed along the MV network. It will also use high granularity measurement data from field DER (RES, batteries, EV and selected loads that can offer flexibility to the operation of the grid), together with external data (e.g. local weather forecasts), to generate future snapshots of the local energy system. Machine-learning algorithms will provide day-ahead forecasts for the aggregated load and generation within the area of the Secondary Substation. This will allow a precise identification of local grid flexibility requirements in the short and mid-term.

MV grid smart operation algorithms will rely on the knowledge of the grid state and on the forecasting results. The flexibility requests upon DSO needs will be sent to the Secondary Substations, where different answers from the downstream connected assets will be considered and implemented in the Energy Boxes or other IEDs thanks to the FUSE platform. In addition to flexibility needs, optimized operation will be sought: the optimization algorithms included in the software module will suggest grid operation orders aiming to balance the demand curve and maximize the integration of RES generation without compromising security of supply and grid stability. They will calculate the optimal operation of generation, storage and consumption points, and operation orders will be applied in distributed assets.

Software module for congestion management

As explained above (see "software module for forecasting and grid operation"), using forecasts, a software module will assess the flexibility that needs to be provided to the grid under different operation conditions and optimization objectives. Under normal operation, the local energy system will be optimized towards minimizing energy costs, while under abnormal network conditions (i.e. blackout), specific critical loads will be supplied by battery systems whose storage capacity will be locally supplied by RES.

The software module for congestion management will recognize congestion situations and improve current management algorithms to reduce them, notably through measures that decrease the amount of energy purchased from the utility company during peak demand hours. The suite will host a repository of DER models (generation, storage, EVs), along with instantiated flexibility profiles. This will allow a detailed analysis of flexibility and a proper classification of DERs for properly and effectively addressing evolving grid requirements and events (local congestion, peak demand). High profiles of demand will be defined in an interactive manner with building occupants (e.g. through an intuitive app) and used to provide additional flexibility without disrupting daily schedules or comfort. Based on these various profiles, the system will facilitate the definition of local micro-virtual power plants (VPP) that will aggregate distributed flexibilities based on their suitability for congestion management and peak shaving services. The VPP configuration will in turn feed the control component (see "software module for forecasting and grid operation") dispatching the DER (DR, storage, generation, EV) of the local grid.

Virtual thermal energy storage (VTES) model

The VTES software will exploit the thermal storage capabilities of HVAC (heating, ventilation, air-conditioning), water heaters and building spaces to dispatch desired amounts of flexibility without disrupting occupant comfort and operations (e.g. through preheating/cooling strategies). It will include models, techniques and algorithms to provide a smart solution for automated building-level demand-response and energy consumption optimisation services.

Dynamic building thermal inertia models will be configured to reflect the thermal behaviour of buildings under varying usage constraints (e.g. operations, occupancy, occupant comfort preferences and behaviour) and building envelope characteristics that define its thermal mass/inertia properties. In addition, comprehensive parametric models of properties (e.g. capacity retention period, "discharge rate") of thermal storage equipment (water heaters, boilers, etc.), as well as their electrical response characteristics (e.g. response time, rated and actual power/energy consumption, ramp up/down times), will be developed to define their thermal storage capacity and flexibility considering daily schedules and preferences of occupants. This dynamic modelling approach will deliver accurate VTES profiling models for individual spaces and equipment within buildings, and thereby contribute to the definition of the pre-heating/cooling flexibility that can be offered within the framework of optimized DR strategies.

The FUSE platform adaptors

FUSE is an open-source platform that enables the seamless integration of devices at the edge by fully exploiting the data from local and distributed energy resources in order to build and provide value-added services for several user profiles. It is designed to guarantee interconnectivity with external devices, including other existing platforms (SCADA, AMM, AMI, etc.). It harmonizes the data to a common information model based on standards, in order to facilitate interoperability.

To achieve this, FUSE consists in a modular ensemble with different internal components: service API, semantic repository, data management services, data API, and adaptors. The integration of data is done through the adaptors, which simplify its pre-management. FUSE therefore establishes a common framework (middleware) for the applications to be executed, sharing the access to information regardless of the underlying data models and structures. Issues related to cybersecurity and data management and protection are taken into account: FUSE enables end-users to control their own data, and combines the latest technologies for data collection, management and exposure in its backbone.

3.2. Market positioning of the FLEXIGRID approach

Potential customers and end-users

Potential customers and other beneficiaries: identification and business case overview

The FLEXIGRID approach targets two main customer segments:

- DSOs, as FLEXIGRID solutions contribute to the optimization of their assets and of the services that they provide. They will indeed enable these operators to manage their network and address its constraints more actively, and to improve the quality of supply. Besides, leveraging flexibility will allow the deferment and/or minimization of network investments;
- and aggregators/ESCos, as FLEXIGRID solutions enable them to optimize the management of and the value extraction from their flexibility pool (i.e. their customers' generation and storage units and DR capabilities).

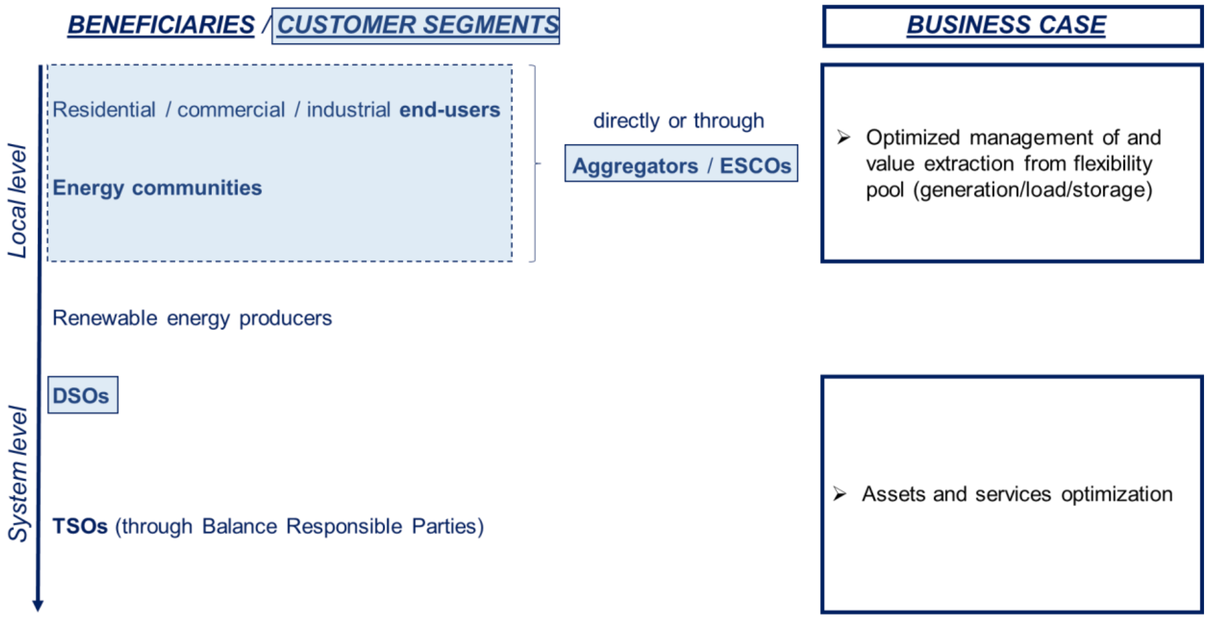
FLEXIGRID solutions therefore enhance these actors' ability to meet the expectations of end-users, who are willing to play a more active role in the energy system, benefit from an improved reliability of their energy supply, and make savings on their energy bills. These customers (especially commercial and industrial ones) may also choose to directly take on the aggregator role, if their assets' flexibility potential is large enough to justify it. In this regard, the FLEXIGRID approach gives an opportunity to clarify the business case for energy communities and foster their uptake.

The FLEXIGRID approach also provides TSOs with opportunities in terms of assets and services optimization, through their interactions with DSOs on the one hand, and through the interactions between aggregators and BRPs on the other hand.

Renewable energy producers (beyond the "prosumers" among residential, commercial and industrial end-users or within energy communities) are other beneficiaries of the FLEXIGRID approach, as the latter will improve the distribution networks' hosting capacity for RES, maximizing their integration and reducing curtailment.

The analysis of the Value Proposition Canvas designed for each potential customer segment and beneficiary of the FLEXIGRID approach allows to refine the identified business cases.

Figure 19. FLEXIGRID approach: identification of customer segments and other beneficiaries, and of the corresponding business cases



Targeted geographical markets

The demonstration of FLEXIGRID solutions will be carried out in four European countries – Croatia, Greece, Italy, and Spain – which represent the first targeted geographical markets. In parallel of the demonstration campaign, FLEXIGRID partners will analyse the potential impact that the different use cases and the overall FLEXIGRID approach could have in other European regions (task 7.1, M25-M48). The analysis of the regulatory framework and of the future market design context in European countries that will be performed (tasks 7.2 and 7.3, M37-M48) will also provide important insights to refine the identification of potential markets. The results of these analyses will allow to specify the targeted geographical markets for the deployment of FLEXIGRID solutions and to provide more elements on this dimension in later versions of Deliverable 8.1.

Value proposition of the FLEXIGRID approach

The FLEXIGRID approach creates many opportunities for DSOs to optimize their assets' utilization and their service provision. Figure 20 details its value proposition for this customer segment. The customer job(s), gains and pains sections build on the analysis of DSOs' challenges (see part 2.2. above). Table 8 and Table 9 specify how the FLEXIGRID approach can enable DSOs to address these challenges and leverage the opportunities offered by flexibility solutions and services to reach their objectives.

Figure 20. FLEXIGRID approach Value proposition Canvas #1 - DSOs

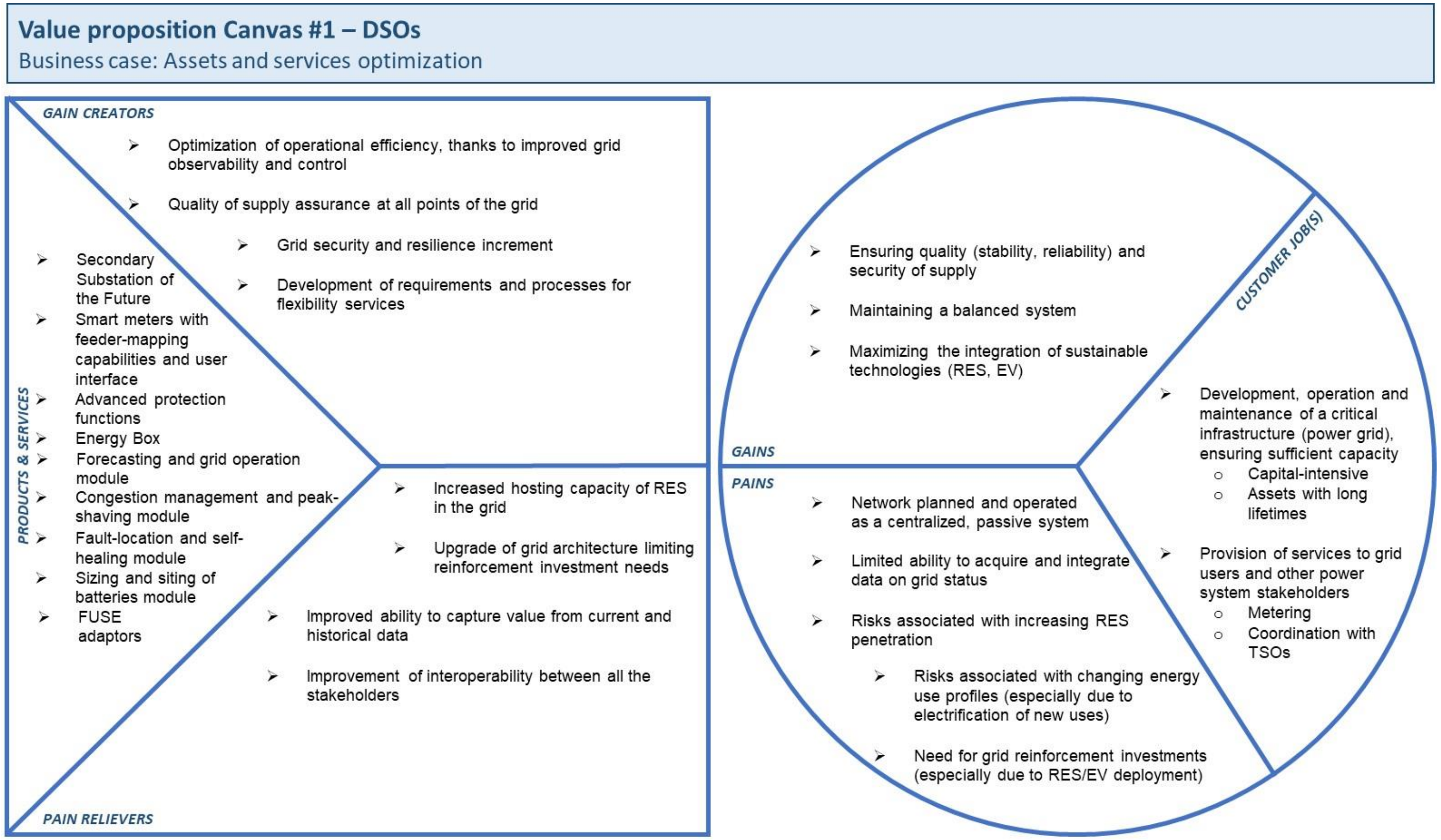


Table 8. FLEXIGRID approach Value proposition for DSOs: Gain creation

Gain creation through the FLEXIGRID approach	Corresponding gains of DSOs
Optimization of operational efficiency, thanks to improved grid observability and control - Higher and widely distributed intelligence - Monitoring of grid status, in real time and in advance (notably allowing to assess congestion) - Higher automation and (remote) control of the grid - Reduced response time, thanks to new communication protocols - Enhanced accuracy of load and generation forecasting, allowing improved identification of flexibility requirements in the mid and short-term - Load and generation balancing and management: dispatch of flexibility resources (DR, EV, storage, generation) to serve different optimization objectives - Power loss reduction through optimal switching states - Integrated management of the grid (interoperability of the solutions)	*Gains:* ☑ Ensuring quality (stability, reliability) and security of supply ☑ Maintaining a balanced system ☑ Maximizing the integration of sustainable technologies (RES, EV)
Quality of supply assurance at all points of the grid	*Gains:* ☑ Ensuring quality (stability, reliability) and security of supply
Grid security and resilience increment - Reduction of the number and impact of system interruptions (lower SAIDI and SAIFI) - Resilience against possible faults (automatic detection and location, insulation of the damage zone and automatic reconfiguration steps to restore supply) with reduced time of actuation - Tool for islanded operation of a portion of the network	*Gains:* ☑ Ensuring quality (stability, reliability) and security of supply
Development of requirements and processes for flexibility services - Use of third-party flexibility for provision of distribution-level ancillary services (network peak reduction, voltage stability, N-1 criterion, switching operations) - Creation of an enabling environment, ensuring secure operation and delivery of service for new flexibility providers - Development of dynamic grid tariffs encouraging third-party service provision	*Gains:* ☑ Ensuring quality (stability, reliability) and security of supply ☑ Maintaining a balanced system

Table 9. FLEXIGRID approach Value proposition for DSOs: Pain relief

Pain relief through the FLEXIGRID approach	Addressed pains of DSOs
Increased hosting capacity of RES in the grid - Real-time prediction of system inertia and frequency reserves needed - RES curtailment reduction - Protections able to overcome bidirectional energy flow challenges - Reduced power and voltage congestion due to RES and EV - Voltage control strategies (active/reactive power control)	*Pains:* ☒ Risks associated with increasing RES penetration ☒ Risks associated with changing energy use profiles ☒ Need for grid reinforcement investments
Upgrade of grid architecture limiting reinforcement investment needs - Mitigation of short and long-term congestions - Smartening of existing grid infrastructure (e.g. retrofitting existing secondary substations) with solutions compatible with existing systems of European DSOs	*Pains:* ☒ Need for grid reinforcement investments
Improved ability to capture value from current and historical data - Upgrade of grid architecture allowing field-level digitalization - Interoperability of data from different sources (independent of underlying acquisition and management layers) - Collection, integration and smart analytics of the data from IEDs (e.g. demand/generation/pricing forecasts based on information from IEDs)	*Pains:* ☒ Network planned and operated as a centralized, passive system ☒ Limited ability to acquire and integrate data on grid status
Improvement of interoperability between all the stakeholders - Real-time data exchanges with grid users (collection of monitoring data, delivery of control signals) - Possibility to deliver to the TSO real-time data about distribution grid operation - Provision of real-time information to end-users about their power consumption	*Pains:* ☒ Network planned and operated as a centralized, passive system ☒ Limited ability to acquire and integrate data on grid status

The FLEXIGRID approach enables aggregators / ESCos to optimize the management of their flexibility pool – which is built upon the DER (generation and storage assets, loads with modulable profile) of their residential, commercial and industrial customers – and the value extraction from it. Figure 21 details its value proposition for this customer segment. The customer job(s), gains and pains sections build on the analysis of aggregators / ESCos' challenges (see part 2.2. above). Table 10 and Table 11 specify how the FLEXIGRID approach can enable them to address these challenges and leverage the opportunities offered by flexibility solutions and services to reach their objectives.

Figure 21. FLEXIGRID approach Value proposition Canvas #2 – Aggregators/ESCos

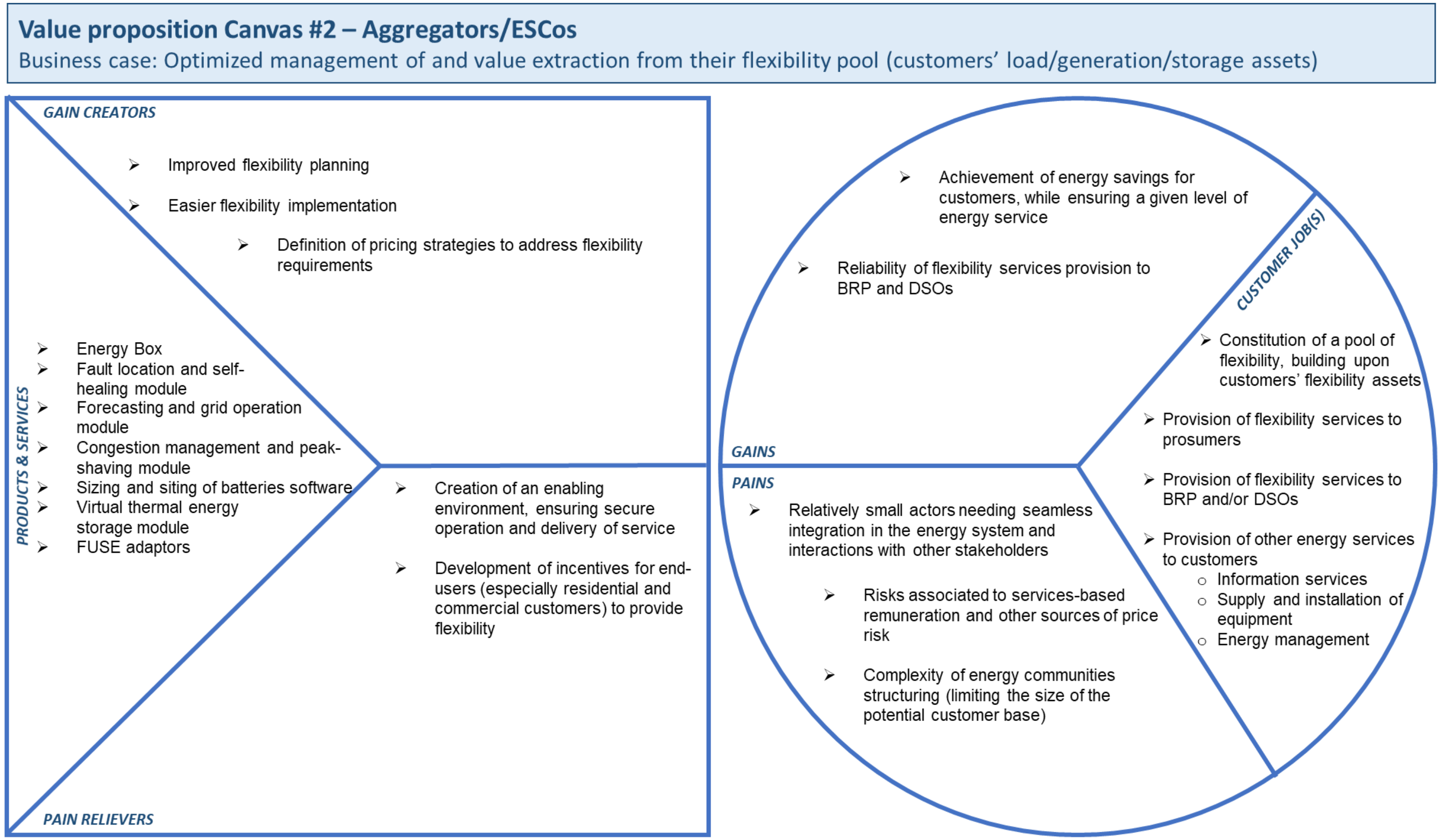


Table 10. FLEXIGRID approach Value proposition for Aggregators/ESCos: Gain creation

Gain creation through the FLEXIGRID approach	Corresponding gains of Aggregators/ESCos
Improved flexibility planning - Enhanced accuracy of load and generation forecasting, allowing improved identification of flexibility resources in the short and mid-term - Repository of DER models and flexibility profiles: DER classification enabling to effectively address evolving grid requirements and events (local congestion, peak demand) - Definition of high-level profiles of demand in an interactive manner with building occupants, to ensure comfort of users	*Gains:* ☑ Achievement of energy savings for customers, while ensuring a given level of energy service ☑ Reliability of flexibility services provision to BRPs and DSOs
Easier flexibility implementation - Repository of DER models and flexibility profiles: DER classification enabling to effectively address evolving grid requirements and events (local congestion, peak demand) - Definition of local micro-VPPs aggregating distributed flexibilities based on their suitability for congestion management and peak-shaving services, and dispatch of the flexibility resources (DR, EV, storage, generation) of the local grid based on this VPP configuration - Use of the flexibility resources register in the settlement phase (comparison between meter measurements and the unit's baseline)	*Gains:* ☑ Achievement of energy savings for customers, while ensuring a given level of energy service ☑ Reliability of flexibility services provision to BRPs and DSOs
Definition of pricing strategies to address flexibility requirements - Development of dynamic grid tariffs encouraging third-party service provision	*Gains:* ☑ Achievement of energy savings for customers, while ensuring a given level of energy service

Table 11. FLEXIGRID approach Value proposition for Aggregators/ESCos: Pain relief

Pain relief through the FLEXIGRID approach	Addressed pains of Aggregators/ESCos
Creation of an enabling environment, ensuring secure operation and delivery of service	*Pains:* ☒ Relatively small actors needing seamless integration in the energy system and interactions with other stakeholders
Development of incentives for residential / commercial end-users to provide flexibility - Reduced energy costs (notably through dynamic network tariffs) - Demonstration of business case for energy communities	*Pains:* ☒ Complexity of energy communities structuring (limiting the size of the potential customer base)

Some end-users – especially industrial and commercial prosumers – may have a pool of DER assets large enough to justify the direct management of the flexibility that it can provide – i.e., they may choose to act like an "aggregator" for their asset portfolio. The latter can comprise their own assets, but also shared assets, within the framework of energy communities (see box below). The FLEXIGRID approach enables these end-users to optimize the management of their flexibility pool and the value extraction from it. Figure 22 details its value proposition for this customer segment. The customer job(s), gains and pains sections build on the analysis of end-users and energy communities' challenges (see part 2.2. above). Table 12 and Table 13 specify how the FLEXIGRID approach can enable them to address these challenges and leverage the opportunities offered by flexibility solutions and services to reach their objectives.

Figure 22. FLEXIGRID approach Value proposition Canvas #3 – Industrial / commercial / residential end-users and Energy communities

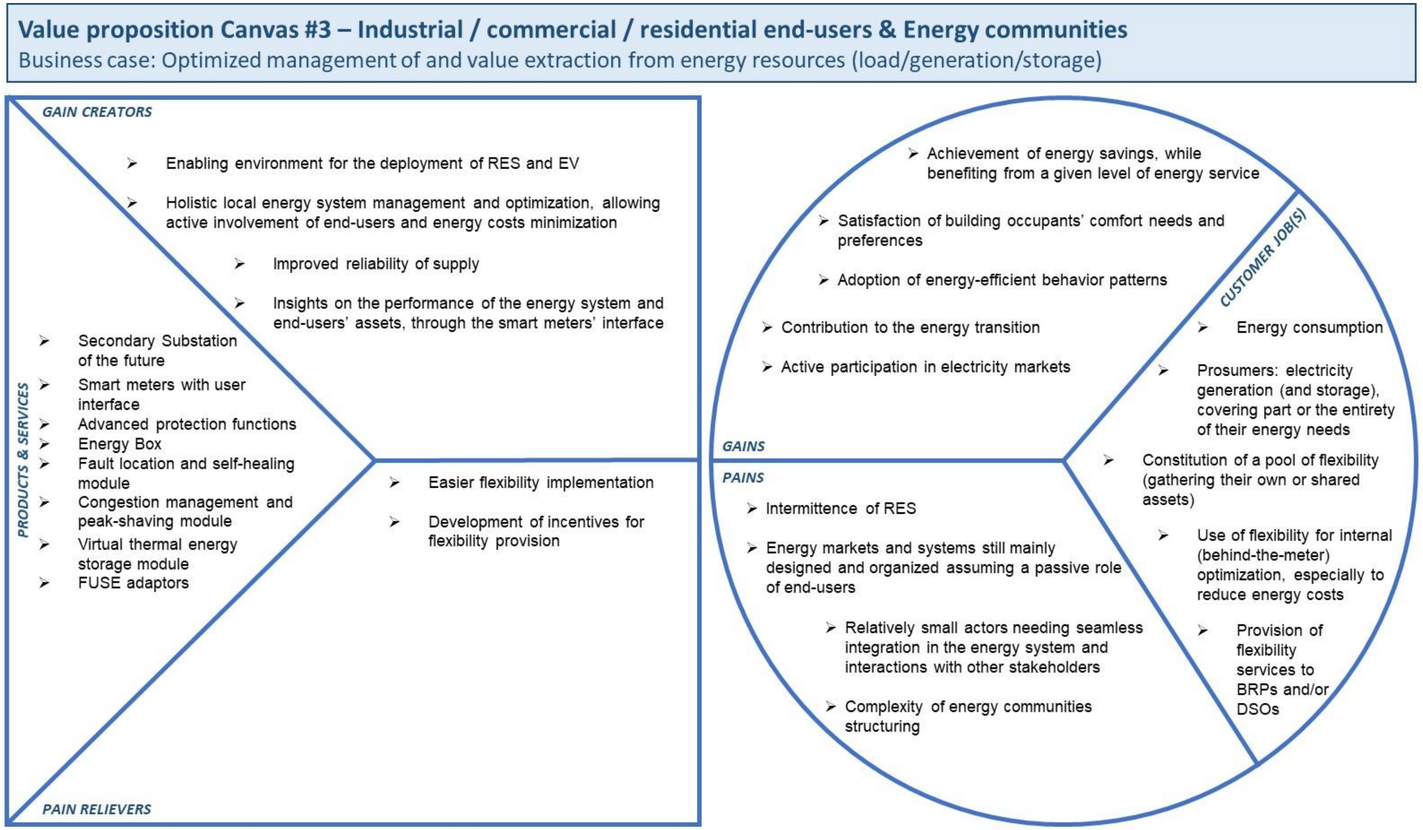


Table 12. FLEXIGRID approach Value proposition for End-users and Energy communities: Gain creation

Gain creation through the FLEXIGRID approach	Corresponding gains of End-users & Energy communities
Enabling environment for the deployment of RES and EV - Grid congestion management and peak-shaving - Maximization of variable RES output absorption (self-consumption) and RES curtailment reduction - Opportunities for a shared use of DER (energy communities)	*Gains:* ☑ Achievement of energy savings, while benefiting from a given level of service ☑ Contribution to the energy transition
Holistic local energy system management and optimization, allowing active involvement of end-users and energy costs minimization - Generation and load forecasting (short and medium-term) and scheduling to accurately organize the use of the site's assets - Real-time monitoring and control of DER (DR, EV, RES, storage) - Repository of DER models and flexibility profiles: DER classification enabling to effectively address evolving grid requirements and events (local congestion, peak demand) - Definition of high-level profiles of demand in an interactive manner with building occupants, to ensure users' comfort - Potential DR strategies and control of set-points - Estimation and provision of context-aware flexibility from heating/cooling loads and thermal storage equipment in buildings (independent of their size, use and construction characteristics) - Coordination of DER (RES, storage) to maximize the owner's benefit while ensuring optimal operation of the local grid	*Gains:* ☑ Achievement of energy savings, while benefiting from a given level of service ☑ Satisfaction of building occupants' comfort needs and preferences ☑ Adoption of energy-efficient behaviour patterns ☑ Contribution to the energy transition ☑ Active participation in electricity markets
Improved reliability of supply - Reduction of customer minutes lost for critical loads (battery systems to supply them under abnormal network conditions (blackout))	*Gains:* ☑ Achievement of energy savings, while benefiting from a given level of service ☑ Satisfaction of building occupants' comfort needs and preferences
Insights on the performance of the energy system and users' assets, through the smart meters' interface - Real-time observability - Real-time and historical data analytics (e.g. generation, consumption, flexibility) - Restricted and secure access (authentication mechanisms)	*Gains:* ☑ Achievement of energy savings, while benefiting from a given level of service ☑ Adoption of energy-efficient behaviour patterns ☑ Active participation in electricity markets

Table 13. FLEXIGRID approach Value proposition for End-users and Energy communities: Pain relief

Pain relief through the FLEXIGRID approach	Addressed pains of End-users & Energy communities
Easier flexibility implementation - Definition of local micro-VPPs aggregating distributed flexibilities based on their suitability for congestion management and peak-shaving services, and dispatch of the flexibility resources (DR, EV, storage, generation) of the local grid based on this VPP configuration - Use of the flexibility resources register in the settlement phase (comparison between meter measurements and the unit's baseline)	*Pains:* ☒ Energy markets and systems still mainly designed and organized assuming a passive role of end-users ☒ Relatively small actors needing seamless integration in the energy system and interactions with other stakeholders ☒ Complexity of energy communities structuring
Development of incentives for flexibility provision - Reduced energy costs (notably through dynamic network tariffs) - Demonstration of business case for energy communities, and recommendations for optimal arrangements adapted to different scenarios of ownership and operation	*Pains:* ☒ Energy markets and systems still mainly designed and organized assuming a passive role of end-users ☒ Complexity of energy communities structuring

Energy communities: business case challenges

The notion of "energy communities" refers to the constitution of cooperative organizations by multi-stakeholder teams willing to co-own, co-operate and/or retrieve the benefits from green investments in the energy sector. Energy communities' development could contribute to the transition towards more sustainable and efficient energy systems, and the EU as well as several of its member States have enacted enabling legislation to foster it (see part 2.2. above).

However, the actual uptake of energy communities remains low, due to technological and economic challenges (see part 2.2. above).

The FLEXIGRID approach will contribute to evidence how to address these technological and economic barriers, by:

- clarifying the possible ownership models for energy communities including various DER in a commercial environment;
- developing a business case evaluation tool that will identify and quantify the benefits for energy communities;
- emulating the operation of energy communities with various DER (PV panels, batteries and EV charging stations) within the framework of the demonstration campaign, and assessing the identified business cases in light of real data;
- issuing recommendations for optimal structuring and operation of energy communities.

Key differentiating features

A consortium of best-in class partners

The FLEXIGRID solutions have been developed by a consortium of best-in-class partners covering the complete energy system value chain. In addition to research and technology developers and providers (CIRCE, LINKS, UNIZG-FER, UNICAN, ATOS, ORMAZABAL, ZIV, HYPERTECH, SELTA), some of these partners are representative of the potential customers and end-users of the FLEXIGRID approach. They indeed include 3 DSOs (VIESGO, HEP-ODS and EDYNA), as well as an aggregator/ESCo (VERD) and a commercial end-user (IOSA). The design and the functionalities of the FLEXIGRID solutions, as well as their articulation, builds upon these partners' expertise. The diversity of their perspectives will also enrich the testing and subsequent evolutions of the solutions and of their integration in the different use cases during the demonstration campaign.

Solutions associating innovative features and technology readiness

The FLEXIGRID solutions rely on innovative technologies which have already been tested and validated in relevant environments and are therefore currently in Technology Readiness Levels (TRLs) 5/6. They will evolve over the course of the project in order to reach TRLs 7/8 by its end, especially thanks to their implementation in grid-integrated environments during the demonstration campaign. This extensive, 18-month demonstration campaign, during which FLEXIGRID solutions will be tested under varying operating conditions, will be instrumental in validating their performances and reliability. The latter is a key prerequisite to their larger-scale deployment, as power grids are critical infrastructures.

Other advantages compared to competition and current solutions

- <u>Edge computing paradigm</u>: The FLEXIGRID approach aims to increase the field intelligence by limiting as much as possible the transmission of raw data towards upper layers, and having the decisions made as close as possible to the element that will implement them. This approach contrasts with the classical reliance on central control systems.

- Cost-efficiency: The FLEXIGRID approach rests on the smartening of current grid infrastructure, giving when necessary the possibility to retrofit certain grid assets (especially secondary substations). It also ensures the interoperability of data from different sources, independently from the underlying acquisition and management layers, which may constitute a barrier for other, less adaptive solutions.

- Evolving nature: in addition to the day-one functionalities of the FLEXIGRID solutions, the acquisition and upstream of field data will be leveraged for the subsequent development and evolutions of the applications.

Choices aiming at fostering a swift market uptake

Beyond the development of new products and services, innovation requires their successful uptake in the market. This overarching objective has presided to the design of the FLEXIGRID project. The composition of the consortium, whose members represent the whole energy value chain in various EU member States, ensures the alignment between the strategic and implementation choices made during the project's execution and the business realities and regulatory contexts in the European and national markets. It therefore guarantees that the FLEXIGRID approach is in line with the ongoing modernization of European distribution grids. Besides, the 18-month demonstration campaign planned within the framework of the FLEXIGRID project aims to pave the way for the deployment of commercial-ready products, meeting all the predicted functional and operational targets.

Several built-in features of the FLEXIGRID solutions should also contribute to a swift market uptake – the most significant ones being their interoperability, their replicability, and their modularity and scalability.

Interoperability

The FLEXIGRID approach rests on an integrated architecture, which puts emphasis on the interoperability between the different solutions developed within the framework of the project on the one hand, and on the interconnectivity of these solutions with different existing platforms and environments on the other hand. The demonstration campaign, taking place in four European countries, will in particular evidence the compatibility of the FLEXIGRID solutions with the existing platforms and architectures of different DSOs.

The FUSE adaptors play a key role in ensuring this interoperability, by allowing a standardization of the communication and data flows. It indeed establishes a common framework (middleware) for the applications to be executed, enabling access to the required information regardless of the underlying data models and structures.

Replicability

Interoperability, which is a key dimension of the FLEXIGRID approach, favours its simple replication beyond the demonstration sites chosen as pilots.

Besides, the interest and attractiveness of the FLEXIGRID solutions for various energy stakeholders are to be evidenced by the replicable scenarios retained for the eight use cases, which are representative of the challenges faced by these stakeholders in different operational, regulatory and market contexts. These use cases, which are a cornerstone of the project, address the most common EU distribution grid challenges. They will be represented in the four demonstration sites, which have been selected to illustrate different environments (a segment of a peri-urban MV/LV distribution network in Spain, a micro-grid in a Greek island, an urban district distribution network in Croatia, and a valley in a mountainous Italian region where the grid could operate in islanded mode) and shed light on the viability and efficiency of the FLEXIGRID solutions in these diverse contexts. The possibility to extrapolate the impacts achieved in these demo-sites thanks to the FLEXIGRID solutions and the replication potential of the corresponding use cases in other European regions are to be assessed within the framework of a specific task (task 7.1, M25-M48) of the project.

Modularity / Scalability

Modularity is at the core of the FLEXIGRID approach: different hardware and/or software solutions can be combined in order to best address the specific needs of each stakeholder and help them to overcome the challenges that they face (depending on context parameters such as power output capacity, rate of RES generation, congestion levels, or quantity of losses along the grid). The use cases exemplify various potential combinations of the FLEXIGRID solutions (Table 14) and will represent an already proven concept of their viability and of the increment of grid flexibility that they will allow.

Table 14. FLEXIGRID demonstration sites and use cases: combinations of hardware and software solutions adapted to the different scenarios

		S1 – Secondary Substation of the future	**S2** – Smart meters with feeder-mapping capabilities	**S3** – Protections for high RES penetration	**S4** – Energy Box	**S5** – Software module for fault location and self-healing	**S6** – Software module for forecasting and grid operation	**S7** – Software module for congestion management	**S8** – Virtual thermal energy storage model	**S9** – FUSE platform
Spain – segment of a peri-urban MV/LV distribution network	**Use case 1** – Secondary Substation upgrading for higher grid automation and control	X	X		X	X	X			X
	Use case 2 – Protections functions operating with large RES share penetration in the distribution grid			X		X				X
Greece – micro-grid in an island	**Use case 3** – Holistic energy system optimization and emulation for commercial and residential customers				X		X			X
	Use case 4 – Microgrid congestion management and peak shaving				X			X		X
Croatia – urban district distribution network	**Use case 5** – Coordinating distribution network flexibility assets and protections schemes in urban districts			X		X		X		X
	Use case 6 – Virtual energy storage for urban building						X		X	X
Italy – mountainous valley where the grid could operate in islanded mode	**Use case 7** – Dispatching platform for MV generation	X	X		X		X			X
	Use case 8 – Mountainous valley grid operating in islanded mode					X	X			X

3.3. Exploratory business models of the FLEXIGRID solutions

In parallel of the identification of the Value Proposition of the FLEXIGRID approach mentioned above, exploratory business models for the nine individual solutions have been defined. This analysis was conducted by working groups gathering all the partners involved in the development of each solution, coordinated by one or several lead partners.

A common methodological framework was used, resting on the Business Model Canvas (see appendix 1). At these early stages of the business model development process, the choice was made to focus more specifically on four building blocks: customer segments, value propositions, and revenue streams and cost structure. The first two are key to define the market positioning of the FLEXIGRID solutions, while the last two lay the foundations for the evaluation of the profitability of the considered model.

Secondary Substation of the future (S1)

Figure 23. Business Model Canvas for S1 – Secondary Substation of the future

Business Model Canvas for S1 – Secondary Substation of the future
Lead partner: ORMAZABAL

KEY PARTNERS
- Technology supplier, in charge of R&D
- Production suppliers, in charge of developing and manufacturing components

KEY ACTIVITIES
- R&D
- Industrial manufacturing
- Sales

KEY RESOURCES
- Human resources (R&D, production workers)
- Manufacturer infrastructure
- Investment provider

VALUE PROPOSITIONS
- Reduction of service interruption in real time
- Tap regulation
- Voltage regulation
- Safety improvements LVB
- LV grid efficiency
- Optimization of grid topologies
- Stabilization of volatile grid
- Consumption reduction

CUSTOMER RELATIONSHIPS
- Service improvement
- Control developments: new functionalities
- Retrofit on secondary substation

CHANNELS
- Sales services
- Forums
- Public tenders
- Innovation projects

CUSTOMER SEGMENTS
- DSOs
- Renewable energy producers
- Commercial and industrial customers

COST STRUCTURE
- Manufacturer cost of production
- R&D investment
- Marketing costs
- Sales costs

REVENUE STREAMS

Products:
- Smart Transformer deployment
- LV board

Services:
- Web services RTU MV deployment

Three products and related services constitutive of the Secondary Substation of the future are developed within the framework of the FLEXIGRID project: a Smart Transformer, a LV Board monitored, and MV automation developments. Their combination will be used to provide a complete smart solution for MV and LV distribution.

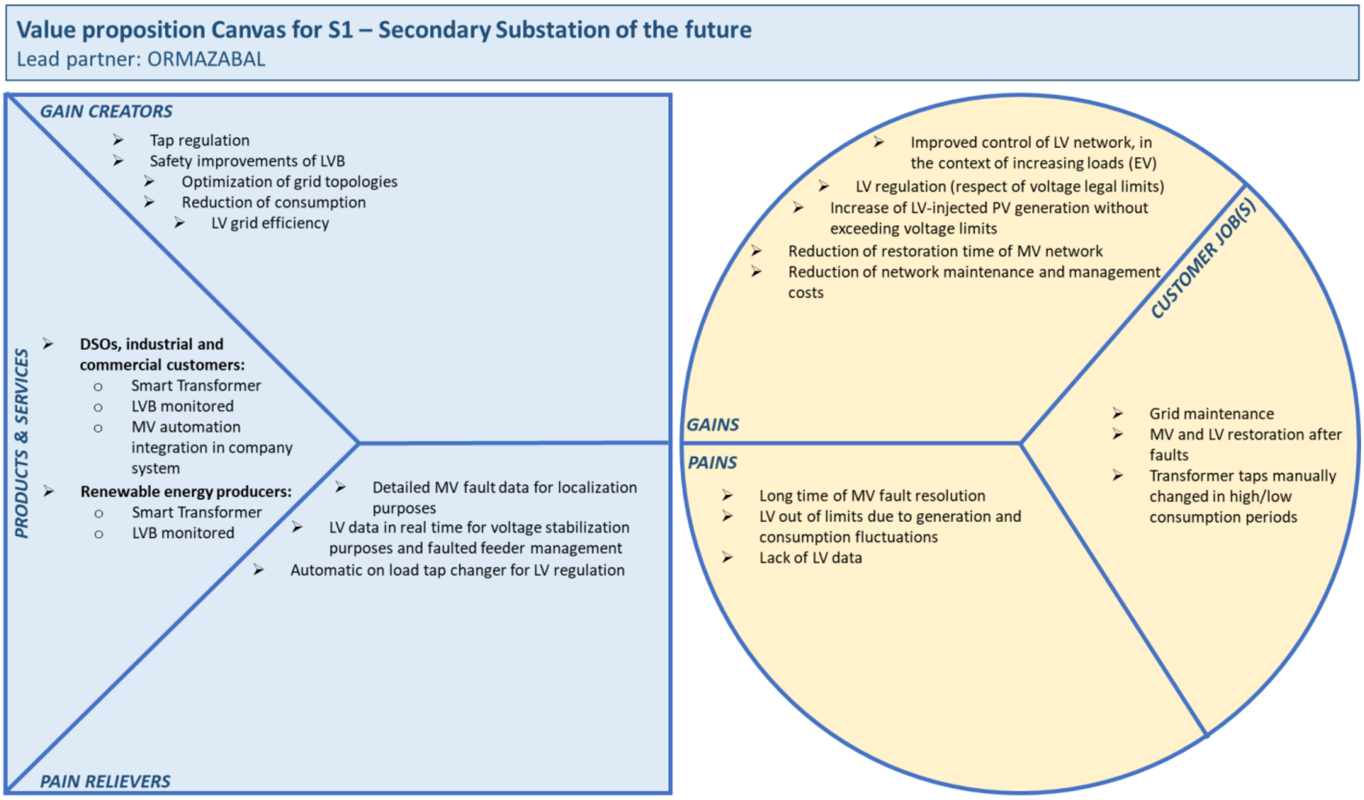
Customer segments

The customer segments of the Secondary Substation of the future are common to the overall FLEXIGRID approach. DSOs will be a key customer segment and will act as prescribers of the technical solutions for their customers. Electrical energy consumers with MV supply – mostly industrial and commercial customers – and renewable energy producers – especially PV plants having a MV interconnection – will also be interested in this solution. Besides, the LV Board could be used by private companies with high LV consumption in order to obtain improved information on consumption and reorganize their internal networks.

In terms of geographical markets, European countries will be among the main primary targets; yet, the objective is to deploy the solution worldwide.

Value Proposition Canvas

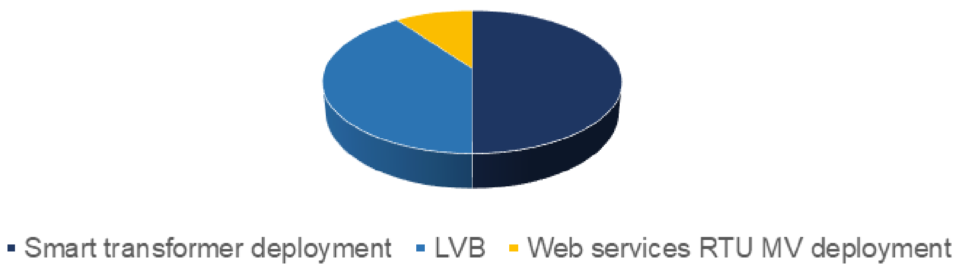
Figure 24. Value proposition Canvas for S1 – Secondary Substation of the future



The Value Proposition Canvas is very similar for the three customer segments. The main difference in the offering is that renewable energy producers do not require a specific installation and integration in the company system.

Revenue streams

Figure 25. S1 – Secondary Substation of the future – Revenue streams



Most of the revenue streams associated with the Secondary Substation of the future would be linked to products. Smart transformer deployment, for all the identified customer segments, would represent half of revenues, and LVB, also targeting all customer segments, would represent another significant share of revenues. Both may come from participation to tenders.

Web services RTU MV deployment for DSOs and industrial and commercial customers would complement these revenue streams.

Cost structure

The manufacturer's production costs, covering the related human resources and the necessary infrastructure and equipment, will represent the most significant cost item. R&D investment and the associated human resources will also have to be taken into account. Besides, the commercialization of the Secondary Substation of the future will entail some marketing and sales costs.

Alternative versions of the Secondary Substation of the future

In addition to the Secondary Substation of the future presented above, two alternative solutions are developed within the framework of the FLEXIGRID project:

- An alternative Secondary Substation of the future is specially designed for remote isolated areas, to address the situations when the grid is forced to operate in island mode due to blackouts. It will mainly involve modifications to the Plant Central Regulator (PCR) and the Medium Voltage Regulator.
- A solution for the refurbishment and upgrading of existing secondary substations is also developed. It requires some hardware and software modifications in these substations and relies on the Energy Box (see below).

Smart meters with feeder-mapping capabilities (S2)

Figure 26. Business Model Canvas for S2 – Smart meters with feeder-mapping capabilities

Business Model Canvas for S2 – Smart meters with feeder-mapping capabilities
Lead partner: ZIV

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
- DSOs - Smart meter manufacturers - Research centers - Laboratories - Big Data/AI software providers - Software providers	- Application and design engineering - Simulation of feeder identification - Demand simulation - Testing - Field installation - Manufacturing of meters	- Improved performance of the network thanks to LV network monitoring - Demand management: improved end-user information - Promotion of efficient energy use through extended information on the demand profile of smart meters' end-users - Flexible solution: preparedness for changes in communication technologies, cybersecurity or regulation	- Setup, maintenance and technical support - Customer loyalty based on confidence and continuous improvement of the solution	- DSOs - Industrial, commercial and residential customers
	KEY RESOURCES		**CHANNELS**	
	- Application and design engineers - DSOs' demonstration sites with multiple feeders - Test sets - Intellectual property - Laboratories for simulation		- Direct relationship with DSOs - Utility tenders	

COST STRUCTURE		REVENUE STREAMS	
Opex: - Design and manufacturing of smart meters - Engineering - Lab tests	**Capex:** - Test sets - Smart meter production lines and manufacturing equipment	**Products:** - Smart meters - Software designed to analyze demand profiles for customers - Software designed to analyze demand profiles for DSOs	**Services:** - Data analysis to provide services to customers - Data analysis to provide information to DSOs

The smart meters developed within the framework of the FLEXIGRID project will present advanced functionalities beyond the measurement of consumption, as well as extended communication capabilities. They will especially provide an active interface between end-users and other actors of the energy system.

The modular characteristics of these smart meters will allow them to be adapted to potential evolutions in information and communications technologies. The platform on which they rely could also be adapted to certain existing generations of smart meters, depending on their technical characteristics.

Customer segments

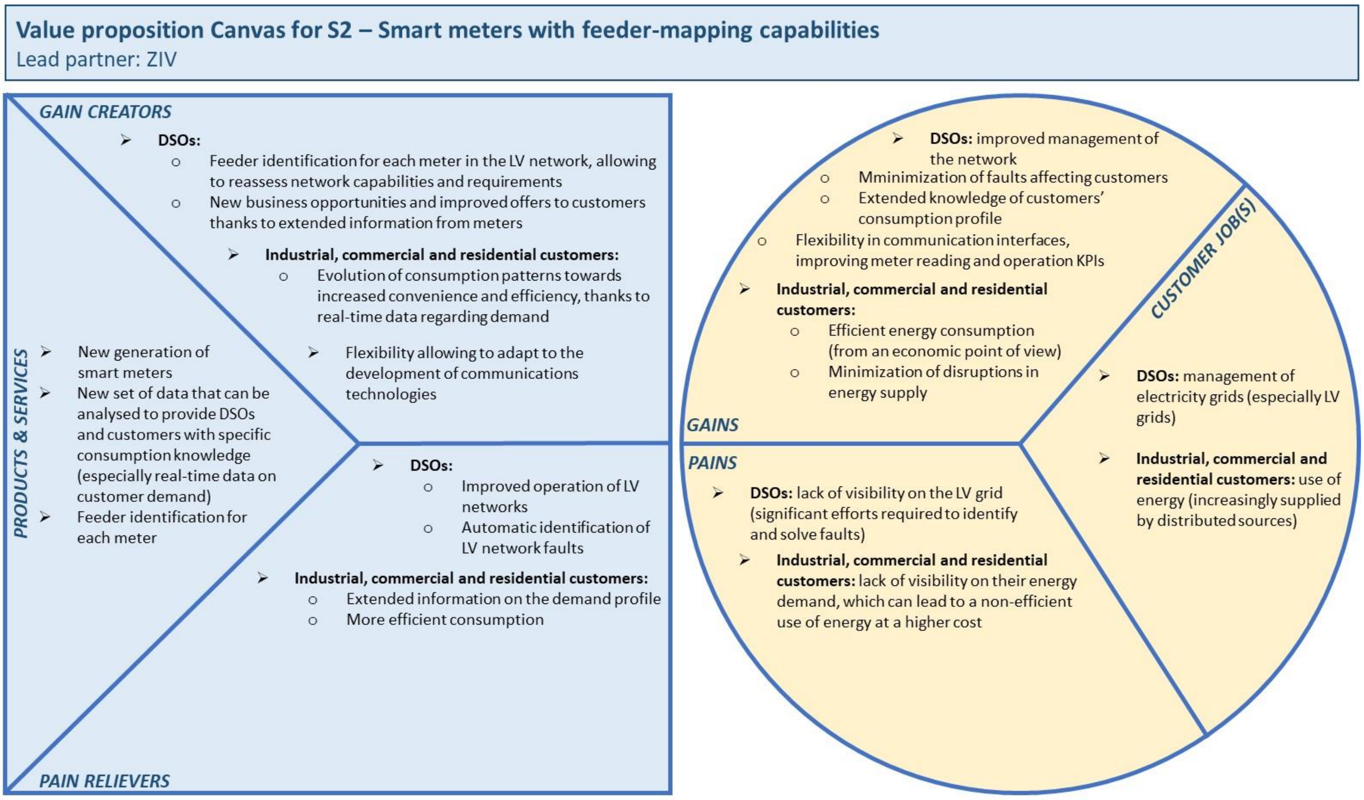
The smart meters developed within the framework of FLEXIGRID will present interesting functionalities for DSOs, enabling them to improve the observability and management of the network (especially by giving them the possibility to identify feeders for each customer). Industrial, commercial and residential customers will also benefit from the possibility to obtain extended information on their demand in real-time and adjust their consumption patterns accordingly.

Other actors of the energy system (especially energy producers) could make use of the data provided by the smart meters.

The meter platform is designed according to European and international standards and could be adapted to the requirements of different countries, in the EU and beyond. Energy actors could make more or less extensive use of the meters' functionalities depending on the maturity of the national markets.

Value Proposition Canvas

Figure 27. Value proposition Canvas for S2 – Smart meters with feeder-mapping capabilities

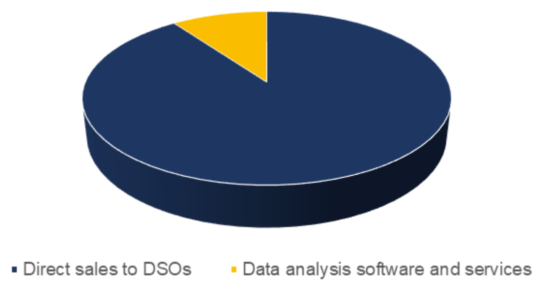


The smart meters will extend the possibility to provide data in real-time to end-users beyond industrial customers which, for some of them, have already developed an extensive knowledge of their energy consumption profiles, due to significant energy costs.

The advanced functionalities of the smart meters will reinforce DSOs' knowledge of the topology of the LV grid and of the state of the network in real time, enabling them to react quickly. Besides, DSOs may be able to leverage the data acquired on consumption profiles to offer new services to their customers. The solution may therefore create new business opportunities for them, the scope of which is quite open at this stage.

Revenue streams

Figure 28. S2 – Smart meters with feeder-mapping capabilities – Revenue streams



Most of the revenues would come from direct sales of the smart meters to DSOs, which could especially take place within the framework of tenders. They could be complemented by software sales and by the provision of services leveraging the smart meters' data with a view to provide information and guide action in the field of energy use efficiency. Such services could be interesting both for energy end-users aiming to reduce their energy costs and for DSOs. The latter could indeed use the extended information provided by smart meters to improve network operation and management.

Cost structure

Figure 29. S2 – Smart meters with feeder-mapping capabilities – Cost structure – OPEX

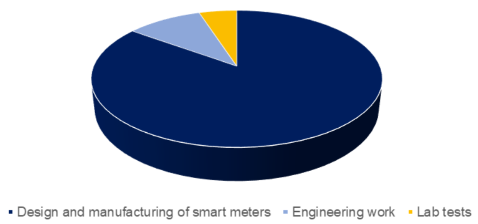
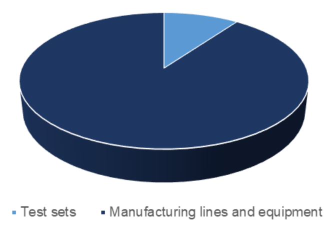


Figure 30. S2 – Smart meters with feeder-mapping capabilities – Cost structure – CAPEX



The design and manufacturing of the smart meters would represent a significant part of the operating costs related to this solution. Many human resources would indeed be involved in the R&D activities for the development of the meters (e.g. design engineers), and in the industrialization and manufacturing processes necessary to deploy them into the market in large volumes. Operational engineering work would also be required for data analysis and field operation. Finally, lab tests would represent a limited share of operating costs.

In terms of capital expenditures, the main item to be considered would be related to the equipment required for the manufacturing of the smart meters, especially automatic lines and production moulds. The tests realized by laboratories (simulations) and application design engineers would also be part of the capital expenditures associated with the development of this solution.

Protections for high RES penetration (S3)

Figure 31. Business Model Canvas for S3 – Protections for high RES penetration

Business Model Canvas for S3 – Protections for high RES penetration
Lead partner: ZIV

KEY PARTNERS
- TSOs and DSOs
- Power electronics manufacturers
- Research centers
- Laboratories

KEY ACTIVITIES
- Application and design engineering
- Simulation of networks with high RES penetration
- Testing
- Field installation

KEY RESOURCES
- Application and design engineers
- Simulation tools
- Test sets
- Intellectual property
- Demonstration sites

VALUE PROPOSITIONS
Improved performance of the protection system

CUSTOMER RELATIONSHIPS
- Setup, maintenance and technical support
- Customer loyalty, confidence, continuous improvement of the solution

CHANNELS
- Direct relationships with TSOs, DSOs and MV customers
- Sales through integrators, EPCs, and switchgear manufacturers
- Seminars and conferences

CUSTOMER SEGMENTS
- TSOs
- DSOs
- Industrial customers and other MV customers
- Renewable energy producers
- Switchgear manufacturers
- Integrators and EPCs

COST STRUCTURE

Opex:
- Human resources (engineers)
- Simulation software
- Lab tests

Capex:
- Test sets

REVENUE STREAMS

Products:
- Protection IEDs and fault detector sales

Services:
- Setting studies

Protections for high RES penetration include protection IEDs, which are installed in primary substations, and MV fault detectors, which are installed in secondary substations. Algorithms are to be implemented in these platforms, requiring engineering and setting calculations.

Customer segments

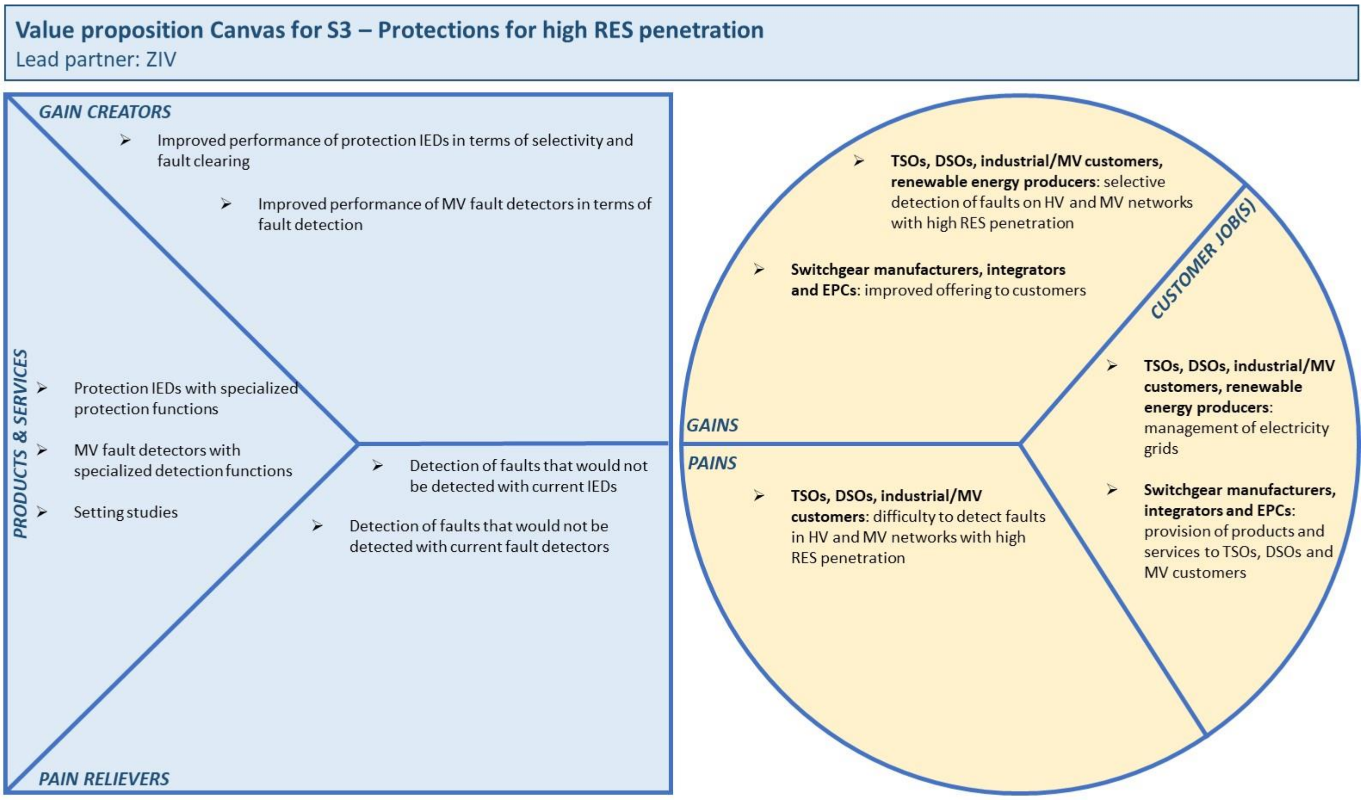
TSOs and DSOs are key customer segments for this solution. MV customers – which are mainly industrial customers, as well as other customers owning their grid infrastructure or microgrids – and renewable energy producers owning generators may also be interested in it.

Specific customer segments include switchgear manufacturers (i.e. manufacturers of HV and MV breakers, load break switches and reclosers), integrators of sub-systems and Engineering, Procurement and Construction (EPC) contractors, which act as turnkey project providers.

The solution could be deployed in all of the EU markets, as well as in other markets globally.

Value Proposition Canvas

Figure 32. Value proposition Canvas for S3 – Protections for high RES penetration



Current protection IEDs present dependability and security problems: under certain circumstances, they may lose selectivity and trip lines which are not defaulted, causing erroneous operation. Besides, the current protection system is not able to detect certain types of faults, especially in networks characterized by a high penetration of RES. The improvement of its performance is therefore at the core of the solution's value proposition.

Revenue streams

Figure 33. S3 – Protections for high RES penetration – Revenue streams

The products – protection IEDs and MV fault detectors – can be sold to final end-users either directly or through switchgear manufacturers, integrators and EPCs. Setting studies are a related service, leveraging the manufacturer's knowledge of the products' functionalities to provide recommendations. They are included in the sale of the products.

Cost structure

Figure 34. S3 – Protections for high RES penetration – Cost structure – OPEX

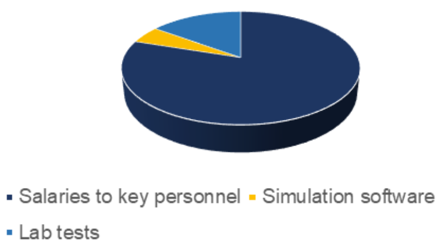
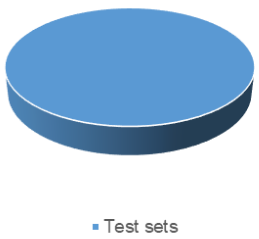


Figure 35. S3 – Protections for high RES penetration – Cost structure – CAPEX



The improvement of the solution throughout its exploitation mobilizes to a large extent the same resources as its development. The associated operating costs therefore include salaries to key personnel (especially engineers), the software used for network simulations, and the tests outsourced to external laboratories for the obtainment of certificates. The test sets realized for the development of the solution, involving simulations by laboratories and application design engineers, constitute the main capital expenditure.

Energy Box (S4)

Figure 36. Business Model Canvas for S4 – Energy Box

Business Model Canvas for S4 – Energy Box
Lead partner: CIRCE

KEY PARTNERS
- DSOs
- Aggregators
- Renewable energy producers
- Industrial, commercial and residential partners
- Energy communities
- Experts and actors of the refurbishment industry
- Materials suppliers
- Energy Box manufacturers
- Commercial partner

KEY ACTIVITIES
- Solution testing (demonstration sites)
- Market analysis
- Project dissemination and replication
- Exploitation
- Installation at customer premises
- Manufacturing
- Commercial activities
- Cooperation with other projects and networking

KEY RESOURCES
- Human resources
- IP legal and administrative assistance
- Components and material hardware
- Design of modular architecture
- Technological features: signal injection and time domain reflectometry (TDR), IoT communication protocols, Linux-based OS, real-time management

VALUE PROPOSITIONS

Hardware and software solution to solve field-level communication and management
- High-level services and monitoring (performed remotely) and locally-processed services, improving service quality, security and efficiency
- Autonomous real-time management
- High interoperability when using standard protocols
- Adaptability to each specific scenario for improving management
- Debian-based computer operating system
- Different physical communication interfaces (modules): Ethernet, ZigBee, WiFi

Modern and compact design
- Reduced form factor, light weight
- Quiet operation
- Low power consumption
- Competitive price

CUSTOMER RELATIONSHIPS
- Customer and maintenance services
- Customer service call center

CHANNELS
- Distribution at demonstration sites
- Dedicated website (giving access to relevant non-IP sensitive results)
- Media, conferences, workshops and events
- Innovation forum

CUSTOMER SEGMENTS
- DSOs
- Aggregators
- Renewable energy producers
- Industrial, commercial and residential customers
- Energy communities
- Experts and actors of the refurbishment industry
- Local authorities in charge of the management of social housing

COST STRUCTURE

Opex:
- Human resources
- Manufacturing
- Hardware components costs
- I&D activities
- Marketing costs
- Sales costs

Capex:
- Aggregation and transmission hardware infrastructure

REVENUE STREAMS
- Direct sales
- Sales through intermediaries
- Technology transfers

The Energy Box is a hardware solution for smart grid and micro-grid management, acting as a multi-purpose concentrator for operation in various scenarios of advanced electrical networks and DER. It can also be used to provide advices as to the sustainability of a building or other installations.

Customer segments

These features of the Energy Box make it interesting for a range of customer segments seeking energy efficiency, communications capabilities, and cybersecurity.

Many of the customer segments targeted by the overall FLEXIGRID approach could be interested in this solution: they include DSOs, aggregators, industrial, commercial and residential customers and energy communities, as well as renewable energy producers.

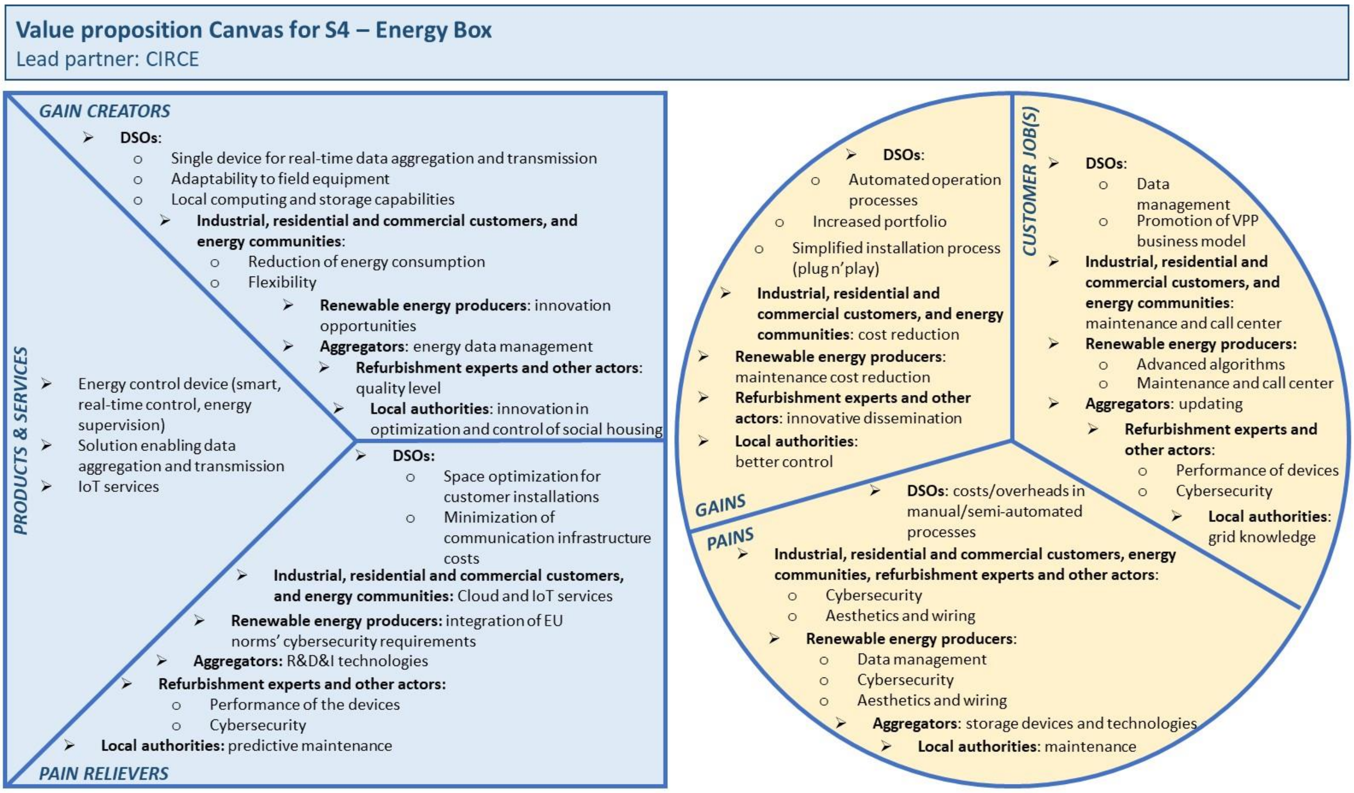
The Energy Box could also raise interest from specific customer segments, motivated especially by sustainability objectives. Those include technical experts and other actors from the refurbishment industry (e.g. architects), who may want to include the Energy Box in the projects in which they intervene, as well as local authorities, which are in charge of social housing management in many countries.

Telecommunication companies wishing to improve their service offerings may also be among the potential beneficiaries and end-users of the Energy Box, as the latter can act as a router.

Regarding geographical markets, the main countries to be targeted would include France, Switzerland, Austria, Slovenia, Italy (especially the Northern regions), the United Kingdom, and Germany.

Value Proposition Canvas

Figure 37. Value Proposition Canvas for S4 – Energy Box



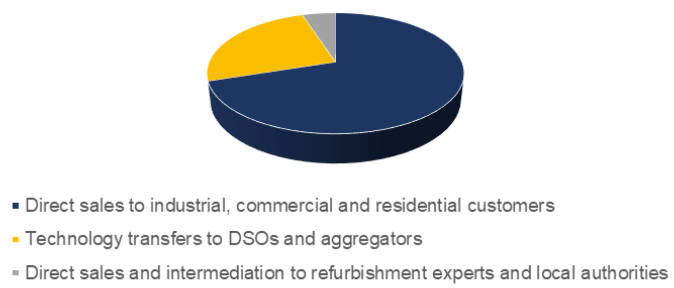
The value proposition of the Energy Box is articulated around its hardware and the software solutions that leverage it, which allow solving field-level communication and management challenges. Thanks to them, high-level services and monitoring can be performed remotely, while other services can be processed locally, which improves service quality, security, and efficiency.

The benefits to be drawn from the Energy Box include autonomous real-time management and high interoperability when using standard protocols, making it possible to adapt it to each specific scenario. It presents different physical communication interfaces (modules), among which Ethernet, ZigBee and Wi-Fi, and uses a Debian-based computer operating system.

From a practical point of view, the design of the Energy Box is modern and compact, with a reduced form factor and a light weight. The choice of a fanless design ensures a passive cooling and quiet operation. Power consumption by the Energy Box is low, and its price is competitive.

Revenue streams

Figure 38. S4 – Energy Box – Revenue streams



Revenue streams for the Energy Box are expected to come mainly from direct sales to industrial, commercial and residential customers, and refurbishment experts and local authorities. The latter could also act as intermediaries to reach end-users. Technology transfers to DSOs and aggregators could complement these revenue streams.

Cost structure

Figure 39. S4 – Energy Box – Cost structure – OPEX

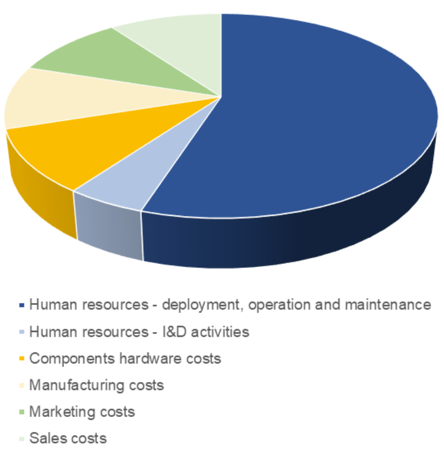
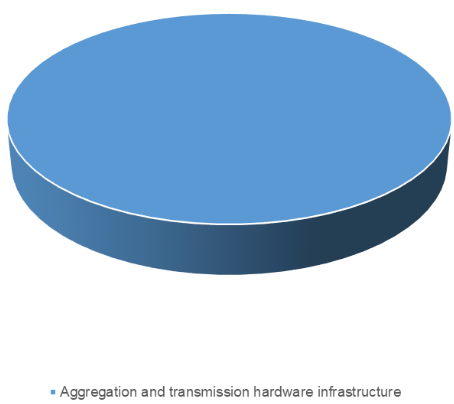


Figure 40. S4 – Energy Box – Cost structure – CAPEX



The operating costs will be mainly related to human resources. Most of them are linked to the deployment, operation and maintenance of the modules, and their significance will depend on the number of sites and the details of the offering. A smaller share of human resources-related costs will be dedicated to research and I&D activities. The components cost and hardware manufacturing will represent other operating cost items. Besides, the exploitation of the Energy Box will involve some costs associated with marketing activities, resources and materials, and sales (which may require agreements with a commercial partner).

The provision of aggregation and transmission hardware infrastructure is likely to be the main capital expenditure associated with the Energy Box. The number and type of energy assets to be interfacing with the Energy Box will have to be identified in each site, before designing the solution's integration and implementation in the customer's infrastructure. The related costs will depend on the number of installation sites and the details of the offering. They could be funded directly by the aggregator, or rest on a bank leasing option.

Software module for fault location and self-healing (S5)

Figure 41. Business Model Canvas for S5 – Software module for fault location and self-healing

Business Model Canvas for S5 – Software module for fault location and self-healing
Lead partner: CIRCE

KEY PARTNERS
- TSOs
- DSOs
- Aggregators/ESCOs
- Renewable energy producers
- Industrial, commercial and residential partners

KEY ACTIVITIES
- Market analysis
- Identification, assessment and comparison of the technological solutions for monitoring and control systems in the distribution network and in the customer premises
- Development of recommendations for the cost-effective application of advanced distributed sensors, monitoring and control systems to increase distribution networks' intelligence
- Development of a device for LV grids monitoring with new functionalities
- Testing of algorithms (simulation, small scale demonstration)
- Performance test of the developed applications in a real grid
- Cooperation with other projects and networking

KEY RESOURCES
- Developers and other human resources
- Gathered data
- Technical knowledge
- Electricity market knowledge
- Close knowledge of consumers and local markets

VALUE PROPOSITIONS
- Provision of information and control on the MV network allowing to operate it in real time, ensuring the security of supply
- Fault detection/location and energy supply restoration (self-healing) algorithms, upgraded and included in a software module
    - Detection of faults in the distribution grid
    - Orders to open/close the relevant breakers to isolate the affected area in a milliseconds range
    - Provision of reclosing sequence

CUSTOMER RELATIONSHIPS
- Customer service call center
- Maintenance services

CHANNELS
- Distribution at demonstration sites
- Sales representatives
- B2B and/or bilateral multiservice offerings using existing customer channels
- Company website and dedicated website giving access to non-IP-sensitive results
- Online and printed marketing tools
- Social media, media
- Conferences, workshops and events

CUSTOMER SEGMENTS
- TSOs
- DSOs
- Renewable energy producers
- Energy retailers
- Aggregators/ESCOs
- Industrial customers

COST STRUCTURE
- Human resources
- Testing and implementation
- Marketing costs
- Sales costs

REVENUE STREAMS
- Direct sales
- Sales through intermediaries

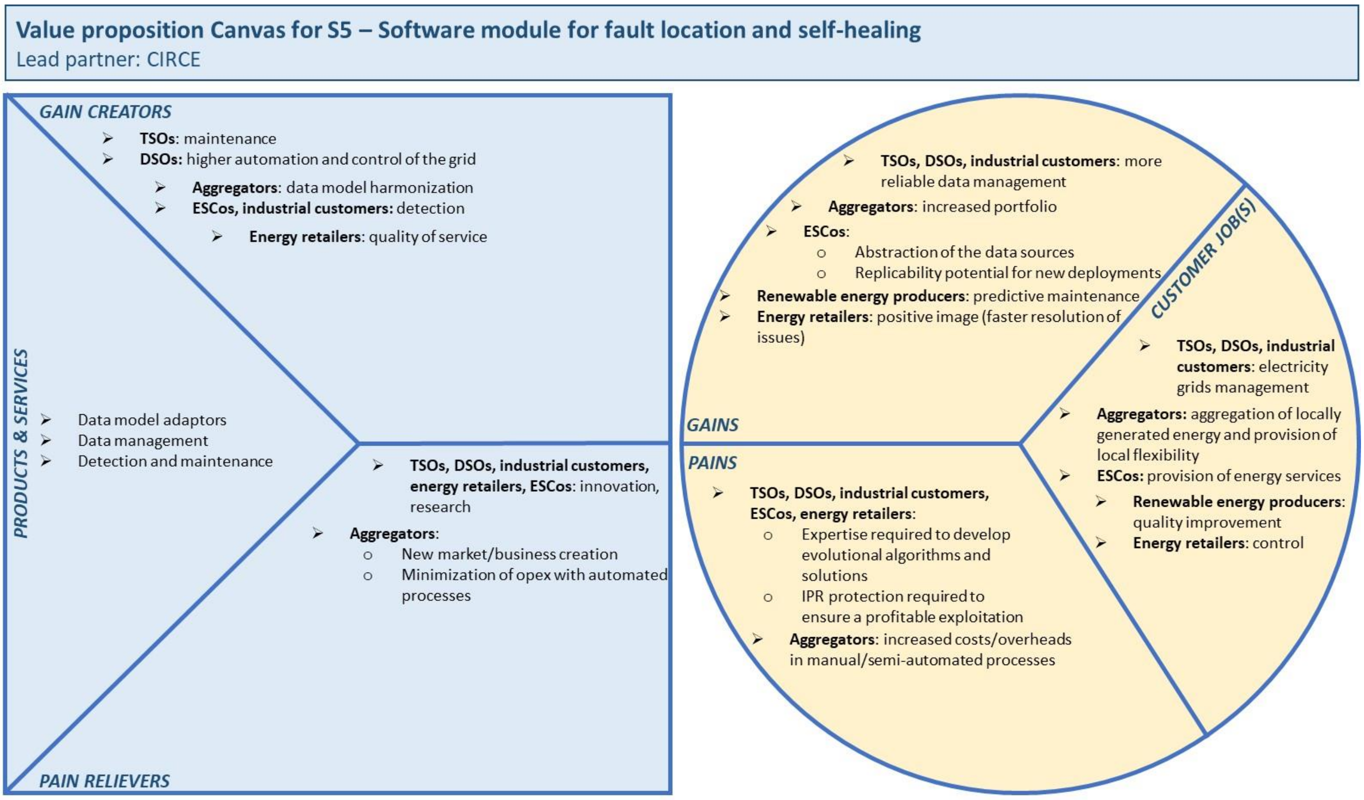
Customer segments

The Software module for fault location and self-healing, which provides its users with both information and control on MV networks, could be used by TSOs, DSOs, industrial customers, ESCos and energy retailers for detection and maintenance purposes. Aggregators could be interested in it for data management. Renewable energy producers are another potential customer segment, inasmuch as the solution would enable them to guarantee the supply of energy in the advent of a break.

Regarding geographical markets, the main countries to be targeted would include France, Switzerland, Austria, Slovenia, Italy (especially the Northern regions), Spain, the United Kingdom, and Germany.

Value Proposition Canvas

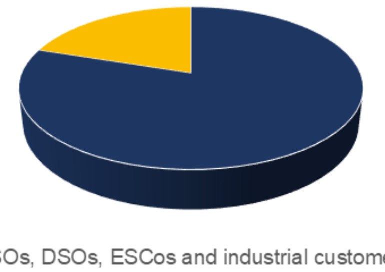
Figure 42. Value proposition Canvas for S5 – Software module for fault location and self-healing



The Value Proposition of the Software module for fault location and self-healing is articulated around the provision of information and control on the MV network, allowing to operate it in real time. Upgraded fault detection, location and energy supply restoration (self-healing) algorithms are included in this software module.

Revenue streams

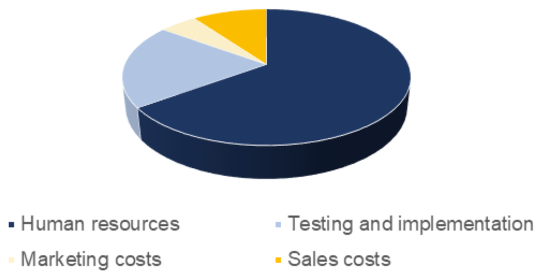
Figure 43. S5 – Software module for fault location and self-healing – Revenue streams



Most of the revenues would come from direct sales to TSOs, DSOs, ESCos and industrial customers. A complementary revenue stream could come from energy retailers and renewable energy producers, acting as intermediaries.

Cost structure

Figure 44. S5 – Software module for fault location and self-healing – Cost structure



Human resources required to operate the software module and interfaces, address billing and invoicing, and provide training and customer support represent the most significant cost item. The related costs will depend on the number of sites and the type of offerings.

Other cost items include testing and implementation, as well as marketing and sales costs.

Software module for forecasting and grid operation (S6)

Figure 45. Business Model Canvas for S6 – Software module for forecasting and grid operation

Business Model Canvas for S6 – Software module for forecasting and grid operation
Lead partners: CIRCE and VERD

KEY PARTNERS
- TSOs
- DSOs
- Aggregators/ESCos
- Energy retailers
- Renewable energy producers
- Industrial, commercial and residential partners

KEY ACTIVITIES
- Market analysis
- Identification, assessment and comparison of the technological solutions for monitoring and control systems in the distribution network and in the customer premises
- Development of recommendations for the cost-effective application of advanced distributed sensors, monitoring and control systems to increase distribution networks' intelligence
- Development of a device for LV grids monitoring with new functionalities
- Testing of algorithms (simulation, small scale demonstration)
- Performance test of the developed applications in a real grid
- Cooperation with other projects and networking

KEY RESOURCES
- Human resources (developers)
- Gathered data
- Technical knowledge
- Electricity market knowledge
- Close knowledge of consumers and local markets

VALUE PROPOSITIONS
- Forecasting algorithms to accurately predict energy generation, demand and electricity price
- Optimization algorithm taking advantage of the forecasting results and suggesting grid operation orders
- Provision of optimal settings for network controllable assets, prevention of network congestion

CUSTOMER RELATIONSHIPS AND CHANNELS
- Distribution at demonstration sites
- B2B and/or bilateral multiservice offerings (using existing clientele channels)
- Sales representatives
- Company website and dedicated website giving access to non-IP-sensitive results
- Online and printed marketing tools
- Media and social media
- Conferences, workshops and other events

CUSTOMER SEGMENTS
- DSOs
- Aggregators

COST STRUCTURE
- Human resources
- Testing and simulation
- Licenses for a specific software
- Marketing costs
- Sales costs

REVENUE STREAMS
- Direct sales

Customer segments

DSOs may be interested in the software module for forecasting and grid operation, which they could use to quantify their flexibility requirements and pass them on to other participants. The solution also allows higher automation and control of the grid. DSOs would then draw both direct revenues (flexibility) and indirect revenues (deferred investment) from its implementation.

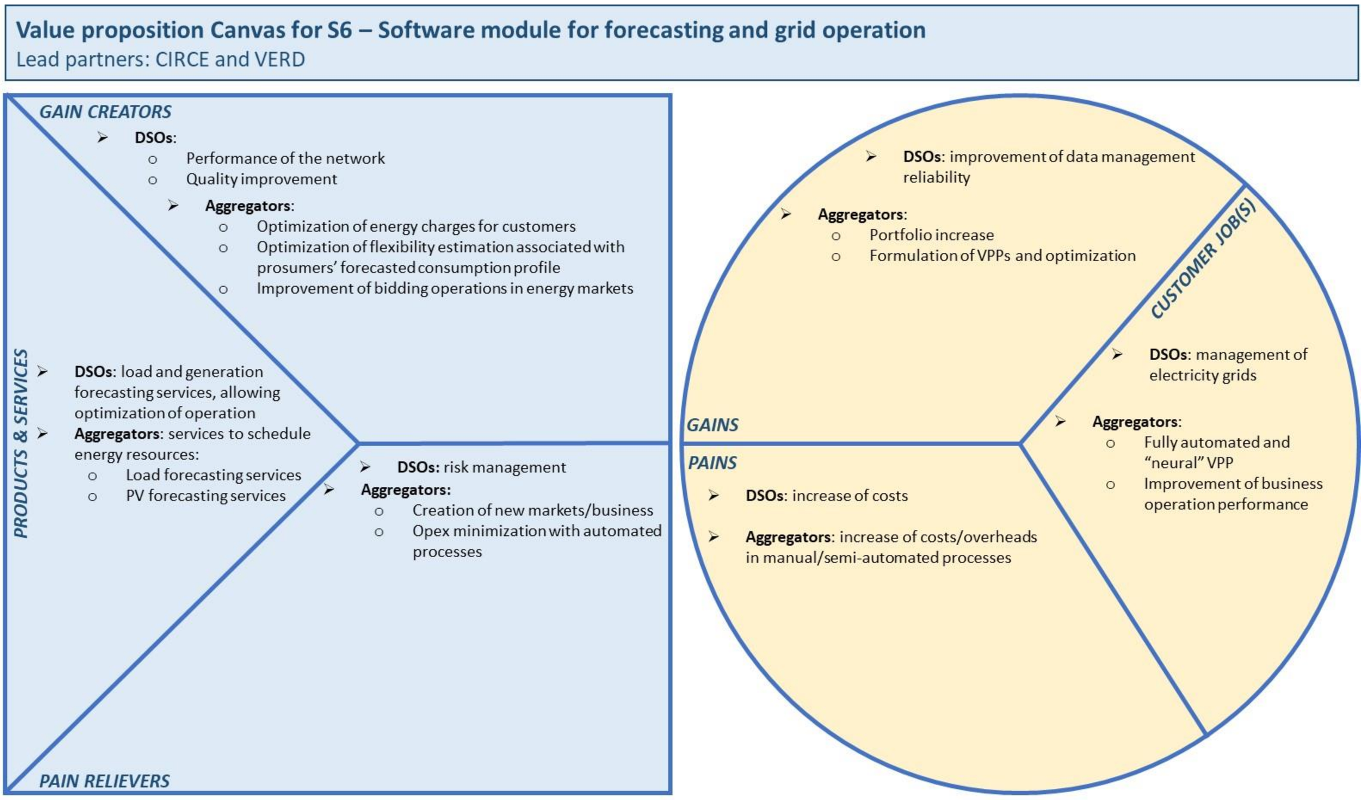
Aggregators are other potential customers, as the software module may enable them to expand their activities on the consumption and production sides.

Renewable energy producers and technology providers should also benefit from the solution, as it will allow a large penetration of RES in the grid and may therefore open market opportunities for them in case of a wide application. Other potential beneficiaries and end-users could include TSOs, energy retailers, ESCos, industrial, commercial and residential customers, and actors of the refurbishment industry.

Regarding geographical markets, the main countries to be targeted would include France, Switzerland, Austria, Slovenia, Italy (especially the Northern regions), the United Kingdom, Germany, Greece and Spain.

Value Proposition Canvas

Figure 46. Value proposition Canvas for S6 – Software module for forecasting and grid operation



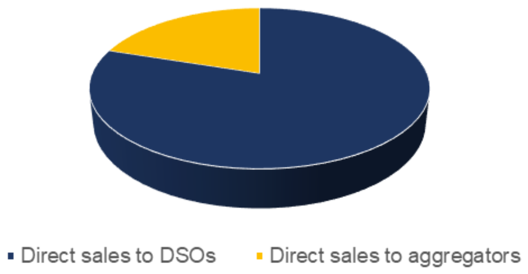
The solution consists of a self-contained module including a set of forecasting algorithms able to accurately predict energy generation, demand and electricity price. They rely on measurements registered by sensors and other IEDs installed along the MV network. These forecasting capabilities can be leveraged by aggregators to optimize participation in energy market schemes (flexibility, day-ahead, VPP…).

An optimization algorithm allows to take advantage of the forecasting results and suggests grid operation orders aiming to balance the demand curve and maximize the integration of RES generation without compromising the security of supply and grid stability.

The solution therefore provides optimal settings for network controllable assets and helps to prevent network congestion.

Revenue streams

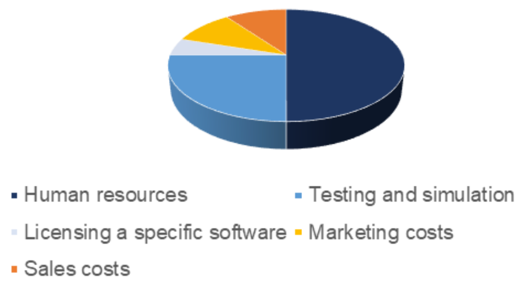
Figure 47. S6 – Software module for forecasting and grid operation – Revenue Streams



Direct sales to DSOs would represent the largest part of the revenues from the software module for forecasting and grid operation. These revenues would be complemented by direct sales to aggregators, which would enable them to optimize their participation in energy markets.

Cost structure

Figure 48. S6 – Software module for forecasting and grid operation – Cost structure



The cost structure of the software module for forecasting and grid operation would involve mainly operating expenses. Half of the costs would be related to the human resources required to operate the software module and interfaces, address billing and invoicing, and provide training and customer support. Their significance would depend on the number of sites and the details of the offerings. Testing and simulation activities, and the licensing of another specified software would also entail specific costs. Besides, marketing and sales costs would have to be taken into account.

Software module for congestion management (S7)

Figure 49. Business Model Canvas for S7 – Software module for congestion management

Business Model Canvas for S7 – Software module for congestion management
Lead partner: VERD

KEY PARTNERS
- Utilities
- Aggregators
- ESCos
- Commercial, residential and industrial customers
- Facility management consultants
- Energy experts
- Regulators

KEY ACTIVITIES
- Business development and marketing
- Development, adaptation and customization of a turn-key solution
- Continuous updating to comply with market rules and tariff structure

KEY RESOURCES
- Historical consumption/generation data to feed the forecasting algorithm that will facilitate scheduling

Technology provider's assets:
- Expertise in energy management
- Software engineering personnel

Aggregators' asset: communications Smart Box

Commercial customers' assets:
- PV infrastructure
- Batteries
- EV chargers
- Communications local backbone infrastructure
- Local energy/communications O&M personnel

VALUE PROPOSITIONS

DSOs: establishing an integration layer with load-intensive customers, facilitating the exploitation of their flexibility and thereby creating shared benefits

Aggregators: one-stop solution for setting up, developing and exploiting flexible energy provisioning from the customer to the DSO

Commercial customers: harvesting the full potential of their energy assets in order to reduce network and energy charges while potentially providing services to the grid

CUSTOMER RELATIONSHIPS

(with aggregators):
- Customer acquisition, audits, contracts
- Integration, technical operation and maintenance
- Account management (contract, support, loyalty schemes, billings/settlements)

CHANNELS
- Awareness raised by government and regulations promoting new policies/market schemes
- Networks of DSOs and commercial customers (web portal, social media, etc.)
- Workshops conducted by network operator on new markets' design and operation
- Direct customer support by DSOs and aggregators

CUSTOMER SEGMENTS

Primary:
- Aggregators / ESCos
- Commercial customers

Secondary:
- DSOs
- Industrial and residential customers

COST STRUCTURE

Opex:
- Hardware and software infrastructure maintenance
- Human resources

Capex:
- Hardware and software infrastructure development and integration

REVENUE STREAMS
- Licensing
- Payments for level of support

Customer segments

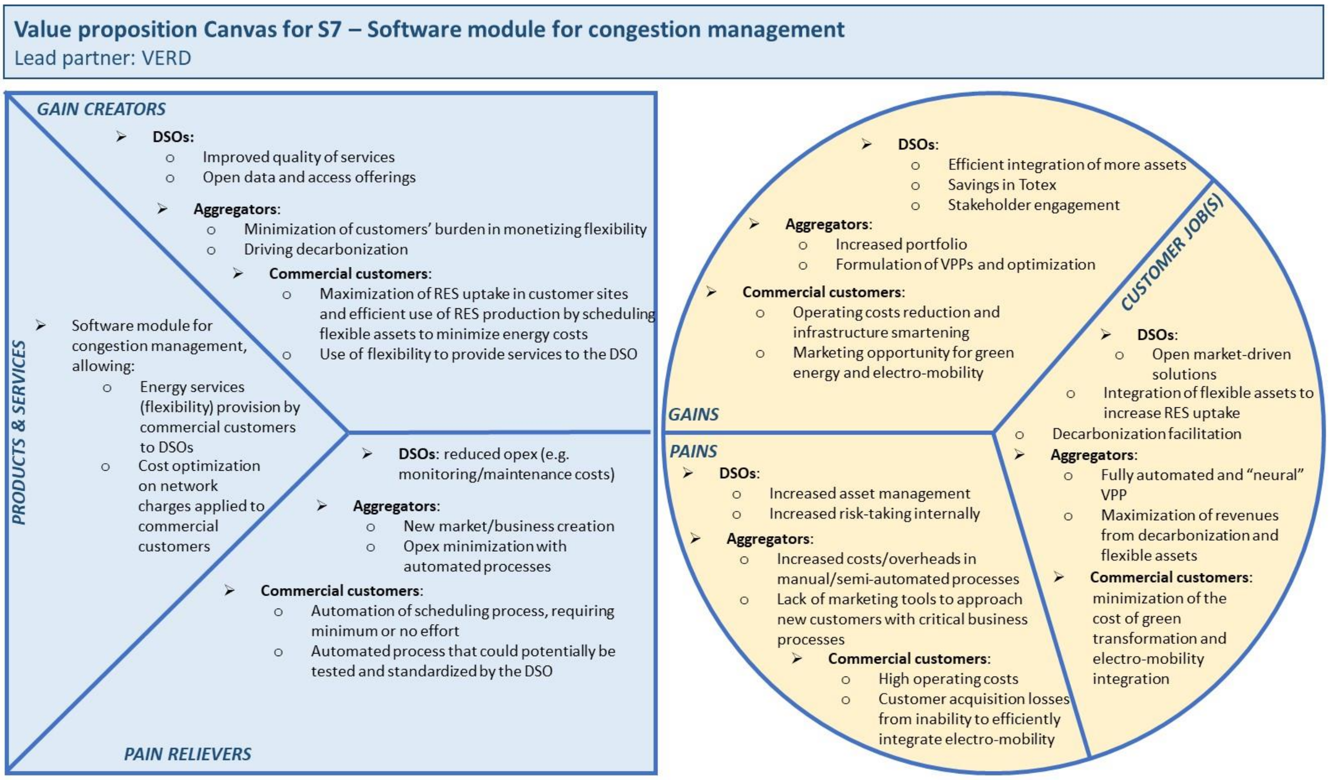
The main customer segments for the software module for congestion management are aggregators/ESCos and commercial customers. Industrial and residential customers may also be interested in the opportunities associated with it in terms of energy costs optimization and revenue from participation in DSM. For industrial customers, the logic and approach would be close to the ones prevailing for commercial customers. In the case of residential customers, however, implementation could intervene at a later stage, due to the large scale required and the IoT challenges to be solved.

DSOs would also benefit from the control given over active and reactive power at pre-defined network points to achieve congestion management, and from the flexibility acquired through aggregators. The solution may especially enable them to defer grid reinforcement investments.

Regarding geographical markets, the objectives of energy and network costs optimization could be pursued in any European country. The development of flexibility offerings can nonetheless only occur in countries with active flexibility markets, such as France, Germany, or the United Kingdom.

Value Proposition Canvas

Figure 50. Value proposition Canvas for S7 – Software module for congestion management



The Value Proposition of the software module for congestion management has been defined for its three main potential customer segments and beneficiaries.

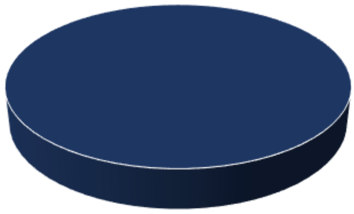
For DSOs facing seasonal congestion issues in local networks, the solution establishes an integration layer with load-intensive customers, thereby facilitating the exploitation of their flexibility and creating shared benefits for the operator and the customers.

The software module would help aggregators to undertake a comprehensive one-stop solution to set up, develop and exploit flexible energy provisioning from customers to the DSOs.

Last but not least, the solution could also be leveraged by commercial facility owners who do not fully exploit their energy assets (RES, batteries, EV charging points, etc.) and face high energy costs. It would enable them to benefit from the full potential of their equipment's capabilities in order to reduce network and energy charges, while potentially providing services to the grid.

Revenue streams

Figure 51. S7 – Software module for congestion management – Revenue streams



Revenue streams from all customer segments would take the form of licensing, which could consist in a one-off or yearly subscription, or in a Software-as-a-Service solution. In addition, customers may be willing to pay for a given level of support (e.g. hourly to weekly response time).

Cost structure

Figure 52. S7 – Software module for congestion management – Cost structure – OPEX

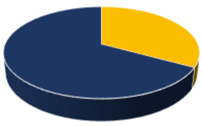
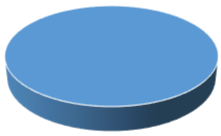


Figure 53. S7 – Software module for congestion management – Cost structure – CAPEX



The operating costs associated with this solution would be related mainly to the human resources in charge of installing and operating the hardware and software infrastructure, and handling monitoring and control, billing and invoicing, training and customer support. Their importance would depend on the data volume and reliability requirements. Besides, the maintenance of the hardware and software infrastructure (including cloud infrastructure, databases, communications and local hardware such as smart boxes) would also entail some operating costs, depending on the number of assets and reliability requirements.

Capital expenditures would be engaged for the development and integration of the hardware and software infrastructure (e.g. smart boxes, optimization software, compliance with communication protocols, and databases). This infrastructure needs to be to a certain extent customizable to the needs and specificities of each project and/or customer. In this regard, in addition to the capex committed initially, new investments may be needed over time, for instance to embed new integration options (communication protocols) or offer new, more advanced functionalities.

Virtual thermal energy storage (VTES) module (S8)

Figure 54. Business Model Canvas for S8 – Virtual Thermal Energy Storage module

Business Model Canvas for S8 – Virtual Thermal Energy Storage module
Lead partner: HYPER

KEY PARTNERS
- Certified installers
- ESCos/ESPCs
- Smart home solutions/BMS providers
- Cloud computing service providers
- IoT devices/platforms providers
- Aggregators
- Energy retailers
- Microgrid operators
- Energy communities
- Flexigrid project partners
- European TSOs/DSOs
- Open Source initiative
- Website developers

KEY ACTIVITIES
- Algorithm development
- Software development, operation and maintenance
- Product assembly, testing, packaging and integration
- Product demonstration
- Installation
- Training
- User interface design
- Technical support
- Website development
- Marketing
- Customer engagement

KEY RESOURCES
- Development team
- Databases and collected data
- Cloud hosting space
- Developed algorithms/software
- Controllable devices
- User App
- Smart Box
- Website
- Marketing and sales team and marketing material
- Technical support team
- IT infrastructure

VALUE PROPOSITIONS
- Comfort-based flexibility offering
- Data-driven thermal comfort profiling
- Participation in explicit DR programs
- Delivery of dynamic energy tariffs (implicit DR)
- Monitoring, programming and configuration of smart energy appliances

CUSTOMER RELATIONSHIPS
- Training of certified installers
- Product self-learning
- Customer support team
- Web platform and customer app
- Social media

CHANNELS
- Stakeholder ecosystem
- B2B collaboration (esp. with actors seeking to offer DR smart services, certified installers, ESCOs and energy product retailers)
- Targeted communication with existing clients
- Website (with online shopping platform)/social media
- Marketing and dissemination activities
- Cooperative/networking events

CUSTOMER SEGMENTS
- Energy retailers
- Aggregators
- ESCos/ESPCs
- BMS providers
- Residential customers
- Energy communities
- Local authorities

COST STRUCTURE

Opex:
- HR (development team, marketing and sales team, operations team, technical support team)
- Cloud hosting fees
- Website service party licenses
- Purchase of components for product development

Capex:
- IT infrastructure (hardware, software, licenses)

REVENUE STREAMS

Option 1:
- Smart Box purchases
- Licenses for software products

Option 2:
- Software as a Service

Common to both options:
- Personalization/customization of product/platform
- Sales of additional energy services
- Technical support, training and installation

The VTES module comprises several products and related services. The Smart Box is a smart home standalone solution offering an interface for consumers and prosumers wishing to monitor, program and configure the smart energy devices and appliances located inside their building (e.g. electric heating, ventilating and air conditioning (HVAC), water boilers, and behind-the-meter generation and storage). It acts as a gateway to customer premises, receiving all the information from sensors and devices and sending commands to them. A Prosumer app is associated with it. These products, which are currently at TRL 5-6, are being further developed and adjusted to be in line with the FLEXIGRID approach. To complement them, a Demand flexibility profiling engine and a VES software module are developed within the framework of the FLEXIGRID project. The Smart Box indeed communicates with a Cloud service hosting the algorithms, in order to define a flexibility profile and to process and break down the DR requests sent by DSOs.

Customer segments

Some of the VTES module's potential customer segments are among the main targets of the FLEXIGRID approach. Residential customers may want to use it to be able to adjust their consumption and achieve energy savings. Energy communities could also leverage it to improve their estimations of available demand flexibility within their portfolio of energy assets.

These customer segments may be addressed directly, or through aggregators, ESCos or energy retailers. These actors may indeed be willing to add this solution to the portfolio of services that they offer. The module could help aggregators to acquire more customers by improving user acceptance of DR campaigns and participation to them. ESCos could resort to it in order to provide customized energy efficiency-related applications to their customers.

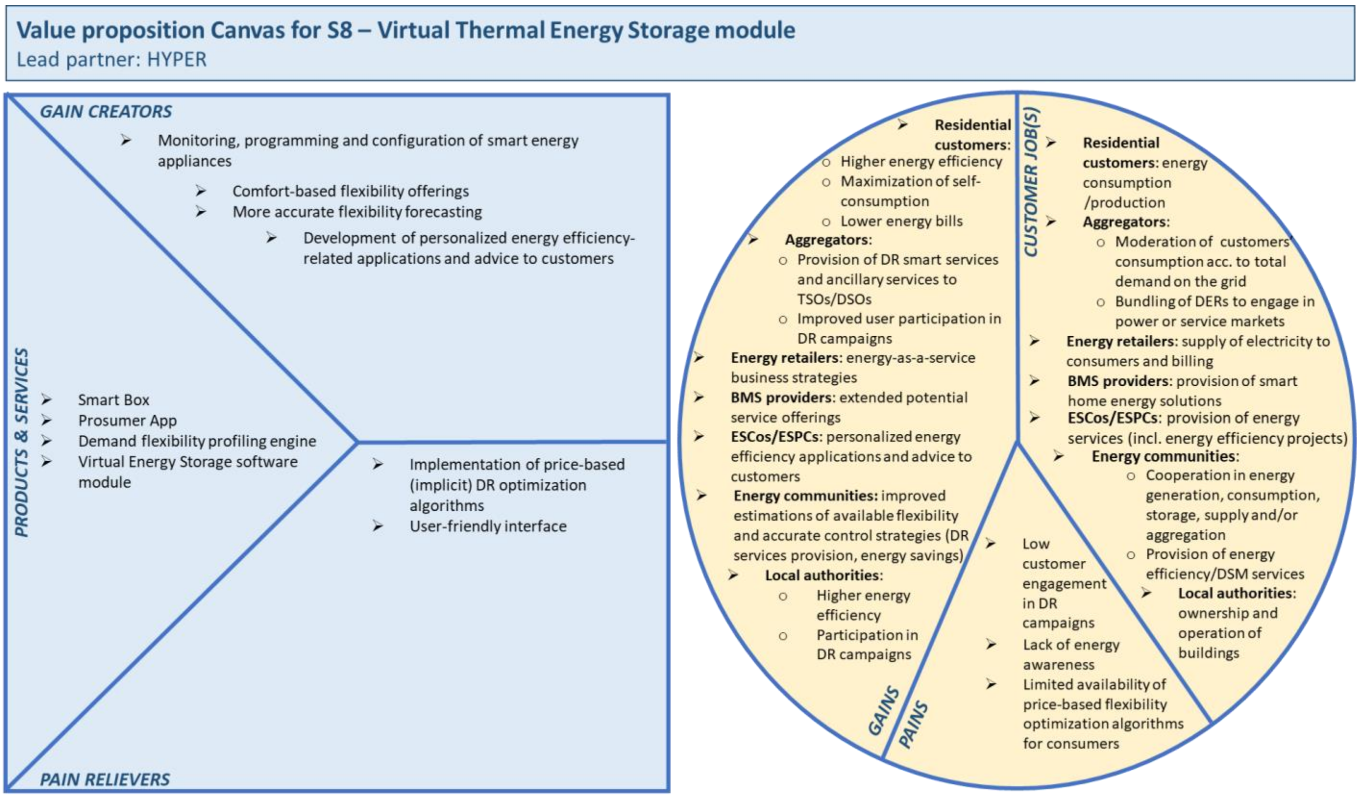
Energy retailers are one of the specific customer segments for this solution. In their case, the module could facilitate the implementation of personalized energy-as-a-service business strategies: they could indeed offer dynamic tariffs and propose consumption adjustments enabling their customers to take advantage of differences in tariffs. Other specific customer segments include building management system (BMS) providers, which offer technology solutions to building owners allowing to optimize and remotely control the operation of buildings' energy systems, usually in order to achieve savings on energy bills. These actors may want to add the VTES module to their portfolio in order to expand their service offerings.

Beyond these intermediaries, another category of potential end-users of the VTES module includes local authorities, which could implement it to achieve energy savings in the buildings that they own and operate (e.g. public facilities, housing blocks) and to participate in DR schemes, either directly or through aggregators.

The geographical markets that could be targeted by this solution would potentially cover the whole EU.

Value Proposition Canvas

Figure 55. Value proposition Canvas for S8 – Virtual Thermal Energy Storage module



The value proposition of the VTES module rests on a comfort-based flexibility offering: the solution takes into account the thermal comfort preferences of the building occupants and defines a data-driven comfort profile. The module is able to learn from customers' preferences and reactions and make the profile evolve accordingly, in order to offer more accurate flexibility services.

These features of the VTES module address some challenges which currently weigh on customers' engagement in DR campaigns, namely the complexity and inconveniences caused by existing solutions, and the lack of energy awareness due to the non-visibility of consumption.

The VTES module is therefore expected to foster participation in DR schemes, which can be:

- explicit DR programs: when the DSO asks for flexibility, the module is able to confront its requests with the flexibility profiles, and translate them in the control and configuration of the devices (adjustment of the setpoints);
- implicit DR schemes, relying on dynamic energy tariffs applied by energy retailers.

Revenue streams

Figure 56. S8 – VTES module – Revenue streams

Two options could be proposed for the commercialization of the VTES module:

i) a combination of Smart box sales and licensing for software products (Prosumer App, demand flexibility profiling engine, VES module);

ii) a Software-as-a-service model, targeting customers who already have controlling devices or a gateway.

In both cases, further revenues could be generated by the personalization of the product or the platform, in function of customers' needs and expectations (e.g. design of a specific customer interface for the App, sales of additional energy services).

The provision of technical support, training (e.g. training aggregators to install and configure the devices) and installation constitutes another potential revenue stream.

Cost structure

Figure 57. S8 – VTES module – Cost structure – OPEX

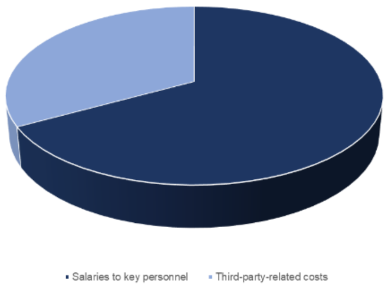
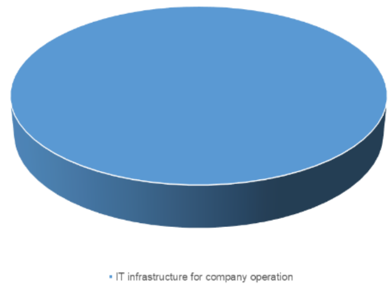


Figure 58. S8 – VTES module – Cost structure – CAPEX

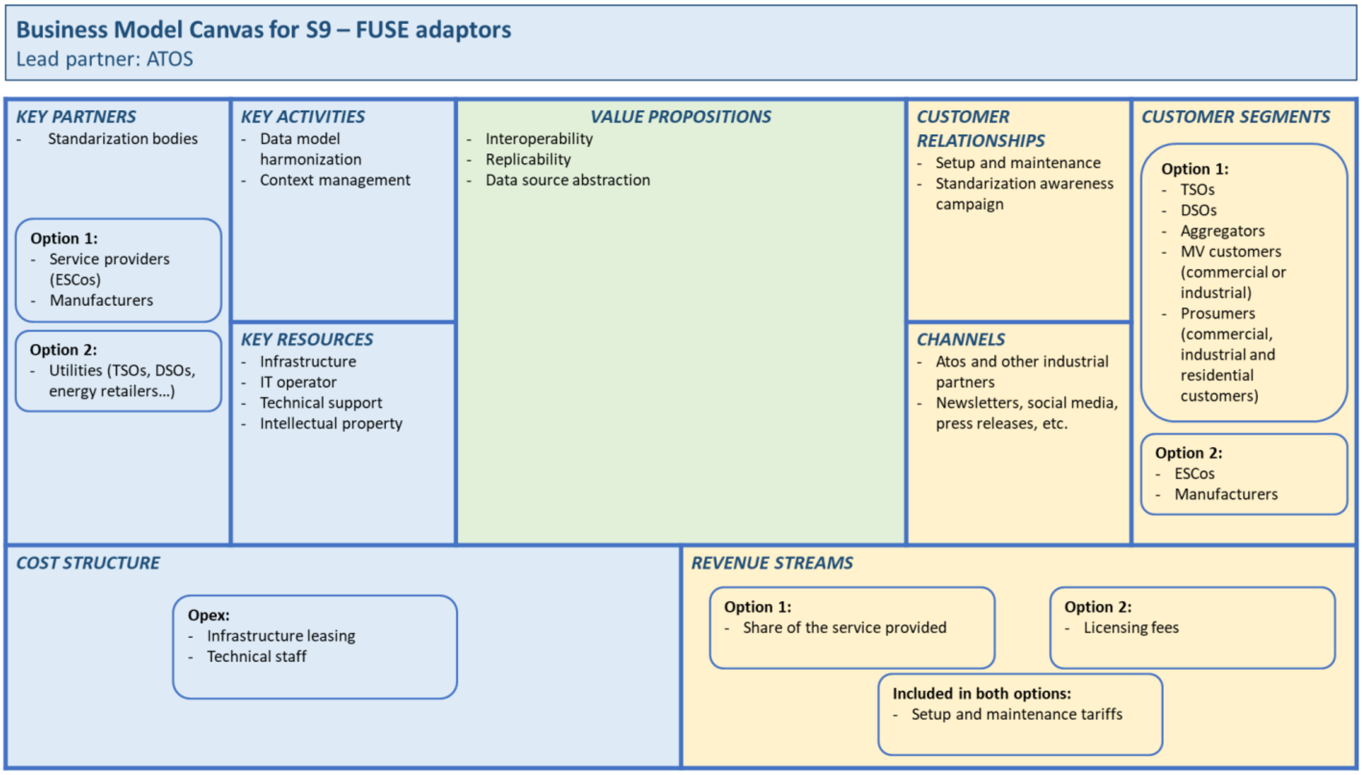


Operating costs are mainly related to the human resources needed for the development and exploitation of the solution (development team, marketing and sales team, operations team, technical support team and helpdesk, and overheads). Third-party-related costs also have to be considered, among which cloud hosting fees, website service party licenses, and the purchase of components for the production of the Smart Box (e.g. sensors, actuators).

Capital expenditures mainly consist in IT infrastructure for company operation, including both hardware (e.g. servers, computers) and software licenses.

FUSE platform adaptors (S9)

Figure 59. Business Model Canvas for S9 – FUSE adaptors



The FLEXIGRID approach uses adaptors from the FUSE platform. They allow data model harmonization and context management, and the future demand for them will especially be contingent upon the requirements set by standardization bodies in these domains.

Customer segments

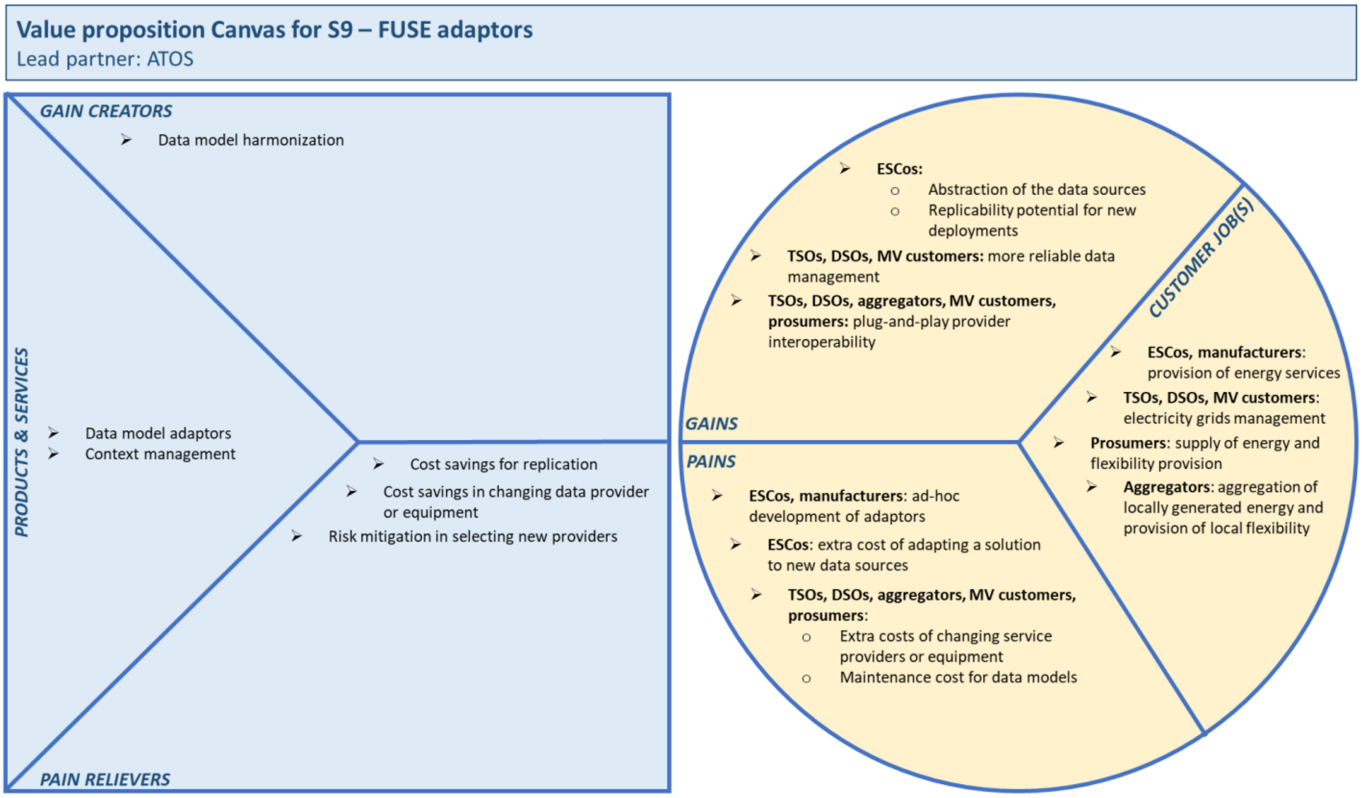
The end-users of the FUSE adaptors will include many customer segments targeted by the overall FLEXIGRID approach, especially TSOs, DSOs, aggregators, MV customers owning their own grid infrastructure or microgrids (commercial or industrial customers), aggregators and prosumers (which can include commercial, industrial and residential customers).

Besides, ESCos and manufacturers producing (smart) electrical equipment for substations (e.g. transformers or meters) could also be either direct customers or key partners in the commercialization of the solution as a service.

The targeted geographical markets are mainly the EU markets.

Value Proposition Canvas

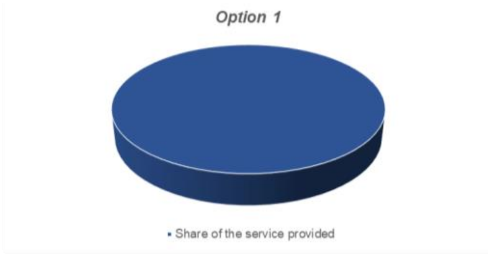
Figure 60. Value proposition Canvas for S9 – FUSE adaptors



The Value Proposition of the FUSE adaptors mainly consists in the avoidance of pains, which can take the form of extra costs or burdensome tasks that customers have to bear for little gain. For instance, in the case of ESCos, the identified pains consist mainly in the extra costs that they face to adapt a given solution to new data sources, either because they want to change it or because they are deploying it in a different site. FUSE adaptors ensure plug-and-play capabilities for customers' products and services, thereby avoiding such adaptation costs.

Revenue streams

Figure 61. S9 – FUSE adaptors – Revenue streams



Two mutually exclusive options could be considered for the commercialization of the FUSE adaptors:

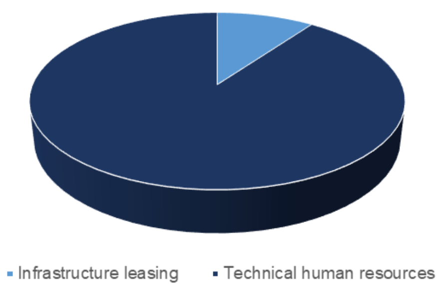
i) The FUSE adaptors could be commercialized as a service. In this case, their end-users (TSOs, DSOs, and MV customers) would be the final customers, while ESCos and equipment manufacturers would intervene as key partners. Revenues would then stem from a share of the service provided by ESCos.

ii) Alternatively, the choice could be made to commercialize the FUSE adaptors as a product. ESCos and equipment manufacturers would this time be the direct customers and would have to pay licensing fees that would have to be renewed at a given frequency.

In both cases, setup and maintenance tariffs would be included in the offer.

Cost structure

Figure 62. S9 – FUSE adaptors – Cost structure



The costs related to the FUSE adaptors include mostly operating expenses.

The most important are the costs associated with the technical human resources, namely IT operators, software developers, and infrastructure maintenance teams. Their importance will be contingent upon the number of deployed solutions and protocols that will have to be managed. The part related to infrastructure maintenance can be a shared cost with other services, as the same infrastructure can be used for other purposes.

The second category of operating expenses consists in the leasing of the infrastructure needed to host the adaptors. It depends on infrastructure providers' tariffs and implementation details. It can also be a shared cost with other services, which should be decided on a case-by-case basis.

4. CONCLUSION

4.1. A first step in the business model development process

This deliverable constitutes the first of four yearly reports over the course of the FLEXIGRID project dedicated to the FLEXIGRID solutions' business model development.

It provides elements of market analysis, centred on the identification of key market trends (the increasing share of variable RES, the electrification of end-use sectors and the development of energy storage systems) and of the ensuing requirements and opportunities in terms of power system flexibility. It specifies the challenges that they create for existing stakeholders (TSOs, DSOs, energy retailers, and renewable energy producers) and emerging actors (aggregators and ESCos), as well as for industrial, commercial and residential end-users who are willing, enabled and expected to play a more active role in energy management.

Building on this analysis of stakeholders' evolving roles, challenges and needs, this deliverable formulates a vision of the Value Proposition of the FLEXIGRID approach for the main customer segments addressed by the FLEXIGRID solutions:

- assets and services optimization for DSOs;
- optimized management of and value extraction from aggregators'/ESCos' flexibility pool (i.e. their customers' load, generation and/or storage assets);
- optimized management of and value extraction from the energy resources (load, generation and/or storage assets) of industrial, commercial and residential end-users, as well as energy communities.

It also evidences the key differentiating features of this approach, as well as the choices made in the development of the solutions that aim at fostering their swift market uptake: interoperability, replicability, and modularity/scalability.

Last but not least, this deliverable gathers key takeaways from a first value proposition and business model design exercise for the individual solutions constituting the FLEXIGRID approach, using a common methodological framework: the Business Model Canvas. At these early stages of the business model development process, the choice was made to focus more specifically on four building blocks: customer segments, value propositions, and revenue streams and cost structure.

4.2. Implications for next steps

In the next steps of the business model development process, the market outlook analysis will have to be updated, taking into account possible context and policy evolutions. The potential implications for the power sector of the crisis resulting from the Covid-19 situation will especially have to be assessed: while this crisis "*tests the EU's resilience and clean energy transitions*" (IEA, 2020a), the recovery packages expected at the EU and national levels may include investments to foster these transitions. An in-depth study will also have to be carried out to analyse the market context of the four EU member States where FLEXIGRID demonstration activities will be implemented.

Besides, the preliminary business models designed for FLEXIGRID individual solutions will have to be refined and complemented by a reflection at the level of the use cases. As the solutions will constitute technological bricks for the use cases, this reflection will build on the exploratory business models which have been designed and will have to be carried out in close coordination with the preparation of the demonstration activities, which will centre on the use cases.

REFERENCES

Books:

Alexander Osterwalder and Yves Pigneur, *Business Model nouvelle génération, Un guide pour visionnaires, révolutionnaires et challengers*, Pearson Education France, Paris (2011)

Scientific papers:

S. Sagiroglu, R. Terzi, Y. Canbay and I. Colak, "Big Data Issues in Smart Grid Systems", *2016 IEEE International Conference on Renewable Energy Research and Applications (ICRERA)*, Birmingham (2016), pp. 1007-1012

Reports:

Carbone 4, "Baromètre de la décarbonation, Comment décarboner en profondeur et sans tarder le bâtiment, les transports et l'industrie ? » (November 2018)

EC - European Commission, Communication to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank, *A Clean Planet for All, European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy* (November 28, 2018)

EC - European Commission, Communication to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, *The European Green Deal* (December 11, 2019) (EC, 2019a)

EC - European Commission, "Recommendation on Cybersecurity in the Energy Sector" (April 3, 2019) (EC, 2019b)

ETIP SNET - European Technology & Innovation Platform (ETIP) Smart Networks for Energy Transition (SNET), *Vision 2050, Integrating Smart Networks for the Energy Transition: Serving Society and Protecting the Environment* (June 2018)

IEA - International Energy Agency, "Status of Power System Transformation 2019, Power System Flexibility" (2019) (IEA, 2019a)

IEA - International Energy Agency, "European Union 2020, Energy Policy Review" (IEA, 2020a)

IEA - International Energy Agency, "Tracking Clean Energy Progress" (2020) (https://www.iea.org/topics/tracking-clean-energy-progress) (IEA, 2020b)

JRC - European Commission, Joint Research Centre, *Smart Grid Projects Outlook 2017 - Facts, Figures and Trends in Europe*, JRC Science for Policy Report (2017)

JRC - European Commission, Joint Research Centre (JRC), *Energy Communities: An Overview of Energy and Social Innovation*, JRC Science for Policy Report (2020)

USEF, "The USEF Framework Explained" (2015)

Web resources:

European Commission, "2020 climate & energy package" (https://ec.europa.eu/clima/policies/strategies/2020_en#tab-0-0)

European Commission, "2030 climate & energy framework" (https://ec.europa.eu/clima/policies/strategies/2030_en)

European Commission, "Clean energy for all Europeans package" (https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en)

European Commission, "Guidelines on State aid for environmental protection and energy 2014-2020" (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014XC0628(01))

European Commission, "National energy and climate plans (NECPs)" (https://ec.europa.eu/info/energy-climate-change-environment/overall-targets/national-energy-and-climate-plans-necps_en)

European Commission, "New Electricity Rules Enters into Force" (https://ec.europa.eu/info/news/new-electricity-rules-enters-force-2020-jan-06_en)

APPENDIX

Appendix 1: Business model development for FLEXIGRID solutions: A methodology which rests on the Business Model Canvas

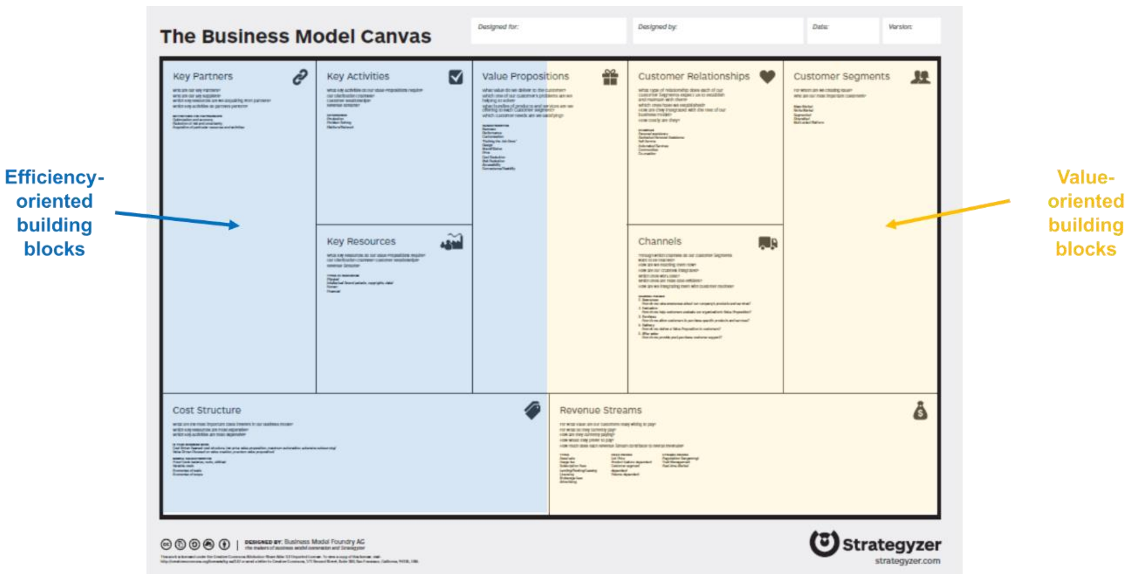
Presentation of the Business Model Canvas and rationale for its choice

The common formal procedure retained for the development of the business models rests on the Business Model Canvas designed by A. Osterwalder and Y. Pigneur (*Business Model Generation*, 2010).

The advantages of this tool are threefold, as underlined by its creators. First, it provides a useful material to initiate and guide collaborative thinking on a project's business model (e.g. during workshops or brainstorming sessions), both at its beginning and during its evolution. Secondly, the Canvas's construction helps to ensure that all of the key dimensions of the business model have been taken into account, and to verify that they are articulated in a consistent way. Last but not least, once the business model has been designed, the Canvas can be used to communicate it efficiently.

The Business Model Canvas is organized around nine building blocks. The Value Propositions are at the core of the Canvas. The blocks on their right-hand side ("Customer segments", "Customer relationships", "Channels" and "Revenue streams") can be described as "*value-oriented*", while the ones on their left-hand side ("Key activities", "Key resources", "Key partners" and "Cost structure") are more "*efficiency-oriented*" (A. Osterwalder and Y. Pigneur, 2010). The tables below give an overview of the Business Model Canvas's presentation, as well as a description of the intended contents of each block.

Figure 63. Business Model Canvas: Overview



Source: adapted from strategyzer.com

Table 15. Business Model Canvas building blocks: intended contents

VALUE PROPOSITIONS This block specifies how the proposed solution addresses the needs and expectations of each customer segment. It should therefore identify the products/services offered, and how they help customers to solve a specific problem, and/or bring them added value compared to current practices or tools. This value can be quantitative (e.g. performance in terms of costs or delays, risk mitigation) and/or qualitative (e.g. design, customization, support brought to the customer, ease of use/access…). The value proposition therefore implicitly or explicitly sheds light on the innovative features of the solution, and on those which differentiate it from competition.
CUSTOMER SEGMENTS This block identifies the targeted group(s) of customers for which the proposed solution will create value. A group can be considered as a distinct segment when it has specific needs or characteristics, or due to differences in terms of willingness-to-pay, profitability, or customer relationship. Segments can be clearly distinct from one another (in the case of diversified markets), but some interdependencies between them may also exist (e.g. in the case of multi-sided platforms). The identification of customer segments is a prerequisite before choosing on which group(s) to focus, and determining how the products/services offered can be tailored to their needs and expectations. An in-depth analysis is necessary to develop a good knowledge and understanding of the latter.
CUSTOMER RELATIONSHIPS Different forms of customer relationships can be established, depending on the targeted customer segment(s), and on the objectives pursued (customer acquisition, customer loyalty management…). They range from self-service and communities of users to dedicated assistance or co-creation. A specific attention has to be paid to their consistency with the needs and expectations of each targeted customer segment, and to their implications for other blocks of the Canvas (especially in terms of resources, costs…).
CHANNELS This block refers to the different forms of interaction with the identified customer segments; it especially evidences how the latter can be reached for purposes of marketing and communication, sales, and distribution. A. Osterwalder and Y. Pigneur distinguish between five "*phases*" that these channels should cover: raising awareness, helping customers to evaluate the value proposition, managing purchases, ensuring delivery of the value proposition, and providing after-sales support. Channels can be direct or indirect, and they can be managed in-house or rely on partnerships. Yet, a specific attention has to be paid to the consistency and integration between the different channels, to their relative efficiency, and to the quality of the interactions with customers that they allow.

REVENUE STREAMS This block analyses how the value that the solution creates for the various customer segments can translate into revenue sources, and assesses the relative importance of each of them. Several pricing schemes can be contemplated, depending on the product/service that is considered. They may be transaction-based (e.g. asset sales, brokerage fees), or recurring (e.g. subscription fees, license fees, or fees based on usage). Various pricing mechanisms (fixed or dynamic) may also be used.
KEY ACTIVITIES This block identifies the activities (e.g. engineering, production…) that are essential for strategy and operations, for the design of the proposed solution and its deployment in the market (i.e. for the delivery of the value propositions). Most of them can be derived from the building blocks considered above (value propositions, customer relationships, channels…).
KEY RESOURCES This block identifies the assets that are essential to carry out the activities evoked above, and deliver the value propositions. Most of them can be derived from the building blocks considered above (value propositions, key activities, customer relationships, channels…). They can be physical, human, financial, and intellectual (e.g. patents, data). They can be internal resources, or resources from key partners (see below).
KEY PARTNERS While the design and delivery of the value propositions will mobilize internal resources, and some of the related activities will be managed in-house, the choice may be made to rely on partnerships for some dimensions of the project. Such partnerships can take different forms (e.g. procurement, joint ventures, strategic alliances), depending on their specific objectives (e.g. organizational optimization, acquisition of specific resources or activities, risk mitigation). Partnerships can also, to some extent, involve customers. This block identifies the concerned resources and activities, and the key partners and suppliers that may provide or perform them.
COST STRUCTURE This block analyzes the different costs entailed by the design and delivery of the value propositions, and assesses the relative importance of each of them. They may include both fixed and variable costs. Most of them can be derived from the building blocks considered above (especially the key activities and key resources). Besides, they are closely related with the orientations retained in the value propositions: the solution’s innovative or differentiating features may indeed imply a cost-driven model (e.g. value proposition resting on a low-cost offering), or a more value-driven model (e.g. value proposition resting on a premium offering).

Source: adapted from A. Osterwalder and Y. Pigneur, 2010, and CCI Business Builder

Application within the framework of the FLEXIGRID project

The following steps are proposed for the application of the Business Model Canvas to the FLEXIGRID solutions, approach and use cases, over the course of the project:

(1) Exploratory business model design for FLEXIGRID solutions

From the early stages of the project development (M7-M12), all partners will contribute to the business model creation process for the FLEXIGRID solutions. In order to facilitate this process, working groups coordinated by each lead partner will design an exploratory business model for each solution. Their analysis will be supported by the Business Model Canvas template.

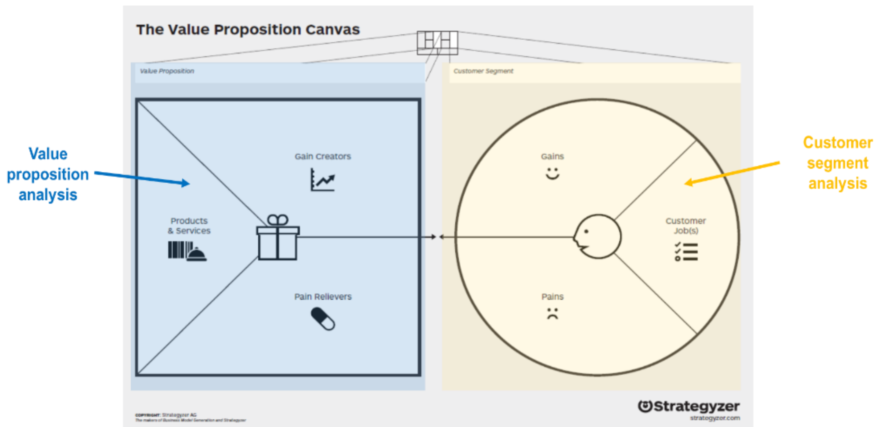
While the nine building blocks of the Canvas will have to be considered, a specific attention will be paid to four of them:

- "Customer segments": their identification is a prerequisite for the definition of the value propositions, and will also help to refine the business cases that will be presented in the market analysis (D8.1);
- "Value propositions": this block, which follows from the identification of customer segments, is at the core of business model development, as evidenced by its central position within the Canvas. This justifies the use of a dedicated tool to specify it: the Value Proposition Canvas (presented in the box below);
- "Revenue streams" and "Cost structure": the first reflection on these building blocks will lay the foundations for the evaluation of the profitability of the considered model. To initiate it, it is proposed to distinguish between working hypotheses to be used for the computation of each potential revenue stream and cost item, objectives and first projections, depending on their availability at this stage. These elements are intended to be specified and refined over the course of the project (with milestones at M24, 36 and 48).

The Value Proposition Canvas

The Value Proposition Canvas (A. Osterwalder, Y. Pigneur, G. Bernarda, A. Smith, 2014) has been designed to be used along with the Business Model Canvas, insofar as it helps to refine the "Value Propositions" block, which is positioned at the core of the latter. The targeted customer segments have to be identified beforehand. The needs and expectations of each of them can then be analysed in a dedicated Value Proposition Canvas, in order to define the corresponding value proposition.

Figure 64. Value Proposition Canvas: Overview



Source: adapted from strategyzer.com

The right-hand side of the Canvas aims at reaching a better knowledge and understanding of a customer segment's specific needs and expectations, by considering its current situation from its own viewpoint. Three blocks are dedicated to this analysis:

- "Customer job(s)" identifies the missions that the customer performs (e.g. the problems that they are seeking to solve), their activities and tasks, and their relative importance and order of priority;
- "Gains" identifies the objectives and results that the customer is striving to achieve through these activities and tasks (e.g. a given performance / quality level, a positive image …). These gains can be "*required*", "*expected*", "*desired*" or "*unexpected*", and their relative importance has to be assessed. This analysis will help specify the criteria that may drive customers' willingness to adopt a given solution.
- Conversely, "Pains" identifies the problems, risks and hurdles that the customer faces before, when or after carrying out their "jobs", and those that may prevent them from reaching their objectives (e.g. excessive or unexpected costs, time required, financial or technical risks…). Their relative acuteness and emergency also have to be assessed. This analysis will especially help identify the shortcomings of existing solutions, as well as the potential obstacles that may limit the customer's willingness to adopt new ones.

The left-hand side of the Canvas aims at specifying the project's value proposition, i.e. the way in which it will create value by addressing the customer segment's needs and expectations. It also comprises three building blocks:

- a description of the "Products and Services" which could be offered, assessing their relative significance within the whole value proposition, as well as the relative importance of their different features;
- the "Gain creators", describing how these products and services could create opportunities for the customer (e.g. an improved performance / quality level), and how they would differentiate from existing solutions (e.g. in terms of features, design, ease of use or access…). These opportunities should be articulated with the "Gains" block of the customer-segment analysis;
- and, conversely, the "Pain relievers" that these products and services could represent for the customer. They should address some of the "Pains" identified in the corresponding block of the customer-segment analysis (e.g. through cost savings, risk mitigation…).

(2) Identification of the value proposition of the FLEXIGRID approach

In parallel of the reflection on exploratory business models for the FLEXIGRID solutions, a first vision of the value proposition of the whole FLEXIGRID approach will be defined, using the Value Proposition Canvas. The outcomes of the analyses realized at the level of the individual solutions will then be leveraged to refine this initial vision.

(3) Complementary business model development for other exploitable results (ER)

In addition to the analysis conducted at the level of FLEXIGRID solutions, business models will be developed for other exploitable results of the FLEXIGRID project identified within the framework of the Exploitation Strategy (Task 8.5). The Canvas methodology already applied for individual solutions will be followed, and the resulting exploratory business models will be presented in the planned updates of this Deliverable (see part 1.2 above) and adjusted over the course of the project, in close coordination with Task 8.5.

(4) Analysis of the applicability of the exploratory business models designed for the individual solutions

The demonstration campaign implementation and the cost-benefit analysis will both start at M22. Within the framework of their preparation, an analysis of the applicability of the exploratory business models designed for the individual solutions will be realized.

In some cases, alternative business models may be considered for a given solution. Their respective advantages and drawbacks will then be highlighted and compared, possibly by means of SWOT analyzes.

(5) Complementary business model development for use cases

The preparatory work for the cost-benefit analysis and for the demonstration campaign will also require a new level of analysis to be considered: the articulation of several individual solutions within the framework of use cases.

In connection with this preparatory work, and in light of the demonstration organization needs that it will evidence, exploratory business models will be developed for the use cases, following the Canvas methodology already applied for individual solutions. Here also, alternative business models may be explored for a given use case. Their respective advantages and drawbacks for the different stakeholders will be highlighted and compared, possibly by means of SWOT analyses.

(6) Adjustment during the demonstration campaign and validation

The exploratory business models designed for the individual solutions and for the use cases will be updated, adjusted and refined throughout the demonstration campaign. This step will be key to validate the design of the value propositions and their applicability in the context of the various demonstration sites. It will also provide insights regarding the replication potential of the project results in other European countries.

(7) Finalization

The adjustment and validation throughout the demonstration campaign will conclude the business model development process for the individual solutions and the use cases. They will add to the other components of the FLEXIGRID business plan, which are also intended to be refined over the course of the project, in order to pave the way towards the deployment of the FLEXIGRID solutions on the market. This finalized business plan could also be mobilized to seek additional funding or external investment, should they be needed to reach the first sales.