FLEXGRID

A novel smart grid architecture that facilitates high RES penetration through innovative markets towards efficient interaction between advanced electricity grid management and intelligent stakeholders

H2020-GA-863876

Intermediate version of business modelling, dissemination, and exploitation of results

Deliverable D8.2

Document Information

Scheduled delivery	31.03.2021
Actual delivery	31.03.2021
Version	2.0
Responsible Partner	SIN

Dissemination Level

PU Public

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Acknowledgements

The research leading to these results has received funding from the EC Framework Programme HORIZON2020/2014-2020 under grant agreement n° 863876.

Glossary of Acronyms

Project management terminology

Acronym	Definition
D	Deliverable
DoA	Description of Action
EC	European Commission
HLUC	High Level Use Case
MS	Milestone
WP	Work Package
UCS	Use Case Scenario

Technical terminology

Acronym	Definition
AC-OPF	Alternating Current Optimal Power Flow
AFAT	Automated Flexibility Aggregation Toolkit
AI/ML	Artificial Intelligence/ Machine Learning
AI-HLEG	Artificial Intelligence High-level Expert Group
API	Application Programming Interface
ATP	Automated Trading Platform
AUW	Aggregated Users' Welfare
BMC	Business Model Canvas
BRP	Balance Responsible Party
BSP	Balancing Service Provider
BSS	Battery Storage System
B2B/B2C	Business to Business / Business to Consumer
CAPEX/OPEX	Capital Expenditures / Operational Expenditures
CEP	Clean Energy Package
CHP	Combined Heat and Power
DA/ID	Day-ahead / Intraday
DB	Data Base
DC-OPF	Direct Current Optimal Power Flow
DER	Distributed Energy Resource
DFA	Distributed Flexibility Asset
DG	Distributed Generator
DLFM	Distribution Level Flexibility Market
DMP	Data Management Plan
DN	Distribution Network
DR	Demand Response
DSM	Demand Side Management
DSO/TSO	Distribution/Transmission System Operator
ESCO	Energy Service Company
ES	Energy Service
ESP	Energy Service Provider;
ESS	Energy Storage System
EV	Electric Vehicle

FCR	Frequency Containment Reserves
FMCT	Flexibility Market Clearing Toolkit
FST	FlexSupplier’s Toolkit
GUI	Graphical User Interface
HEMS	Home Energy Management System
ICT	Information and Communication Technology
IEGSA	Interoperable European Grid Services Architecture
KPI	Key Performance Indicator
LMP	Locational Marginal Price
MVP	Minimum Viable Product
(NE)MO	(Nominated Electricity) Market Operator; FMO stands for Flexibility MO
NRA	National Regulatory Authority
ORDP	Open Research Data Pilot
QoS/QoE	Quality of Service/Quality of Experience
PaaS	Power-as-a-service
POPD	Protection of Personal Data
PPA	Power Purchase Agreement
RES	Renewable Energy Sources
RESP	RES Producer
RTP	Real Time Pricing
RTM	Real Time Market
SGAM	Smart Grid Architecture Model
SGH	Smart Grid Hub
S/W	Software
SWOT	Strengths Weaknesses Opportunities Threats
VPC	Value Proposition Canvas
VPP	Virtual Power Plant; IPP stands for Independent Power Plant
VRE	Variable Renewable Energy
HEMS	Home Energy Management System

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Document History

This deliverable includes an updated version of FLEXGRID's business models and innovative value propositions based on the market analysis described in D8.1. It also includes an updated version of the so far dissemination and exploitation-related achievements of the consortium.

Table 1: Document History Summary

Revision Date	File version	Summary of Changes
08/04/2020	v0.1	Initial draft ToC circulated with consortium partners
30/11/2020	v0.2	Updated draft ToC shared with main contributing partners, along with writing task delegation and schedule
13/01/2021	v0.3	Final ToC and latest work presented to the consortium, along with additional input requests to other consortium partners
01/03/2021	v0.4	1st round of contributions for review
10/03/2021	v0.5	1st review provided by NODES and NPC
15/03/2021	v0.6	2nd round of contributions for review
22/03/2021	v0.8	2nd review provided by NODES and NPC
29/03/2021	v0.9	SIN addressed all comments from 2nd review, and forwarded the final version to the coordinator (ICCS)
31/03/2021	v1.0 - Final	Submitted to ECAS portal by coordinator (ICCS)
19/04/2021	v2.0	Short version for upload to project website

Executive Summary

This deliverable presents the intermediate results from the FLEXGRID Work Package (WP) 8 – *Business modelling, dissemination, exploitation, and management of innovation impact.* Much has been developed and various achievements have been obtained since the initial concepts were presented in Deliverable (D) 8.1[1] in March 2020. Research WPs 3, 4 and 5 have refined their research threads and proposed initial versions of the FLEXGRID models in D3.1, D4.1 and D5.1 in September 2020. Concurrently, WPs 6 and 7 have kicked off their activities and provide an initial direction for the development of the FLEXGRID software platform (D6.1) and plans for validation and pilot testing (D7.1). Meanwhile, the energy flexibility domain has progressed significantly: new projects and commercial developments provide an evolving context to FLEXGRID. In these circumstances, D8.2 provides a status update at the project month (M)18, notably describing:

- An updated market analysis in the topics relevant to FLEXGRID,
- A refined overview of the FLEXGRID business ecosystem,
- An analysis of the business cases explored by commercial actors in the FLEXGRID concepts,
- The intermediate description of the FLEXGRID Key Exploitable Results (KERs),
- The intermediate version of the FLEXGRID value propositions and business models,
- The refined process to assess the FLEXGRID project impact.

Updated market analysis for the FLEXGRID topics

The concepts initially proposed in FLEXGRID's D2.1 and further refined in the research WPs, look at developing solutions to improve market and network interactions towards a smarter and more efficient power system. For this, the project presents research topics that look far into the future (i.e., 2030 and beyond). To better understand how this connects to today's reality, a market analysis considers the latest developments in flexibility markets and solutions provided by different commercial actors in the electrical sector.

One trend explored is different business models that are carried out by actors considered relevant for the Energy Service Provider (ESP) role described by FLEXGRID. Here, the ESP is defined as a "profit-oriented company, which may make contractual arrangements with various types of flexibility assets (e.g. DSM, RES, storage)"[2]. This role can in fact be performed by different types of companies such as aggregators, retailers, independent aggregators, and energy service companies (ESCOs). New business models observed are utilising new revenue streams such as advertisement and building aggregation and flexibility management services into a wide variety of end-user services. Power-as-a-Service (PaaS) is one such example of a business model that embraces new trends in end-user services that can be relevant for ESPs in FLEXGRID. Furthermore, commercial aggregators are providing flexibility services to network operators (e.g., providing balancing services), while developing added value service offerings to end-users. For example, aggregators are partnering with hardware providers to offer discounts on batteries in exchange for using end-user flexibility in aggregation services.

In many cases where commercial actors are looking to manage the flexibility in their assets, they require strategies and tools that improve the assets' operation. Effective solutions are necessary for developing a profitable business case for investing in new assets. For example, this is the case for rapid electric vehicle (EV) charging, where high power peaks that are penalised by increased grid

[1] FLEXGRID Deliverable 8.1, 'Data management, dissemination and exploitation plans', https://flexgrid-project.eu/deliverables.html, accessed 22 March 2021.

[2] FLEXGRID Deliverable 2.1 'Use case scenarios, requirements' analysis and correlation with innovative models', https://flexgrid-project.eu/deliverables.html, accessed 22 March 2021.

tariffs must be managed with smart charging in order to achieve a sustainable business case from operating charging infrastructure.

Meanwhile, flexibility markets provide a platform where flexibility buyers (FlexBuyers) can purchase flexibility from suppliers (FlexSuppliers). Such marketplaces continue to be deployed in pilot projects that evaluate how effective market-based flexibility management is utilized towards efficiently solving network challenges (e.g., line congestions). Use cases where DSOs are performing congestions' management by requesting flexibility from local markets are particularly pertinent to the FLEXGRID market architectures.

Developments in policies and regulations relevant for the FLEXGRID topics are also assessed here. We explore recent advances at the EU level and compare this to regulatory frameworks at national level considering three cases: Germany, Croatia, and Norway. While the EU policy has not produced significant news regarding energy flexibility in the last year, national policy makers are considering different approaches to transpose the directives of the Clean Energy for all Europeans Package (CEP).

In Germany, a study commissioned by the Federal Ministry of Economics has evaluated the economic potential for market-based flexibility procurement. Results from this study has ruled out market-based procurement for most flexibility services, except for voltage control and black start capability. Germany has also planned for regulated redispatch mechanisms collectively referred to as "Redispatch 2.0". This redispatch scheme includes all generation assets with an installed power capacity upwards of 100 kW and mandates new responsibilities for DSOs. Under new regulations, DSOs will need to be able to provide forecasts of generation and consumption in their networks and participate in settling the redispatch in collaboration with the TSOs. While the regulations provide less room for the distribution-level flexibility markets proposed by FLEXGRID, the project will evaluate the use of the FLEXGRID software components and algorithm to help DSOs in fulfilling their new responsibilities.

In Croatia, flexibility is currently used to provide manual frequency restoration reserve (mFRR) to HOPS, the Croatian TSO. A new version of the Croatian Electricity Market Act is expected to enter into force by the end of 2021. The main change in flexibility management is shift for the TSO is the creation of a transparent market for mFRR which will be open for DERs and aggregators alike. On the distribution level, Croatia lacks the adequate definition of services and mechanisms needed for the use of flexibility by DSOs.

In Norway, flexibility is currently offered in the TSO balancing and reserve markets. Additionally, the regulator RME is evaluating flexibility management strategies by allowing for specific innovation projects to deviate from the current regulatory framework. In this context, the regulator is assessing both new tariffs to incentivise flexible energy consumption as well as market-based solutions. Through their remuneration framework, DSOs are also encouraged to invest in new technologies that ensure efficient operation of their network. DSOs can apply to increase the investment in research activities to improve network operation. A key area where network operators are encouraged to invest is in the digitization of LV and MV networks. The regulator is also investigating standard methods to assess the value of flexibility as an alternative to traditional network reinforcement. Last, the Nordic regulators (NordREG) published a framework that outlines recommendations for the deployment of independent aggregation which covers market access, financial responsibilities, imbalance compensation and the evaluation of flexibility.

A refined FLEXGRID business ecosystem

The above market analysis provides a context for the refinement of the FLEXGRID business ecosystem, initially presented in D8.1. This refined business ecosystem evaluates the business cases presented to different stakeholders in the flexibility domain, namely market operators (MOs) – including new flexibility market operators (FMOs) – DSOs, TSOs and FlexSuppliers.

First, FMOs aim at increasing their service offering to FlexBuyers and FlexSuppliers by operating a distribution-level flexibility market (DLFM), where FlexServices can be requested, offered, and traded. This business case can also be evaluated by traditional MOs, who could increase their market offerings. Additionally, FMOs can utilise advanced algorithms to increase the efficiency of their market clearing process. The market clearing can be performed in a network-aware way, where distribution network (DN) data is considered to ensure that the flexibility traded on the market can be delivered on the distribution grid. Finally, the FMO evaluates how it can facilitate TSO-DSO coordination regarding the settlement of flexibility at distribution level.

DSOs are presented with different business cases to use flexibility to efficiently ensure quality- and security of supply to end-users, while avoiding or delaying investment in network reinforcement. DSOs could therefore perform a market-based procurement of flexibility to manage line congestions and voltage problems in their networks. To this end, DSOs can detect network congestions by performing a load flow simulation and forecasting demand and generation in their network. They could also evaluate how to facilitate the investment in new FlexAssets by commercial actors that could in turn provide services to support grid operation. Specific business cases are evaluated for German DSOs to cost-effectively carry out their new tasks under Redispatch 2.0, including the daily generation and load forecasting, and coordinating with the upstream network operator to execute the redispatch of assets on the distribution level.

TSOs have the ability to minimise their reserve capacity procurement cost by purchasing flexibility services on a DLFM when the price of flexibility from the distribution level is lower than in the TSO reserve and balancing markets or when there is not enough capacity in the TSO markets.

On the FlexSupply side, ESP/aggregator stakeholders look to increase their profitability from selling flexibility on the markets. This can be accomplished by optimally offering flexibility on different markets or by optimising FlexAssets' operation and investment planning to reduce their operational expenditure (OPEX) and capital expenditure (CAPEX). Aggregators can also utilise new strategies to optimally respond to FlexRequests, dynamically create FlexOffers on the market, and manage an aggregated portfolio of prosumer assets.

Finally, flexibility management allows prosumers to better use their FlexAssets to minimise their electricity bills and sell flexibility to gain additional revenues from their assets. For prosumers, it is of crucial importance that they have access to mechanisms that guarantee their comfort levels, while participating in the provision of FlexServices.

FLEXGRID Key Exploitable Results

The FLEXGRID project develops a set of key exploitable results (KERs) that consist of software solutions, algorithms, as well as policy-related results.

Most of the KERs are designed to be incorporated in the FLEXGRID Automatic Trading Platform (ATP) and its sub-components. This platform acts as a front end for the users of the FLEXGRID solutions and allows for an effective data exchange between the different system components. Users of the ATP include DSOs, FMOs, and ESP/aggregators who each have access to bespoke graphical user interfaces (GUIs) that provide specific functionalities to each user type. On the backend of the ATP, different toolkits equipped with algorithms deliver functionalities that provide value to different target customers.

The first toolkit is the Automatic Flexibility Aggregation Toolkit (AFAT), which provides functionalities that improve the management of an aggregated portfolio of FlexAssets. The AFAT enables the following services:

- Manage a FlexRequest,
- Create a FlexOffer,
- Manage a B2C flexibility market.

The second toolkit is the Flexibility Supply Toolkit (FST), which provides functionalities that help FlexSuppliers improve their profitability from selling flexibility. The FST proposes the following functionalities:

- Minimize ESP's CAPEX,
- Minimize ESP's OPEX,
- Maximize ESP's stacked revenues,
- Market price forecasting.

The last toolkit is the Flexibility Market Clearing Toolkit (FMCT), which consists of advanced optimal power flow (OPF) algorithms to determine the flexibility needs of a DSO. The FMCT also includes auction-based and continuous market clearing algorithms that enable efficient, network-aware market clearing and can be used by the FMO.

Besides the KERs included in the FLEXGRID platform, the project's policy-related KERs consist of several x-DLFM architectures and results of a DSO techno-economic analysis. The former consists of the different market architectures researched in WP5, namely the reactive- (R), proactive- (P) and interactive- (I) DLFM. Their main purpose is to make recommendations to policy makers for improved future energy market frameworks that incorporate a novel Distribution Level Flexibility Market (DLFM). Meanwhile, the DSO techno-economic analysis develops a model that provides data towards finding an optimal price for flexibility in distribution networks, considering scenarios with electric vehicles (EVs), photovoltaic (PV) generation, battery storage systems (BSSs) and demand response service providers. This will provide DSOs with a better understanding of the techno-economics to be considered when evaluating flexibility as an alternative to traditional grid operation. It will also help DSOs to identify the cases for which the introduction of a DLFM will be beneficial for the DSO's business as well as the social welfare.

The intermediate version of the FLEXGRID value propositions and business models

To understand how the FLEXGRID KERs could be leveraged on a commercial basis to provide value to different stakeholders, the business modelling method uses a stepwise, scenario-based approach which describes how the FLEXGRID components can progressively be utilised as technology and regulatory conditions evolve. In a first scenario, the context of today's European DSOs is assumed, which varies significantly between (and even within) each country. Small DSOs may have access to limited data and dynamic observability at the LV level, whereas larger DSOs might already have advanced distribution management systems (DMSs) capable of integrating rapid demand response into operations. In a second scenario, it is assumed that DSOs generally have access to more network data that can be used to request flexibility in near real-time. Finally, a third scenario assumes a more futuristic situation (e.g. 2030 and beyond), where regulatory frameworks might be quite different from today's scenario. For example, we could expect integrated markets that utilise high amounts of granular data to manage the flexibility needs from networks with a high presence of distributed generation assets.

In this evolving context, the FLEXGRID components provide a range of value propositions to key market stakeholders in the business ecosystem. First, the FLEXGRID platform allows FMOs to achieve a more efficient flexibility market operation. This is accomplished by providing an improved market clearing process and an increased service offering to FlexBuyers and FlexSuppliers. FLEXGRID proposes two intermediate business models that could be carried out to leverage the potential of these services:

1. The provider of the FLEXGRID platform for flexibility market operation,
2. A FMO that integrates the FLEXGRID components to provide an increased value to market participants.

The FLEXGRID platform also provides value to DSOs by enabling them to better leverage flexibility to efficiently accommodate a larger share of renewable energy supply (RES) in the DN. FLEXGRID services allow DSOs to reduce their capacity payments to upstream network operators by performing peak shaving, identify congestion and voltage problems in their network, procure flexibility services to support their network's operation, delay or avoid investment in network reinforcement, and participate in a DSO-TSO coordination towards procurement of flexibility. These value propositions provide a basis for a third intermediate business model. This business model is specifically serving DSOs as a target customer and delivers functionalities from the FMCT.

3. The provider of the FLEXGRID platform for DSOs.

The FLEXGRID services also provide several value propositions to FlexSuppliers, both through the FST as a means to improve performance from selling flexibility to different FlexBuyers, and by leveraging the AFAT for an improved management of an aggregated portfolio of FlexAssets. These toolkits are included in the two last intermediate business models proposed below:

4. The provider of the FLEXGRID platform for FlexSuppliers,
5. An aggregator that integrates the FLEXGRID components to provide an increased value to prosumers.

The intermediate business models each have specific components, which can provide certain functionality to target customers in the first stepwise scenario, while additional services can be deployed for an increased value proposition in later scenarios. The value hypotheses formulated in the intermediate business models will be assessed and quantified in subsequent project activities. The results of this assessment will be included in the final version of business modelling work provided in D8.3.

Impact analysis

The objective of the impact analysis is to monitor the innovation development in the FLEXGRID project and assess the potential impact that the project can have on greater society. A refined framework for this assessment is used to map the project's key performance indicators (KPIs) to FLEXGRID's impact targets.

A review of the project impacts focuses on the potential improvements to the operation of flexibility markets. First, the advanced models are considered to improve the overall efficiency of the electricity system, across both network and market domains. Second, the enhanced modelling tools developed in the FLEXGRID project can also facilitate the network operation of a DSO to accommodate more RES. This can further support the cooperation between TSOs and DSOs toward efficiently managing flexibility to support network operation, while also providing value to commercial FlexSuppliers.

On a more specific level, a mapping process is defined, where KPIs specified in the development of research WPs and documented in deliverables 3.1, 4.1 and 5.1 are mapped to project-level KPIs before being linked to the expected project impacts. This is ultimately tied to the broader impact that the FLEXGRID outcomes can bring to the greater society. Here, we consider a quintuple helix model that studies knowledge creation towards academia, governments, civil society, industry, and the impact on the environment.

Updated exploitation plan

Last, an updated exploitation plan is detailed that considers the latest version of the FLEXGRID KERs. This plan explores both joint and individual exploitation options that are in line with ambitions of the FLEXGRID project beneficiaries.

Building from the initial exploitation ambitions described in D8.1, joint exploitation plans are described on a KER-basis. These exploitation pathways are focused on solving specific problems faced by electricity stakeholders and set the basis for subsequent activities to be carried out after the FLEXGRID project (e.g., further research and innovation projects, commercialisation, etc.).

The “modular-by-design” architecture of the FLEXGRID solution allows for a specific arrangement of the FLEXGRID components in specific joint (or individual) exploitation cases. For example, the different toolkits could be exploited on a stand-alone basis or integrated with the ATP in order to facilitate interaction between different business actors.

1 Updated Market Analysis for FLEXGRID's Innovations

Flexibility markets are developing rapidly, with several new innovations rapidly entering the market and new R&I initiatives announced each week. This section describes various developments that have emerged in the last year, particularly looking into the developments that are more closely related to the low TRL research and innovation focus of the FLEXGRID project. The first subsection 1.1 discusses the new developments in different areas relating to flexibility market solutions and the later section 1.2 presents relevant progress in European legislation in this domain, including interesting aspects of national policy and regulations observed at national level in three countries represented in the FLEXGRID project consortium (Germany, Croatia and Norway). The market analysis described here gives an update that build on previous observations included in deliverable D8.1[3]. The purpose of the market analysis is to provide commercial context to guide the FLEXGRID innovations and describe important trends to consider in designing business and exploitation strategies for the FLEXGRID project.

1.1 New Developments in Flexibility Markets

The following subsection provides an update overview of developments in commercial and research areas regarding the following topics:

- Projects and business models for actors participating in flexibility markets,
- Demand response services and optimal operation of flexible assets (FlexAssets),
- Market architectures and distribution-level flexibility markets (DLFMs).

1.1.1 Projects and Business Models for Actors Participating in Flexibility Markets

With advancements in ICT infrastructure and the use of new methods to capture the potential value from flexible distributed energy resources (DERs), many new business models have emerged in the energy sector. Particular developments are discussed below, primarily highlighting the new services and organisational structures related to Energy Service Providers (ESPs) as defined in D2.1[4]. Here, we include case studies of companies taking different roles, including aggregators, retailers that provide aggregation services, independent aggregators, and new roles for energy service companies (ESCOs).

The Integrid H2020[5] project describes different business models that provide services to various stakeholders in the flexibility domain. Here, new business models for ESCOs are analysed where services are provided that aim at minimising the cost of electricity for industrial and residential consumers. A particular business case considered is the provision of energy forecasting to suggest optimal load provides to the end-consumers. These business models utilise non-traditional revenue streams that include advertisements and subscription schemes.

Another type of ESP examined is Tibber[6], a Norwegian company founded in 2016 that is active in several European countries offers a range of electricity services to end-consumers. Tibber began with the electricity retailer business model and added demand-side management (DSM) services to provide additional value to end-consumers. This was achieved by embedding functionalities directly

3 Deliverable D8.1: Data management, dissemination, and exploitation plans
4 FLEXGRID Deliverable 2.1 'Use case scenarios, requirements' analysis and correlation with innovative models', https://flexgrid-project.eu/deliverables.html, accessed 22 March 2021.
5 https://integrid-h2020.eu/
6 https://tibber.com/en/about-us

in smart home devices sold to customers. In the last year, Tibber has expanded its service offering, where it now also acts as an aggregator by managing the flexibility from private electric vehicle (EV) chargers and building heating. During the winter season of 2019-2020, Tibber participated in a pilot project that provided mFRR services in the balancing market operated by the Norwegian TSO Statnett. Other commercial actors like the retailer Entelios also participated in this pilot project[7]. In the project, Statnett reduced the minimum capacity requirement for participation in the balancing market in the bidding zone NO1 from 5 MW to 1MW. In addition it allowed to offer of aggregated demand. In the pilot, it was demonstrated that the aggregators used the flexibility from 150 EV charging points without disturbing the end-users' comfort.[8] Both Tibber and Entelios have developed solutions that enable their current systems to respond automatically to price signals from the TSO.

Another new business model, Power-as-a-Service (PaaS), is championed by Vattenfall in the UK. In this model, Vattenfall takes full responsibility for its end-consumers' electrical infrastructure. This covers ownership, risk, investment, planning & installation, operation and maintenance of different energy assets such as EV chargers, battery storage systems (BSS) and other electrical infrastructure at the high voltage level.[9]

FLEXGRID utilises trends in new business models to develop new business models that provide value in the FLEXGRID business ecosystem. The busines models for ESP/aggregators proposed by FLEXGRID are related to these trends and will be tested in the context of FLEXGRID's high-level use case (HLUC) 02: "FLEXGRID ATP offers advanced flexibility supply services to Energy Service Providers".

The aggregation business model has developed service provisions by aggregating the capacity from various types of DERs located in the LV and MV grids. A group of assets virtually managed together (i.e. a Virtual Power Plant – or VPP) can act as a single entity in wholesale markets. According to the IRENA report of the aggregation landscape, the VPP market value is expected to reach around US 4,597 M$ by 2023 with an annual growth rate of around 26%. A primary growth factor for this market are regulatory changes which allow VPPs to participate in the balancing market (both upward and downward regulation services) where they had previously been excluded.[10] One such example is that of the Tesla Virtual Power Plant project in South Australia, where 250 MW of rooftop solar capacity from 50 000 homes are being aggregated to provide frequency reserve services to the grid operator. As of 2020, 1100 PV and battery systems were already active in providing balancing services.[11]

The last ESP/aggregator business model studied here is that of Eneco Crowdnett in The Netherlands. In this case, end-users are provided with batteries at a discount rate and get additional monetary benefits for offering 30% usage of battery to the aggregator at any time of the day.[12]

7 https://www.entelios.com/en/
8 https://www.statnett.no/en/about-statnett/news-and-press-releases/news-archive-2020/electric-vehicles-and-buildings-help-keep-the-power-grid-in-balance/
9 https://network-solutions.vattenfall.co.uk/services/power-as-a-service
10 https://www.irena.org//media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_Aggregators_2019.PDF?la=en&hash=EB86C1C86A7649B25050F57799F2C0F609894A01
11 https://arena.gov.au/blog/social-housing-added-to-teslas-virtual-power-plant/
12 https://www.irena.org/-/media/Files/IRENA/Agency/Events/2017/Oct/EU-Utility-week/CrowdNett.pdf?la=en&hash=7FC6D5F20067938A047C5B161EE91184F63BF0CC

The different case studies presented here provide examples of commercial actors who could adopt the outcomes of the FLEXGRID HLUC 04, which develops methods for optimising aggregator portfolios to maximise the social welfare in the aggregated portfolio of FlexAssets. The design of new services such as those proposed by the Eneco Crowdnett initative are relevant for the aggregator business models developed in FLEXGRID.

1.1.2 Demand Response and Optimisation of Flexible Assets

D8.1 presented several commercial solutions and companies that offer demand response (DR) and optimisation services for FlexAssets. Two of the companies presented, Next Kraftwerke and Sonnen, announced a cooperation agreement in September 2020 to supply services for Frequency Containment Reserves (FCR) in Germany. In this agreement that enables the flexibility providers to participate in the markets, Sonnen will be responsible for aggregation, control and availability calculation while Next Kraftwerke will provide access to the TSO reserve market in addition to bidding and settlement services.[13]

Another area where DR has proven important is in EV charging, where smart charging services are becoming common features in public chargers where the peak power demanded from the grid needs to be limited. With the development of rapid charging – several DC chargers offer upwards of 250 kW – distribution network operators are faced with technical constraints in accommodating public charging infrastructure.[14] The development of EV charging infrastructure also impacts commercial building operators (e.g. office buildings) and residential end-users: according to International Energy Agency (IEA), around 89% of the global EV chargers are being installed at residential and work locations[15]. Therefore smart charging solutions that can perform peak shaving are important technologies that help the business case for EV charging infrastructure providers. Different strategies are considered here, including two-way smart charging technologies like vehicle to Everything (V2X), including vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I).[16]

FLEXGRID develops optimization mechanisms that aim to improve how different DER assets can provide effective DR services to network operators. HLUC 03 notably looks at the effectiveness of using DLFMs to respond to the needs of network operators to support the operation of the grid.

1.1.3 Market Architectures and Distributed Level-Flexibility Markets (DLFMs)

Several different platform providers that offer flexibility market services for DSOs are described in D8.1.

Different pilot projects have ongoing activities developing these platforms as a service to DSOs investing in flexibility to support their network operation. For example, a new market for flexibility operated by NODES was opened in late 2020 in the Stockholm region. This Sthlmflex project involves the DSOs Vattenfall Eldistribution and Ellevio who purchase flexibility on the NODES platform to relieve congestion in their networks. FlexSuppliers include an energy generator, a property

[13] https://www.next-kraftwerke.com/news/sonnen-next-kraftwerke-co-operate-fcr-home-batteries
[14] https://www.spglobal.com/platts/en/market-insights/blogs/electric-power/042420-evs-are-on-a-roll-how-will-us-power-grids-manage-rising-demand-for-charging
[15] https://www.iea.org/reports/global-ev-outlook-2020
[16] https://corporatefinanceinstitute.com/resources/knowledge/other/vehicle-to-everything-v2x

management company, and an aggregator. Furthermore, in addition to NODES as the market operator, EON provides a decision support tool that provides analytics to the DSOs.[17]

Flexibility market platform providers also develop strategies that aim to provide additional value to market participants. One example is the NODESconnect program[18] developed in June 2020 that develop partnerships with FlexSuppliers to help them optimise their FlexAssets in order to increase the available flexibility on the market.

The rapid developments in piloting flexibility markets for DSO congestion management provides inputs to FLEXGRID's business modelling work. Furthermore, the different strategies that FMOs implement to support FlexBuyers and FlexSuppliers to better make use of their flexibility are relevant for the FMO business model design in FLEXGRID.

1.2 Policy and Regulatory Developments at European and National Levels

Building on the overview provided in D8.1, this section expands on the latest developments in European policy and regulation related to energy flexibility. First, relevant developments at the EU level are presented, while the subsequent sections focus on regulations at the national level in Germany, Croatia, and Norway.

1.2.1 Update on the European Commission's Strategy for Flexibility Initiatives

Several changes happened in the last year due to the COVID-19 pandemic across the globe. According to International Energy Agency (IEA)[19], in the EU around 7-10% economic downturn was observed due to the pandemic's health crisis. Several initiatives for the decarbonization of the European energy sector were down-prioritized due to the major health crisis during the pandemic.

During the same period EU Coal demand fell by 20% and the share of renewable energy generation reached an all-time high, while energy related emissions were reduced by 8% during 2020 compared to 2019. The EU has also submitted an updated National Determined Contribution (NDC) for the Paris Agreement at the 26th Conference of the Parties (COP26). This update in the EU contribution to global reduction in GHG has been the key focus of the European Green Deal (EGD) under the new administration in Brussels. Last year, the EC also presented an EU Climate Law to improve governance related aspects that will help in emission reduction during 2030-50 based on five-year reviews.

There has been no clear focus in the last year on how the increasing share of renewables in the electricity sector can be facilitated with improved policy and regulatory frameworks. Some suggestions are put forward by the IEA, where the power system flexibility will be a key resource in facilitating a rapid and effective integration of renewables. A clear focus in the new initiatives under the Horizon Europe framework needs to be further supported by additional regulations and policy updates to ensure an increased market uptake of flexibility in the EU electricity sector. There are, however, several developments on member state level that are interesting to observe.

[17] https://nodesmarket.com/new-marketplace-resolves-congestion-issues-in-stockholm/
[18] https://nodesmarket.com/nodesconnect/

[19] https://www.iea.org/reports/european-union-2020

1.2.2 Redispatch 2.0 and German context

The regulatory framework regarding the electricity market in Germany is changing significantly at the moment. In the following, some of the regulatory “mega trends” are described.

1.2.2.1 Redispatch 2.0

With the national Network Expansion Acceleration Act (“NABEG”), numerous new regulations will enter into force from 1st of October 2021, which are collectively referred to as “Redispatch 2.0”. In this new framework, DSOs will be responsible for active redispatch of generation devices and controllable loads. The new redispatch regime also extends to VRE and CHP plants from 100 kW and even smaller systems “ that can be remotely controlled at any time by the grid operator” – for example through smart meter gateway technology. In the past the task of re-dispatching power plants and controllable loads was reserved exclusively to Transmission System Operators (TSOs).

The term “dispatch” generally refers to the operational planning of a power plant by its operator or a central dispatch centre. The purpose of dispatch is to realize the most efficient operation mode of the power plant portfolio from a business point of view. For this purpose, the use of all available power plants is planned by taking into account their variable costs (whereas regarding thermal power plants the costs related to fuel usage are mostly dominant) and the expected prices on the respective sales market. The result of the dispatch optimization is called a schedule.

All power plant operators are obliged to notify the relevant TSO of their production schedules with the quantities of electricity to be produced during the optimization period – in Europe mostly for the following calendar day. For this purpose, they transmit the schedules of all their own power plants to the TSO, in whose control area the respective power plants are located, until a certain time. In Germany, the deadline for submitting day-ahead schedules is 2:30 p.m. on D-1. The sum of all production (and consumption) schedules in all control areas is the economic dispatch in the entire German bidding zone for the following day. Germany is the only country in the EU with four control areas and in consequence with four different responsible TSOs.

While in the case of fluctuating renewable energies such as photovoltaics and wind energy, the schedules for the following day are solely based on weather forecasts and plant availability, controllable RES such as biomass and partly hydropower are able to operate in a dispatchable mode. E.g. in the case of biogas plants, dispatch decisions are made by using expected high-price phases ("peaks") on the electricity exchange as a basis for the operation planning the day-ahead.

Once the TSOs have received all the schedules for the day-ahead process at the specified time, they are able to draw up a total overview of the expected feed-in and consumption in their control areas and carry out a load flow calculation. It is determined which parts of the power grid, such as line sections or coupling transformers in the transmission grid, would be stressed by the scheduled dispatch. In order to minimize the number of short-term interventions in the running operation of conventional and renewable power plants and to ensure grid stability on the following day, the result of the load flow calculation is already used by the TSOs the day before to instruct power plant operators to change their scheduled electricity production. This enables predicted congestions to be avoided. Furthermore, it can happen during the operation day, that forecasted generation and load differ significantly from the scheduled values; in case of renewable generation, this happens mostly due to inaccuracies in weather forecast. This leads to imbalances between generation and consumption. These imbalances are handled in the first step with power and energy purchased on the balance energy markets. If this is not sufficient, additional national and even international redispatch measures are taken. This instruction to shift planned production day ahead or even in the running day is called “redispatch”.

It turns out nowadays more and more often the regular balance energy markets are no longer capable of reliably compensating the fluctuations caused by volatile RES generation. An increasing number of regulatory interventions in the operation of the power plants is necessary. The remuneration is not market based but is calculated individually on a cost-based normative settlement procedure that incorporates many different parameters. Basically, a power plant affected by redispatch measures has to be financially compensated as if it could have produced power as previously planned. The costs of redispatch are socialized via the grid tariffs in Germany. Under the “old” regime it was amounted to 41.63 M€ in 2011, 164.79 M€ in 2012 and rose to 411.9 M€ in 2015. In 2016 the expenditure amounted to around 505 M€, and in 2017 already about 1 B€ with trend continues to rise.

Redispatch has so far only been carried out in Germany for dispatchable plants with a nominal installed capacity of more than 50 MW. The new regulation in Germany reduces the nominal capacity to a system size of 100 kW. With the new Redispatch 2.0 process coming into force, distribution system operators (DSOs) thus become a new cornerstone of re-dispatching. Like TSOs, they must model and forecast their networks in terms of expected load and generation, including VRE-systems, CHP plants and storage facilities. This requires adjustments in control systems – in particular for calculation of generation and load flow forecasts in 15-minute resolution and extensive network security calculations. Redispatch 2.0 brings new processes and commitments for almost all market players in Germany, which require intensive preparation in a tight timeframe until 1st October 2021.

The aim of the new regulation is to find a cost-optimal overall solution for each network problem, while respecting network reliability and security of supply. For this, it is necessary to be able to assess and weigh up the effectiveness and costs of possible measures in advance, i.e. based on forecasts and load flow analysis. Grid operators then define appropriate redispatch measures at the various voltage levels in a close coordination process in order to avoid identifiable grid congestions.

1.2.2.2 DSOs specially affected

So far, the forward-looking redispatch based on power plant schedules was a task only for TSOs. However, with the introduction of Redispatch 2.0, DSOs will also be involved in the process. In particular, the costs for data acquisition, forecasting, modelling of the networks and parameterization of the network elements for these calculations will be high. In addition to the management task, the DSO also assumes responsibility for data exchange as well as financial compensation with the Balance Responsibility Parties (BRPs).

The regulations therefore potentially affect not only all 890 DSOs in Germany, but also all power plant operators, BRPs and direct marketers of plants above 100 kW, who must provide, among other things, the necessary data and communication channel for control commands. Table 2 indicates where the outcomes of FLEXGRID may help the introduction of the national Redispatch 2.0 procedures.

Table 2: Redispatch 2.0 tasks and contribution by FLEXGRID

New tasks for DSOs in Germany	FLEXGRID H2020
Daily generation forecasts of generation units above 100kW in DSO’s grid areas	During project lifetime
Daily load forecasts for the whole grid. If multiple grids are supplied which are not directly interconnected with provision of multiple load forecasts	During project lifetime
Daily load flow analysis based on full electrical grid model, generation and load forecasts to detect congestions	Post-project
Daily transmission of forecasts and expected congestions in a given format via national data platform	Post-project
Expectation and execution of redispatch requests from the upper voltage levels	During project lifetime
Calculation of financial losses for affected generation units and financial settlement	Post-project
Maintenance of communication links not only to own generation units but to all above 100kW (mostly owned by private companies	Post-project

<u>FLEXGRID H2020 contribution</u>: In cooperation with UCY and AIT, bnNETZE will evaluate different forecasting approaches. With additional research completed by the bnNETZE team, it will be analyzed which methods of forecasting algorithms are best suitable for flexibility marketing purposes and how accuracy could be further improved. If a satisfactory accuracy can be reached, the application of these algorithms is intended within bnNETZE for 'Peak Shaving' and in the context of the national 'Redispatch 2.0' concept, which shall be implemented by October 2021.

1.2.3 Transposition of the Clean Energy Act into national law

In addition, the national legislative process for the implementation of the EU Clean Energy Act is currently under way in Germany. It requires transmission and distribution system operators to procure "non-frequency related system services including congestion management" in a transparent, non-discriminatory, and market-based way. The regulatory authority may allow exemptions from market-based procurement if it is not economically efficient. If it is economically efficient, the regulatory authority shall determine the requirements of the procurement system or approve them on the basis of drafts provided by the grid operators.

Such an obligation did not exist in national law in the past. The system services in question have so far been provided mainly through technical connection rules in grid connection contracts, bilateral contracts with individual power plant operators and from grid operators' own resources.

The aim of the new rules is to open up the provision of system services to all possible market participants by introducing transparent, non-discriminatory, and market-based procedures. So it is intended to increase potential for technical provision and economic efficiency. Safe, reliable, and efficient grid operation must always be maintained.

"Non-frequency related system services" as proposed by the EU directive are the following services used by transmission and distribution system operators:

1. Voltage control,
2. Feed in of dynamic reactive power,
3. Inertia of local grid stability,
4. Fault current
5. Black start capability
6. Islanding operation

A study was carried out by [20] on behalf of the Federal Ministry of Economics in order to determine, which of these services must be classified as economically inefficient, so that the regulatory authority can allow exemptions from market-based procurement. The results of the study were presented on 18th of August 2020.[21] As a result, the economic efficiency of market procurement for four of the services were excluded – based on an analysis horizon from 2021 to 2025:

2. Feed in of dynamic reactive power
3. Inertia of local grid stability
4. Fault current
6. Islanding operation

Only for two services the economic potential of market procurement could be stated

[20] ef.Ruhr GmbH, Re-xpertise; Neon Neue Energieökonomik GmbH; House of Energy Markets and Finance Universität Duisburg-Essen; Becker Büttner Held PartGmbB

[21] 'Effizienzprüfung marktgestützter Beschaffung von nicht-frequenzgebundenen Systemdienstleistungen (NF-SDL)', Report within the project "SDL-Zukunft", 18.08.2020

1. Voltage control
5. Black start capability

According to the draft of the bill, therefore, only these services will be subject to market-based procurement. All others are excluded to start with.

> **FLEXGRID H2020 contribution**: One main purpose of FLEXGRID is to build up a platform for running regional markets. This concept could be used also for voltage control and black start capability, first on TSO level, and later on DSO level.

1.2.3.1 Termination of national feed in system for renewables

At the end of 2020 regulated feed-in tariffs ended for the first VRE installations in Germany. This was the first dropouts to take place, and thousands more are expected in the following years. The affected plant owners have to decide now whether or not to shut down their installations, to look for a direct marketer, to use as much energy as possible in their own premises, or to accept the low market-oriented price given by the DSO for a transition period until the end of 2027. This option is only available for PV-installations below 100 kW.

There is a potential to take over PV installations with 100kW or more as well as wind turbines and provide the owners with a solution that is both beneficial for them and is financially opportunistic for an energy service provider or a flexibility provider working as direct marketers. Marketing flexibility on organized power exchanges is the first choice for many plant owners. There are multiple established platforms that provides all market participants with equal opportunities to market their flexibility and to maximize revenues by capitalizing on potential of volatile prices electricity markets.

FLEXGRID H2020 contribution: bnNETZE will carry out within the FLEXGRID project an economical simulation for dedicated PV-installations dropping out of the national feed in tariff system. For real installations, we will simulate the possible revenues by marketing the produced energy on EPEX in the spot and intraday market taking into account the necessary costs for enhancing the technical installations and metering devices on the plant site. Starting with these singular systems we plan to generalize the outcome to stipulate general statements regarding the potential of added value due to flexibility marketing.

A pivotal aspect for energy marketing from the perspective of an energy service provider or a flexibility provider are forecasting methods. Renewable power sources are an imperative aspect of Germany's electricity market, so it is important to understand how electricity generation from wind turbines and photovoltaics, along with weather and consumption data, impact future electricity prices.

For flexibility marketing, spot trading as well as intraday trading are especially interesting. Spot trading takes place one day ahead for a single or all 24 hours of the following day. Intraday trading is executed in the running day until one hour ahead of the execution time. The resolution here is quarter hour. In addition to PV Forecasting, UCY will also be the associated partner for Price Forecasting. bnNETZE will provide historic energy prices from spot market as well as intraday trading originating from EPEX, which is the relevant energy trading authority for Germany, France, Austria, and Switzerland.

The chosen forecasting methods are not novel; however, they are a prerequisite in terms of the much bigger picture of flexibility marketing. Forecasting the electricity market price is important because electricity demand is highly dynamic depending on the time of year, weather, and human activity; therefore, it is more susceptible to price volatility. Extreme peaks or dips of energy usage are extremely interesting from a flexibility market perspective. If the algorithms are trained well enough, they could predict and capture the intervals with extreme highs and lows of energy price. Thus, a flexibility operator would be able to purchase and store energy when it is selling at a negative price and sell it later for double the profit when the price increases again.

With these preliminary studies the performance of the FLEXGRID ATP platform can be improved.

1.2.4 Policy and Regulatory Developments in Croatia

The Electricity Market Act [22] regulates rules and measures for safe and reliable production, transmission, distribution, and supply of electricity. The same Act also regulates the trading of electricity and organization of the electricity market as part of the internal electricity market of the European Union.

The Distributed Energy Resolution (DER) flexibility regulations provided in this overview include:

- Definition of DER and aggregators in main laws and secondary legislation,
- DER flexibility provision to TSO,
- DER flexibility provision to DSO.

The creation of smart networks, in addition to technical and scientific challenges, will be primarily a political, economic, and regulatory issue. According to Article 10 of the Electricity Market Act, which refers to the production of electricity, the electricity producer, according to market principles, is obliged to offer ancillary services to the transmission and distribution system operators, in accordance with the technical capabilities and transmission and distribution system rules. The Electricity Market Act still does not define neither aggregators nor DERs in any way but secondary legislation consisting of the POUEES[23] and POTEE[24] requirements for the secure implementation of the EB GL Regulation[25], and the Clean Energy Package directives (especially 2019/944).

The POUEES & POTEE rules define and specify requirements from Article 18 of the EB GL Regulation. RES units can provide flexibility to the TSO or DSO if they have successfully completed the prequalification process and demonstrated their technical ability to provide balancing services. Technical ability of end users for provision of balancing services is proven by the pre-qualification process. As stated in POUEES, the aggregator is a legal entity that brings together various technical units in a group with the aim of providing the balancing services to the balancing capacity or balancing energy market. Balancing services can be provided by technical units of different technologies at the same time. The technical units may be connected to the transmission and/or distribution network. An aggregator is considered as an independent aggregator if it has no contractual relation with the balancing responsible party of the end user whose assets it aggregates. Distributed energy resources and aggregators are well defined for the provision of balancing services to HOPS (the Croatian TSO) which already procures services from larger consumers that engage in mFRR auctions and provision schemes. New version of Electricity Market Act which should specify flexibility issues in accordance with all temporally valid EU legislation is expected to get in to force by the end of 2021.

Even without a proper legal background, the biggest shift is made by the TSO which created a transparent market for mFRR trading to which DERs and aggregators can also apply on the same level playing field. According to POEES, balancing service providers can be all individual network users and aggregators who have signed Balancing Service Agreement with Transmission System Operator (for each service separately). Balancing Service Agreement can be signed by all individual network users and aggregators who have successfully completed prequalification process and demonstrated technical ability to provide balancing services. Technical ability of end users for provision of balancing services has been proven by pre-qualification process.

An aggregator is defined as legal person connecting different technical facilities in a group with the aim of providing a balancing service on balancing capacity and balancing energy market. Balancing services can concurrently be provided by technical units having different technologies. Facilities can

[22] Electricity Market Act, Croatian Official Gazette: Zagreb, Croatia, 2015.
[23] Electricity Balancing Rules (HOPS 11/2019)
[24] Rules on Electricity Market Organization, Croatian Official Gazette 107/19 07/11/2019
[25] EU Commission Regulation 2017/2195 of 23 November 2017 establishing a Guideline on Electricity Balancing (Text with EEA relevance), EU Official Gazette L 312/6 of 28/11/2017

be connected to transmission and/or distribution grid. An aggregator shall be deemed independent if not connected with a supplier and/or a buyer from the system user in the system it aggregates, which means that aggregators do not have to be balancing responsible party and aggregators can offer assets from different balance responsible parties within the same balancing capacity and/or energy bid.

In practice, aggregators are not implemented yet in the balancing market; only larger DERs already take part on the balancing market. HOPS is planning to expand it on other balancing services as well. The provision of flexibility to DSOs, both for long-term planning and short-term operation needs, is allowed but insufficiently defined. The procedures must be publicly available and unambiguously stated, and the ICT platforms must be created to ease the DERs flexibility provision. This should be coordinated and encouraged by the new law. In general, the Croatian legislation still must define a number of terms and rules that would enable the efficient use of flexibility at the distribution level.

1.2.5 Regulatory developments in Norway

The energy act ("Energiloven") regulates the production, transformation, transmission, commerce, distribution, and consumption of electrical energy in Norway.[26] The regulation concerning the grid and energy market is an instrument to provide an efficient electricity market.[27] The politically independent Norwegian regulator is the regulating authority for energy "Reguleringsmyndigheten for energi" (RME).

RME considers both production and consumption when speaking of flexibility. Flexibility for RME covers everything from connection of new units to tariffs to market-based solutions. Connection of production with conditions[28] is already introduced and a hearing is held with respect to connection of consumption with conditions[29]. This allows DSOs to connect for example new production with limitations in the LV grid without upgrading the grid as opposed to a connection charge. RME has been contributing to CEER[30] focusing on DSO procurement of flexibility.

RME's strategy for the energy transition is to allow innovative solution suppliers to apply for derogations from the regulatory framework. In the RME pilots and demonstration projects[31] RME has gathered the most relevant rules for stakeholders wanting to test or demonstrate innovative projects. DSOs can get their cost from doing innovation projects covered through economic regulation, this is an arrangement to motivate DSOs to invest more in research and innovation. After a hearing in 2019 it was decided that DSOs can apply to increase research expenditures exceeding the regular 0,3 % of return basis[32].

RME has, after a request from the Ministry of Petroleum and Energy (OED), reviewed the coordinated operation of the electricity grid[33]. The digitization process is highlighted as a key enabler to access

[26] OED, "Energiloven," 2021. [Online]. Available: https://lovdata.no/dokument/NL/lov/1990-06-29-50
[27] OED, "NEM," 2021. [Online]. Available: https://lovdata.no/dokument/SF/forskrift/2019-10-24-1413/KAPITTEL_3#%C2%A73-3.
[28] NVE-RME, "Tilknytning av produksjon med vilkår," 2019. [Online]. Available: https://www.nve.no/reguleringsmyndigheten/nettjenester/nettilknytning/tilknytningsplikt/tilknytning-av-produksjon-med-vilkar/.
[29] O. Flataker, "Tilknytning av forbruk," NVE RME, 2020.
[30] CEER, "CEER Paper on DSO Procedures of Procurement of Flexibility," 2020.
[31] NVE, "Pilot- og demonstrasjonsprosjekter," 2020. [Online]. Available: https://www.nve.no/reguleringsmyndigheten/pilot-og-demonstrasjonsprosjekter/.
[32] NVE-RME, "Oppsummeringsrapport: Endringer i forskrift om kontroll av nettvirksomhet," 2019.
[33] NVE-RME, "Driftskoordinering i kraftsystemet," 2020.

flexible resources in the LV and MV networks. As a result, RME proposes to develop a digitization plan for all DSOs; this work is yet to be completed.

A RME report on incentives for consuming participants is ongoing, this goal is to enable the DSOs to make cost efficient decisions. The work includes an investigation of standard methods to assess the value of flexibility compared to traditional grid reinforcement for DSOs. This work would complement the already existing[34] economic regulation, which encourages DSOs to look for alternatives to grid investments.

In February 2020 the Nordic regulators, NordREG, published a "Nordic Regulatory Framework for Independent Aggregation"[35]. NordREG presents their position on how to facilitate fair and efficient execution of independent aggregation in the Nordic electricity system. NordREGs publication covers general market access for independent aggregators, direct financial responsibilities for energy imbalances caused, compensation for unmatched positions caused by independent aggregators, and the evaluation of flexibility according to Clean Energy Package (CEP) requirements. Six legislative changes are recommended by NordREG to ministries and legislators. This is yet to be addressed by OED.

Flexibility is currently offered in the balancing and reserve markets, which are operated by Statnett (the Norwegian TSO), and the need for more flexible resources in mFRR is assessed by Statnett's eFleks project. A report presenting the results from the eFleks pilot, which ended in October 2020, highlights the results from reducing capacity requirements in balancing and reserve markets. The reduced capacity requirements allow aggregated demand sources to participate in the reserve and balancing markets[36].

All metering production and consumption values are stored in a datahub called Elhub. Elhub is a centralized IT-system aiming to improve the efficiency of and support power market processes. Third parties can, via a web-based solution, access end-user metering data. A contract between the end user and the third party must be signed for the third party to access the data. This is to ensure end-user privacy[37]. RME has no separate regulations concerning flexibility.

[34] NVE, "Economic regulation," 2020. [Online]. Available: https://www.nve.no/norwegian-energy-regulatory-authority/economic-regulation/.

[35] NordREG, "Nordic Regulatory Framework for Independent Aggregation," 2020.

[36] Statnett et. al, "Distributed balancing of the power grid," 2021.

[37] Elhub, "Personvern i Elhub," [Online]. Available: https://elhub.no/personvern-og-sikkerhet/personvern-i-elhub/. [Accessed 2021].

2 FLEXGRID business ecosystem and business case analysis

The work presented in deliverable D8.1 provided an initial glance at the business ecosystem that is considered in the FLEXGRID project. To get a better understanding of the interests and drivers of the different commercial actors and their innovations in this business ecosystem , business case analyses are conducted. These provide a refined picture of the FLEXGRID business ecosystem and take a deeper look at the relevant business objectives and business cases for each stakeholder.

A business case can be defined as the "justification for undertaking a project, programme or portfolio." It is what a decision maker evaluates such undertaking, and considers the cost, benefit, and risk as grounds for making a decision.[38]

2.1 Business case analysis methodology

The first input to the busines case analysis is the stakeholder definition and analysis presented in deliverable D2.1. It provides the common nomenclature for the stakeholders considered by the project and is based on the Harmonized Electricity Market Role Model (HEM-RM)[39].

The business case analysis performed in WP8 investigates the business motivations (objectives) and business cases for each of the stakeholders in the ecosystem. This process is complementary to the work presented in deliverable D2.2: The overall FLEXGRID architecture design, high-level model, and system specifications. WP2 uses the Smart Grid Architecture Model (SGAM) framework[40] to specify the FLEXGRID architecture.

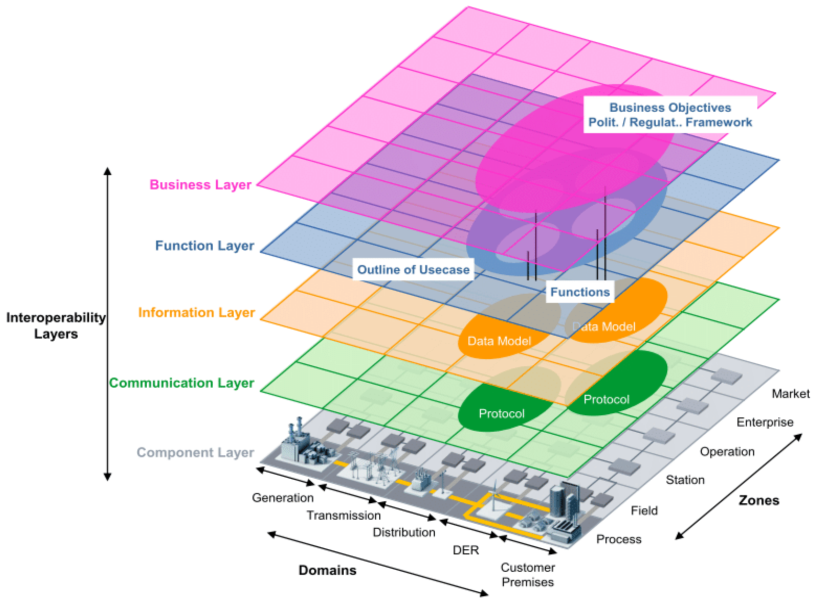

Figure 1: The SGAM Framework.[41]

[38] Association for Project Management, 'APM Body of Knowledge', 7th edition, ISBN: 978-1-903494-82-0 (2019)
[39] ENTSO-E, EFET, ebIX: 'The Harmonised Electricity Market Role Model' (Version 2020-01), 2020, available at: https://www.entsoe.eu/digital/cim/role-models/
[40] CEN-CENELEC-ETSI Smart Grid Coordination Group. 'Smart Grid Reference Architecture.' (Version 3.0), 2012

[41] https://sgam-toolbox.org/downloads/Introduction-to-SGAM-Toolbox.pdf

The SGAM framework consists of five interoperable layers that describe the architecture across the span of different domains and zones, as shown in Figure 1. Within this model, the function layer refers to the High-Level Use Cases (HLUCs) and their corresponding Use Case Scenarios (UCS). These are described in deliverable D2.1. The three lower layers (information, communication, and component) are used to describe the software architecture, as presented in deliverable D2.2. The business case analysis therefore sits on top of the WP2 analysis, and describes the information pertaining to the SGAM business layer.

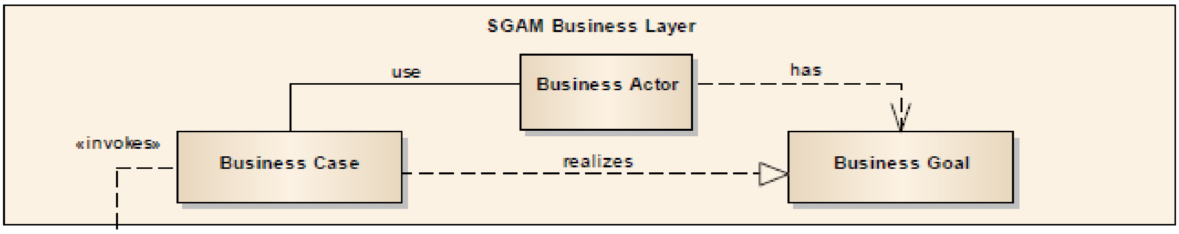

Figure 2: The SGAM Business Layer Metamodel.[42]

As illustrated in Figure 2, the business layer describes each of the business actors, each having their business goals, and business cases are a means to realise these goals. The FLEXGRID business case analysis seeks to illustrate this information across the whole business ecosystem.

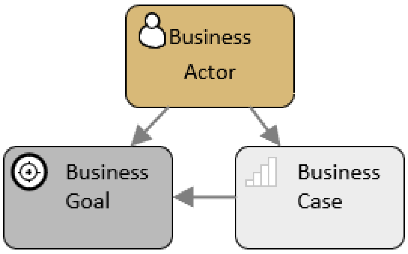

Figure 3: FLEXGRID business layer metamodel.

The use case analysis described in deliverable D2.1 provides a strong starting point, describing the business motivation of the different actors in each of the FLEXGRID use cases. These were formulated on a project concept-level. This conceptual information is refined and validated in this deliverable using the process illustrated below.

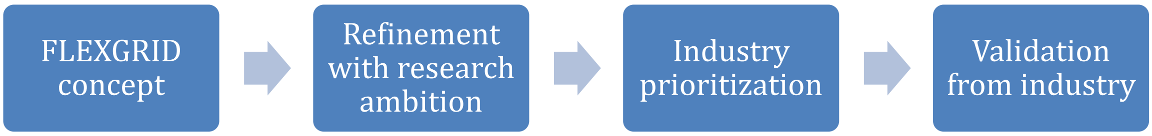

Figure 4: Business case analysis sequence.

First, the business cases examined in FLEXGRID are refined considering the research work carried out in work packages 3, 4 and 5. These activities are pursued to advance the scientific state of the art in areas that are expected to be highly relevant for the European energy domain in a medium to long-term timescale. This context is described in deliverables D3.1, D4.1 and D5.1.

[42] https://sgam-toolbox.org/downloads/Introduction-to-SGAM-Toolbox.pdf

2.2 Refined FLEXGRID business ecosystem

The business case analysis methodology elaborated in the previous section provides a refined description of the FLEXGRID business ecosystem described in deliverable D8.1. This revised ecosystem gives further insights into the different relevant actors, their key business goals, and the business cases that they can pursue to achieve these goals. The business actors considered in FLEXGRID are originally defined in D2.1. Market Operators (MO) and Flexibility Market Operators (FMO) operate market platforms where different actors can exchange energy and capacity products. The FMO is specifically focused on supporting the trade of flexibility products. In this context, we define flexibility as "the modification of generation injection and/or consumption patterns in response to an external signal (price signal or activation) in order to provide a service within the energy system".[43]

The supply of flexibility to the market is performed by different types of FlexSupplier actors, defined in D2.1 as Energy Service Providers (ESPs): a "*profit-oriented company, which may make contractual arrangements with various types of flexibility assets (e.g. DSM, RES, storage)*". This is a generic term which could be embraced by different types of stakeholders in today's electricity sector. In order to accurately describe this role in concrete business models, it is important to characterise ESPs by specific business actors which are generally recognised in the electricity domain today. The refined business ecosystem presented here therefore refers to ESPs specifically as aggregators, suppliers (retailers) or ESCOs, as described below.

Aggregator
An aggregator is a market participant that aggregates flexibility from a portfolio consisting of a range of prosumer assets. The aggregator uses this flexibility to sell services to different stakeholders (e.g., BRPs, DSOs, TSOs).

Supplier (Retailer)
Aggregators can have the role of supplier (retailer), in which case it also sells the electricity to the end-users and in some cases, it could also act as a BRP for the aggregated assets.

Independent aggregator
Independent aggregators do not have the retailer role and are not BRP for the aggregated assets.

Energy Service Company (ESCO)
ESCOs offer "energy-related services to the Party Connected to Grid, but [they are] not directly active in the energy value chain or the physical infrastructure itself"[44]. This is in line with FLEXGRID's definition of an ESP as stated above. However, an ESCO is different from aggregators because they do not sell services to FlexBuyers themselves. An the ESCO would only have a contract with the owner of a FlexAsset, where the ESCO provides energy management services that aim to improve the profit that the FlexAsset owner can make from their assets.

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[43] EURELECTRIC, 'Flexibility and Aggregation, Requirements for their interaction in the market' (2014), available at https://www.usef.energy/app/uploads/2016/12/EURELECTRIC-Flexibility-and-Aggregation-jan-2014.pdf

[44] ENTSO-E, EFET, ebIX: 'The Harmonised Electricity Market Role Model' (Version 2020-01), 2020, available at: https://www.entsoe.eu/digital/cim/role-models/

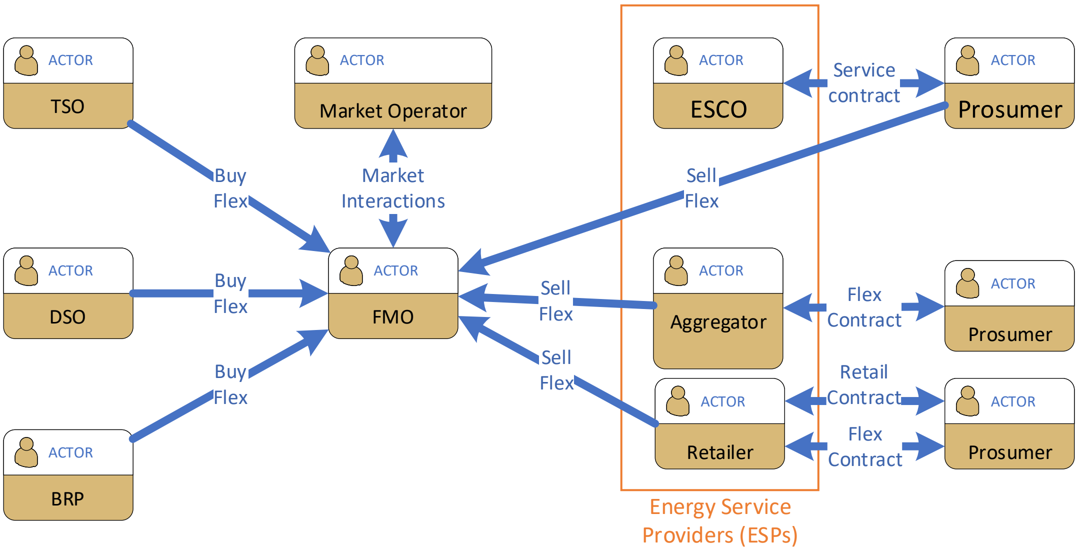

Figure 5: Actors considered in the FLEXGRID business ecosystem.

The FLEXGRID business ecosystem considers a wide range of the electricity value chain, both across market and grid domains, as shown in Figure 5.

Furthermore, the business case analysis considers 18 use cases involving several actors in this ecosystem, where each actor may have multiple business goals (BGs – what they are trying to achieve) and business cases (BCs – how the business goal can be achieved). More specifically, a business case is the justification of the way the business goal can be achieved.[45] This analysis provides a comprehensive overview of the business ecosystem and carries a lot of information about the context of different stakeholders. For simpler understanding, it is useful to group the results of the analysis according to the high-level use cases:

Table 3: FLEXGRID high-level use cases

HLUC_01: FLEXGRID ATP offers advanced market clearing services to the FMO (Interaction between markets'- and networks' operation)
HLUC_02: FLEXGRID ATP offers advanced flexibility supply services to Energy Service Providers
HLUC_03: FLEXGRID ATP offers advanced flexibility demand services to system operators
HLUC_04: FLEXGRID ATP offers automated flexibility aggregation services to ESPs/aggregators (interaction with end users)

[45] https://www.apm.org.uk/resources/what-is-project-management/what-is-a-business-case/

2.3 Business case analysis related to HLUC_01: FLEXGRID Automated Trading Platform offers advanced market clearing services to the Flexibility Market Operator

The main focus of HLUC_01 is the efficient operation of the flexibility market by the FMO. For this reason, the business cases analysis presented in Figure 6 is centred around the FMO role.

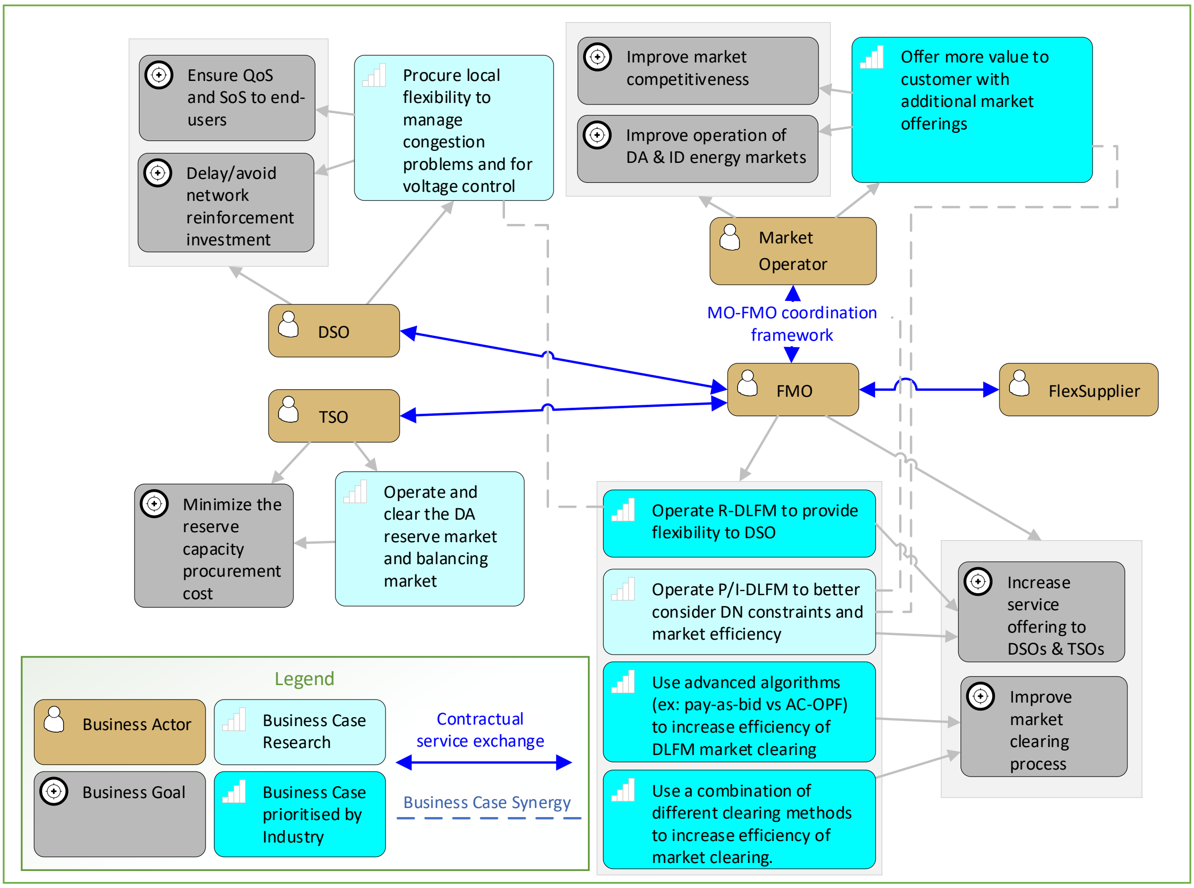

Figure 6: Business case analysis of HLUC_01.

2.3.1 FMO business cases in HLUC_01

The FMO has two main business goals:

Table 4: FMO Business Goals in HLUC01

To increase its service offering to DSOs and TSOs
To improve its market clearing process

To achieve an improved market clearing process, the following business cases are studied:

Table 5: FMO Business Cases in HLUC01

Industry case	**Operate a reactive DLFM (R-DLFM) to provide flexibility to the DSO.**
FLEXGRID has proposed different market interaction architectures for the flexibility market (presented in Deliverables D2.1 and further elaborated in D5.1)[46] that could be deployed in different business cases. First the FMO can operate a reactive DLFM (R-DLFM). This is a flexibility market structure that is compatible with most European electricity market designs and can provide	

[46] Deliverables D2.1, D5.1

<table>
<tr><td colspan="2">DSOs with congestion management, balancing and voltage control services. The value of this DLFM type lies in its compatibility with the current regulatory framework. NODES platform currently has this feature and as per FLEXGRID survey, respondents find this business case very useful for their current operations.</td></tr>
<tr><td>Research case</td><td>Operate a proactive or interactive DLFM (P- or I-DLFM).</td></tr>
<tr><td colspan="2">These market architectures could be utilized by FMOs to increase the social welfare in their markets. Compared to the R-DLFM, these architectures could potentially provide flexibility to DSOs at the lowest available cost, while improving the benefits to flexibility providers. However, these market architectures are more complicated to integrate into the existing regulatory framework and FLEXGRID considers them less mature than the R-DLFM. Such X-DLFM architectures should be agreed with the Market Operator and the regulator. FMO cannot decide on the x-DLFM architecture alone but in close cooperation with the Market Operator, regulator, and the system operators (TSOs / DSOs). It is not the priority business case considered in WP8 because the objective here is to provide insight into sustainable business models on a shorter time scale.[47]</td></tr>
<tr><td>Industry case</td><td>Use advanced algorithms to increase the efficiency of market clearing</td></tr>
<tr><td colspan="2">This consists of auction-based (i.e. pay-as-clear) and continuous price matching (i.e. pay-as-bid) algorithms that a FMO could use to determine the optimal dispatch of generators and loads in an electrical network, considering the network's physical limitations. The objective function of these algorithms proposed by FLEXGRID can be adjusted based on their intended uses, namely:
▪ Maximization of social welfare,
▪ Minimization of voltage deviations,
▪ Minimization of congestions,
▪ Empty objective function to evaluate the feasibility of a given dispatch.
The trade-offs of these algorithms, however, lies in their complexity and increased computational cost. This is detailed in deliverable D5.1.[48] According to FLEXGRID survey, all the participants responded this feature of considering auction-based vs pay-as-bid for market clearing as very useful for the optimal operation of a flexibility marketplace.</td></tr>
<tr><td>Industry case</td><td>Use a combination of market clearing methods to improve market clearing</td></tr>
<tr><td colspan="2">Depending on the characteristics of a given distributed local flexibility market (DLFM), it might be interesting to use an AC-OPF algorithm while pay-as-bid might be sufficient in other cases. So a FMO might want to adopt a hybrid approach in their platform that is modular and adaptable to different local conditions. FLEXGRID will develop, test, and validate several types of network aware market clearing algorithms at low TRL level in order to identify the pros & cons of each algorithm. However, the respondents of FLEXGRID survey mentioned the particular case of a flexibility market platform facilitating the clearing and settlement upon dispatch of flexible assets not very useful for current operations of a flexibility marketplace. This feedback by the commercial actors will be taken into account in further investigation of this business case.</td></tr>
</table>

2.3.2 DSO business case in HLUC_01

In HLUC_01, the DSOs' main goals are twofold:

Table 6: DSO Business Goals in HLUC01

To ensure quality of supply (QoS) and security of supply (SoS) to end-users
To delay or avoid investment in network reinforcement infrastructure

[47] Deliverable D5.1

[48] D5.1

Table 7: DSO Business Cases in HLUC01

Research case	Procure local flexibility to manage congestion problems and for voltage control.
The business case for DSOs is to achieve both business goals by procuring local flexibility to manage congestion problems and for voltage control. This could be done in a market like the DLFM operated by the FMO. While DSOs could establish and maintain bilateral contracts with flexibility providers directly, a market mechanism has the promise of finding the optimal value for buying flexibility. This also centralises the contract management with multiple flexibility providers which is expected to become very extensive in a scenario of highly decentralised RES production and a large amount of demand-side flexibility. In the FLEXGRID market survey, the DSO responded that currently they do not face congestion constraints or voltage issues regularly in their network but due to increase in distributed RES generation they foresee an increase in congestion and voltage issues in near future. Currently, the network reinforcements are used to deal with any congestion if occurred and in future DSO showed interest in investing in Reactive Power compensation for supporting their network.	

2.3.3 TSO business case in HLUC_01

Table 8: TSO Business Goals in HLUC01

To minimise the cost to procure reserve capacity

Table 9: TSO Business Cases in HLUC01

Research case	Operate the day-ahead (DA) reserve and balancing market
The TSOs' business goal in HLUC_01 is to minimise the cost to procure reserve capacity. To achieve this, it operates the day-ahead (DA) reserve market as well as the balancing market. Via FLEXGRID ATP, the TSO will also be able to have access to small-scale DERs and FlexAssets that reside at the distribution network side. As detailed in deliverable D5.1[49] these are mostly compatible with the R-DLFM as it was designed to fit into the existing market regulatory structure.	

2.3.4 Market Operator business case in HLUC_01

The involvement of the market operator in HLUC_01 is dependent on the architecture of the DLFM and how this flexibility market fits in the market clearing sequence. This poses a number of research questions that are investigated in WP5. On a business level, market operators are driven by the following goals:

Table 10: MO Business Goals in HLUC01

To improve the market competitiveness
To improve the operation of their markets

Table 11: MO Business Cases in HLUC01

Industry case	Offer more value to customer with additional market offerings
If the flexibility market is cleared after the MOs' energy markets, as is the case in the R-DLFM, there is little interaction between the different markets (i.e., they are sequentially cleared at a predetermined time). The business case for the MO depends on the organisational structure of the FMO and the MO. One possibility is that the FMO role is undertaken by a company that is completely independent from the MO. It is however also possible that the MO carries out the FMO role and proposes a flexibility market in addition to its existing energy markets. If we consider a proactive (P-DLFM) or even interactive (I-DLFM), then there would be the need for a MO-FMO framework coordination. This could strengthen the business case of a MO looking to	

[49] Deliverable D5.1

provide a flexibility market as a new product offering to their customers. The MO could for example include reactive power as a product in their order books. There are many relevant research questions in the different architectures, but the business modelling work in WP8 will assume the flexibility market is designed as a R-DLFM. According to the FLEXGRID survey, a flexibility marketplace enabling an increasing clearing volume for DA, Intra-day and other existing electricity market initiatives is considered useful as part of this business case.

2.4 Business case analysis related to HLUC_02: FLEXGRID Automated Trading Platform offers advanced flexibility supply management services to Energy Service Providers

HLUC_02 delves into the provision of flexibility services from the perspective of ESPs, and how such FlexSuppliers can carry out new strategies to improve their operations to achieve increased profitability. An overview of this HLUC is provided in the following figure.

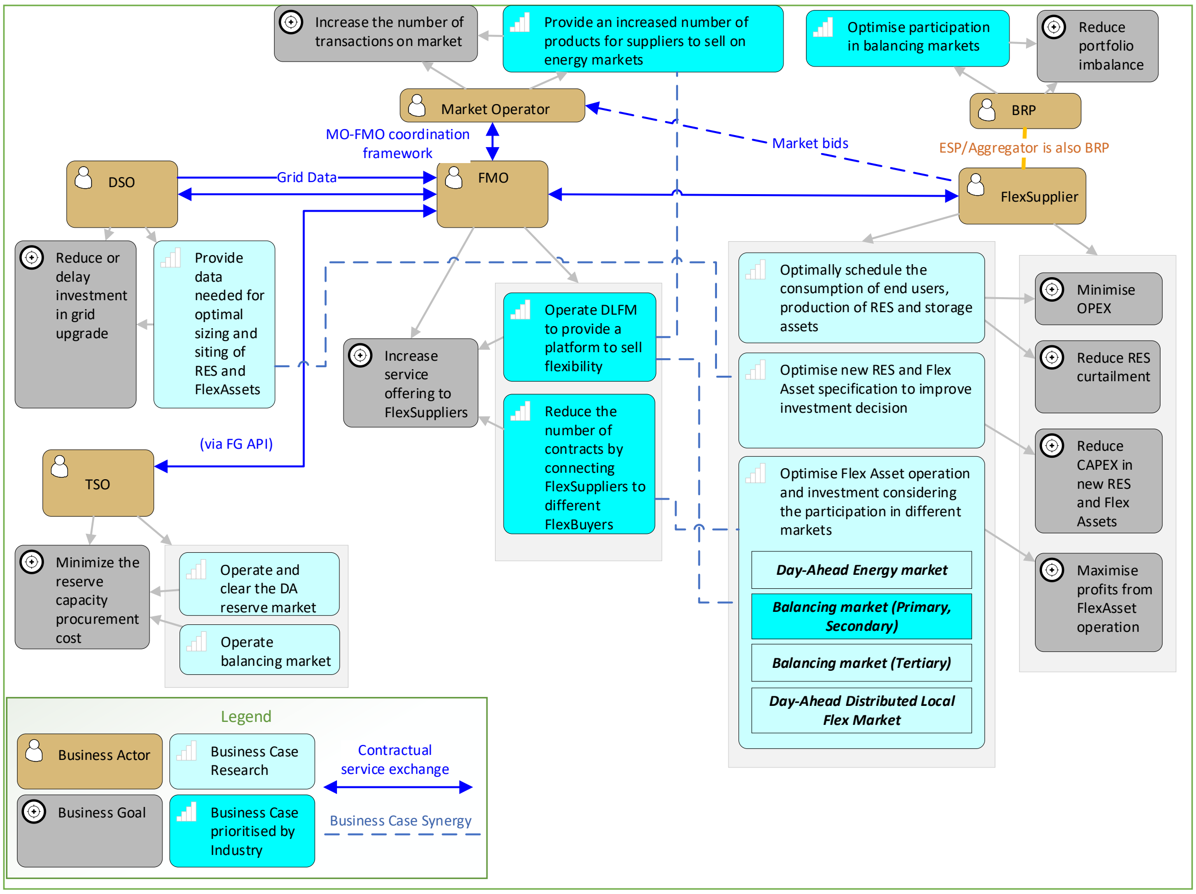

Figure 7: Business case analysis of HLUC_02.

2.4.1 FlexSupplier business cases in HLUC_02

As stated previously, flexibility can be supplied to the market by different types of FlexSuppliers. HLUC_02 specifically considers FlexSuppliers whose business is to operate- and invest in FlexAssets to profit from selling flexibility in different markets. The following business goals are considered here:

Table 12: FlexSupplier Business Goals in HLUC02

To maximise the profit gained from selling flexibility
The FlexSupplier is assumed to have a business model where its revenues are directly linked to the value at which flexibility from an asset is sold to a FlexBuyer.
To minimise balancing costs
In the case that the FlexSupplier is a retailer, and is also BRP for the FlexAssets, balancing costs represent an operational expenditure (OPEX).
To reduce CAPEX in new RES and FlexAsset investments
This goal is relevant for FlexSuppliers looking to either invest in new FlexAssets directly. It could also be the goal of an ESCO who has a business model where it receives a payment for helping a prosumer reduce CAPEX in new FlexAssets.
To reduce RES curtailment
This goal is important for FlexSuppliers who operate RES asset, where generation curtailment translates to a loss of income.

To achieve these goals, the FlexSuppliers consider the following business cases:

Table 13: FlexSupplier Business Cases in HLUC02

Research case	**Optimally schedule the consumption and production of Flex Assets to reduce the balancing costs**
As stated above, an ESP could act as BRP in the balancing market, and an imbalance in its portfolio could incur imbalance fees (i.e., OPEX). Therefore, the ability to improve the scheduling of assets (e.g. prosumer assets, RES curtailment, storage) would directly increase the ESP's profits. In the FLEXGRID survey, 83% of the respondents showed interest in investigating in new algorithms and tools to better scheduling their Flex Assets. However, 66% of the respondents declared this as not something new in the energy sector and therefore would need more clear benefits compared to existing algorithms and tools.	
Research case	**Improve the investment decision in new RES and Flex Assets**
There are many factors that ESPs should be taking into consideration when investing in new RES and Flex Assets. This includes asset sizing, siting, specifications (e.g. battery chemistry), possibility of market participation, demand response contracts, etc. The ability to find the optimal specification and location for new assets can reduce an ESP's CAPEX in new asset investments. 50% of the respondents showed interest in further investigating in this area and 66% declared this as not something new in the energy sector. For the business case to get commercial importance, it will be further investigated with cost-benefit analysis in the FLEXGRID project.	
Research case	**Optimise the operation of Flex Assets considering their participation in different markets**
This optimisation considers the different markets available in order to increase the profit from this market participation. This can be done statically based on historical prices in order to improve investment decisions, or dynamically to improve operational profit margins. The markets considered in this business case include the: ▪ Day-ahead Energy market: energy market operated by a NEMO, ▪ Intraday Energy market: energy market operated by a NEMO, ▪ TSO Balancing markets (Primary, Secondary and Tertiary), ▪ Day-ahead Distributed Local Flex Market: R-DLFM proposed by WP5. ESPs/aggregators prefer to offer flexibility services to DSOs (i.e., congestion management). Of the six ESP/aggregator respondents to the FLEXGRID survey they all showed interest in offering such flexibility services to a DSO via a flexibility marketplace. Four of them showed interest in also providing ancillary services to a TSO (Primary and secondary) and only two showed interest in tertiary reserve service provision.	

2.4.2 FMO business cases in HLUC_02

The FMO proposed by FLEXGRID also has business goal related to HLUC_02:

Table 14: FMO Business Goals in HLUC02

To increase the service offering to FlexSuppliers

To achieve this offering, the FMO considers the following business cases:

Table 15: FMO Business Cases in HLUC02

Industry case	**Operate the DLFM**
The FMO operates the DLFM to provide a platform where FlexSuppliers connected at the distribution level can sell FlexServices to FlexBuyers.	
Industry case	**Reduce the number of contracts by connecting FlexSuppliers to different FlexBuyers.**
The FMO's platform facilitates the contract management for ESPs looking to provide flexibility to different buyers. This would reduce the operational barrier for smaller flexibility providers who would avoid the need to maintain multiple contracts to stack services from the same asset.	

2.4.3 DSO business case in HLUC_02

Although the DSO does not directly interact with FlexSuppliers in HLUC_02, the DSO has the business goal of reducing or delaying the investment in grid upgrade:

Table 16: DSO Business Goals in HLUC02

To delay or avoid investment in network reinforcement infrastructure

An increased offer of FlexService from new FlexAssets installed in the distribution network both reduces the cost of procuring FlexServices, but also reduces the risk of using flexibility as an alternative or postponement measure to network reinforcements through new infrastructure. To this end, the DSO benefits from having FlexSuppliers willing and able to invest in FlexAssets capable of supporting the distribution network in areas vulnerable to congestion and voltage problems.

Table 17: DSO Business Cases in HLUC02

Research case	**Providing specific network data that would allow for more investment in Flex Assets**
A DSO might consider the business case of providing specific network data that would allow for more investment in Flex Assets to support the network. This way, specific information about the need for flexibility at different areas in the network could be provided to FlexSuppliers that could incentivise them to invest in FlexAssets to support network operation. From a practical perspective in today's electricity domain, there may be some regulatory and privacy restrictions that need to be considered. But more importantly, network data is often of strategic importance to DSOs who would need to assess if the added value of the business case is important enough to be carried out.	

2.4.4 TSO business case in HLUC_02

The TSO is responsible for the operation of the reserve and balancing markets. This is already performed by many European TSOs who operate these markets. In this case, the TSO might also procure reserve capacity on the DLFM operated by the FMO when there is not sufficient capacity on the TSO markets or when the price for reserve capacity is lower on the DLFM.

2.5 Business case analysis related to HLUC_03: FLEXGRID Automated Trading Platform offers advanced flexibility demand management services to system operators

While the previous HLUC_02 considers flexibility supply management for FlexSuppliers, HLUC_03 focuses on the flexibility demand management for system operators. This HLUC looks at both DSOs and TSOs and how they procure flexibility to meet their business goals. The overview of the business case analysis is presented in Figure 8.

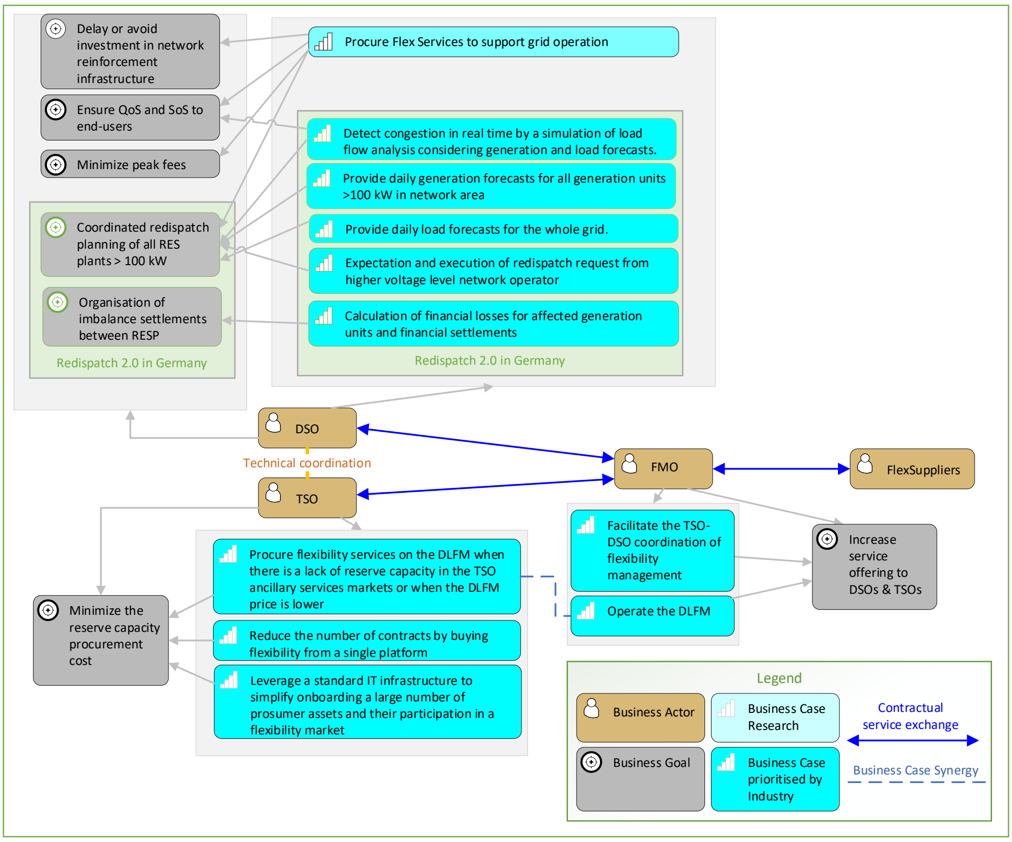

Figure 8: Business case analysis of HLUC_03.

As stated above, the focus of HLUC_03 is on the DSO and TSO. Their goals and business cases are listed and described below.

2.5.1 DSO business cases in HLUC_03

Generally, the DSO has the two following business goals:

Table 18: DSO Business Goals in HLUC03

To ensure quality of supply (QoS) and security of supply (SoS) to end-users
This a regulated task of the DSO, and the failure to deliver this service to end-users results in a financial penalty that depends on the relevant regulatory regime.
To delay or avoid investment in network reinforcement infrastructure
The importance of this business goal depends on the regulatory regime that determine the DSO revenues. While traditional regulatory regimes reward DSOs for investments in new infrastructure, others provide incentives for cost-efficiently managing their grid. For example, the Norwegian

regulation uses a revenue cap model that uses benchmarking models that incentivize DSOs to minimize their overall cost for operating their network.[50]
To reduce capacity payments to upstream grid operators through peak-shaving
Certain regulatory regimes require DSOs to pay peak fees to the upstream network operator. For example, this is a major part of DSOs' OPEX in Germany and Norway.

To these ends, the DSO considers the following business cases:

Table 19: DSO Business Cases in HLUC03

Research case	**Procure Flex Services in a market-based mechanism to support grid operation**
The ability to purchase flexibility to support grid operations has the potential to help DSOs in operating their existing network to meet QoS and SoS requirements. This has direct benefit in reducing the Cost of Energy Not Supplied (CENS) and avoid penalties in case of poor voltage quality. Furthermore, it allows the DSO to delay or avoid investment in new infrastructure for network reinforcement. FLEXGRID provides DSOs with the opportunity to efficiently purchase flexibility via a market-based mechanism. As discussed extensively in Deliverable D2.1, flexibility markets provide a way to find an optimal value for the flexibility services, considering the available demand and supply of flexibility. An additional benefit is centralization of the flexibility management and the possibility to trade standard flexibility products, which lowers the burden on the DSOs. This way, the DSO does not need to manage all the contracts with the flex suppliers, and it is able to purchase the flexibility at a lower price. However, a major challenge with this DSO business case is the available liquidity in the market. Because the DSO is facing local problems (voltage and congestion problems in a specific feeder or node), their needs to be enough available capacity to deliver the required flexibility. The alternative of a bilateral contract agreement, or even a parallel contract agreement, reduces this risk.	
Industry case	**Detect congestion by a simulation of load flow analysis considering generation and load forecasts.**
In order to identify potential line congestions in their distribution network, DSOs could use load flow analysis and rely on generation and load forecasting inputs. This simulation-based approach could be both quicker to implement and cheaper than deploying sensor infrastructure.	

In addition to the business goals discussed above, there are particular DSO obligatory tasks under new national regulations in Germany – Redispatch2.0 – described in Section 1.2.2.:

- To coordinate the redispatch of a RES plants larger than 100 kW.
- To minimize the cost of imbalance caused by redispatching units connected at the distribution level.
- Provide daily generation forecasts for all generation units larger than 100 kW in a specific network area.
- Provide daily load forecasts of the whole network.
- Execute redispatch requests from the upstream network operator.
- Calculate the financial losses of affected generation units and financial settlements.

2.5.2 TSO business cases in HLUC_03

The TSO has the following business goals related to the procurement of flexibility in HLUC_03:

Table 20: TSO Business Goals in HLUC03

To minimise the procurement cost of reserve capacity and balancing energy

To achieve these goals, the TSO considers the following business cases:

[50] https://www.nve.no/norwegian-energy-regulatory-authority/economic-regulation/

Table 21: TSO Business Cases in HLUC03

Industry case	**Procure flexibility service on a distribution level flexibility market.**
This enables the TSO to address frequency problems when there is a lack of reserve capacity in the TSO reserve and balancing markets or when the price for reserve capacity is lower on the DFLM.	

2.5.3 FMO business cases in HLUC_03

In HLUC_03, the FMO pursues the following business goal:

Table 22: FMO Business Goals in HLUC03

To increase the service offering to DSOs and TSOs

Indeed, the FMO is in an interesting position to explore different business cases to increase their service offering to network operators:

Table 23: FMO Business Cases in HLUC03

Industry case	**Operate the DLFM**
The FMO operates the DLFM to provide a platform where both the DSO and TSO to buy flexibility in a competitive way.	
Industry case	**Improve the flexibility optimization by considering data from DSO FlexRequests.**
The FMO aims to deliver a flexibility market that accurately reflects the realities in on the grid level. As per current regulation, FMO will not be allowed to have detailed representation of grid models on their platforms but this business case evaluates of how this can facilitate the overall flexibility market once the regulation starts to support the detailed representation of grid models by an FMO. The FMO can therefore receive information in FlexRequests that consider network data to improve how the flexibility market clearing can respond to DSO grid issues. In order for this business case to be carried out in a fair and neutral way, transparent mechanisms are needed for DSOs and FMOs to exchange the required information. According to the respondents to the FLEXGRID survey, this business case is considered very helpful to facilitate the flexibility requests for a DSO on a flexibility marketplace	
Industry case	**Facilitate the TSO-DSO coordination for flexibility management.**
The FMO can facilitate the coordination of the settlement of flexibility from the same FlexAsset when both the DSO and TSO require capacity in the same location. The technical coordination happens directly between the grid operators within technical coordination contracts, but the FMO can facilitate settlement at the market level by providing a standard API to simplify communication.	

2.6 Business case analysis related to HLUC_04: FLEXGRID Automated Trading Platform offers automated flexibility aggregation management services to aggregators

HLUC_04 looks to improve the management of an aggregated portfolio of Flex Assets. In this context, there are relevant business cases for aggregators as well as prosumers who participate in these portfolios. An overview of the business case analysis is provided in Figure 9. Note, for the research work conducted in HLUC_04, the algorithms do not consider whether a FlexRequest or FlexOffer is made via a bilateral contract with a FlexBuyer, or whether this is accomplished via a market mechanism.

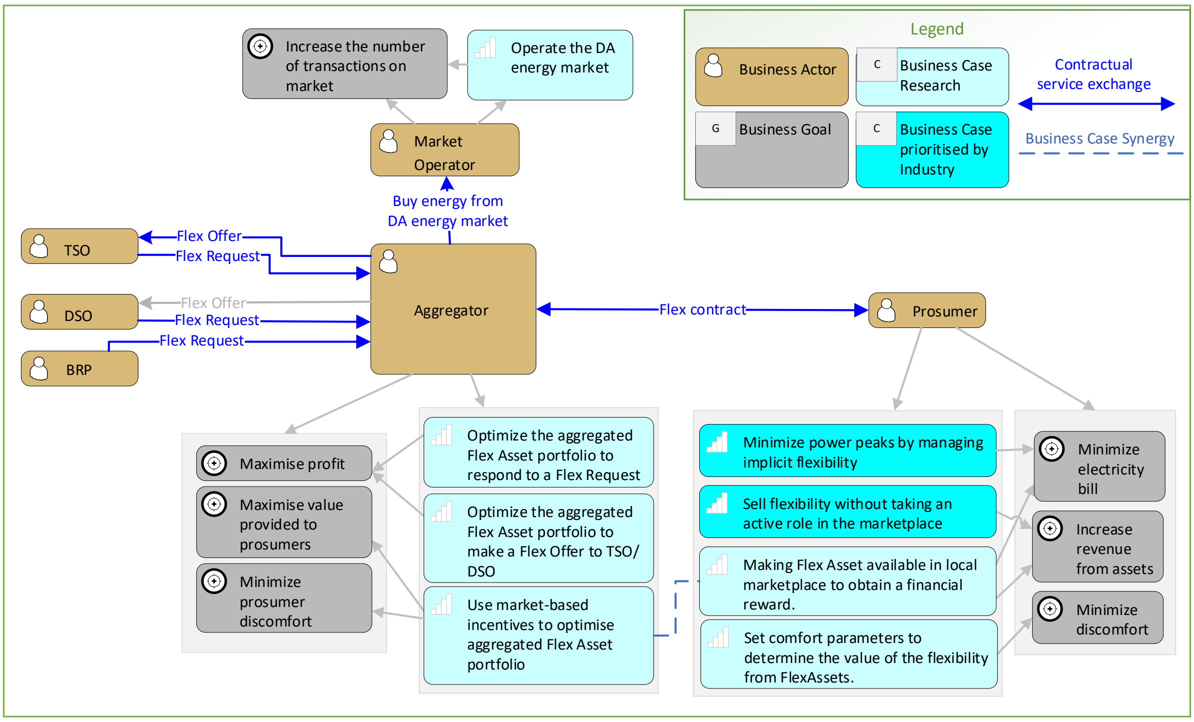

Figure 9: Business case analysis of HLUC_04.

2.6.1 Aggregator business cases in HLUC_04

In the FLEXGRID survey, six respondents consisted of ESP/aggregators. This helped in selecting different business goals of HLUC_04, where 83% of the respondents confirmed that they operate the DERs regardless of the ownership and 50% plans to invest in their own DERs. In addition, all aggregators showed interest in diversifying their FlexAssets portfolio and preferring to operate more EV chargers and battery storage as FlexAssets. The aggregator has the following business goals:

Table 24: ESP/Aggregator Business Goals in HLUC04

To maximize its profit earned from the operation of the aggregated portfolio of FlexAssets.
To maximize value provided to prosumers.
The aggregator aims to maximise the aggregated payoff of all portfolio participants. For each prosumer, this payoff will be different, as it is estimated as the different between their prosumption baseline and the cost of energy and that of the aggregator's fee.
To minimize prosumer discomfort.
This discomfort is dependent on the type of FlexAsset. For example, discomfort in the case of an EV charger, this could be a slower charging session.

To achieve these goals, the aggregator explores the following business cases:

Table 25: ESP/Aggregator Business Cases in HLUC04

Research case	**Optimize the aggregated Flex Asset portfolio to respond to a Flex Request**
In this business case, an aggregator receives a FlexRequest, and performs a central optimization in real time and dispatches the Flex Assets accordingly. This strategy can enable aggregators to respond to a Flex Request optimally given the limits of the aggregated portfolio. For this, each prosumer must set the limits of their own comfort parameters. The prosumers also need to have incentive mechanisms for providing flexibility. There are some challenges in implementing this business case in practice. First, the optimization must be very efficient to if the aggregator carries out this business case in real time. It also requires the aggregator to have an accurate knowledge of the prosumer baselines in order to dispatch FlexAssets in a way that is feasible and maximum value (trade-off between received benefit vs comfort) for the end-prosumer. In the FLEXGRID market survey, 83% of the respondents found it useful to have automated flexibility aggregation management services that help increase profit in their current operations. Also a majority of the respondents showed interest in investing in this area giving a valuable importance to this business case of the FLEXGRID project.	
Research case	**Optimize the aggregated Flex Asset portfolio to make a FlexOffer**
Unlike the previous business case, this one considers a proactive aggregator who optimizes its portfolio to make a Flex Offer. FLEXGRID is evaluating the possibility of a decentralized optimization, where prosumers take a leading role in submitting their cost functions based on their own baseline and the value that they attribute to their flexibility.	
Research case	**Use market-based incentives to optimize aggregated Flex Asset portfolio**
This business case an aggregator manages its portfolio as a local market, described in D5.1[51] as a "B2C Flex Market". The B2C Flex Market performs a decentralized optimization of the FlexAssets and incentivizes prosumers to sell flexibility with a Behavioural-Real Time Pricing (B-RTP) scheme. This business case can help the aggregator improve its own profits while providing value to prosumers who make their assets available in the B2C Flex Market.	

2.6.2 Prosumer business cases in HLUC_04

There can be many different types of prosumers participating in an aggregated portfolio, and the attractiveness of a business case is strongly dependent on the type of prosumer considered. If we consider prosumers on a general level in the context of HLUC_04, we can describe the following business goals:

Table 26: Prosumer Business Goals in HLUC04

To minimize their electricity bill
To increase revenue from their FlexAssets
To minimize their discomfort

To reach these goals in HLUC_04, we look at the following business cases:

Table 27: Prosumer Business Cases in HLUC04

Industry case	**Sell flexibility without taking an active role in the marketplace.**
Prosumers are exploring this business case as a way to gain a new revenue stream from their existing FlexAssets. For many prosumers, this improves the investment case in new energy assets which are not primarily used for the provision of FlexServices. A commonality of different prosumer types is that energy is not their primary business, nor their expertise. Such prosumers do not want to take an active role in selling flexibility but prefer to have this managed by an aggregator. In the	

[51] D5.1

FLEXGRID market survey, 66% respondents indicated the use of models and algorithms that provide improved services to end-users quite useful for their current operations and 83% showed interest in investing in such models and algorithms.	
Research case	**Making Flex Asset available in local marketplace to obtain a financial reward**
This business case would help provide the financial incentives for prosumers to sell their flexibility. Prosumers currently lack a strong enough business case to make the provision of flexibility viable. The use of reward mechanisms like B-RTP has the potential to encourage such viability when the market price is high enough. All the respondents of the FLEXGRID market survey found such incentivisation schemes for end-user very useful and 66% respondents showed interest in investing in this area.	
Research case	**Set comfort parameters to determine the value of the flexibility from FlexAssets**
While prosumers explore different business cases to improve their profits from managing their flexibility, it is important to remember that the core interest of prosumers, whether they are private prosumers or companies, lies outside the energy domain. The ability for prosumers to set their own parameters to determine the value of their flexibility is very important.	

2.7 Summary of business cases

The business case analysis presented in this second chapter provides useful information to understand the goals and business cases driving the different target customers of the FLEXGRID solutions in context of the use cases defined in D2.1. These business cases and business goals are summarised in the following tables according to each business actor group.

Table 28: Summary of FMO business cases

ID	Business Case	Related Business Goal	HLUC
C01	Operate a reactive DLFM (R-DLFM) to provide flexibility to the DSO.	▪ Increase service offering to DSOs and TSOs ▪ Increase service offering to FlexSuppliers	1,2,3
C02	Operate a proactive or interactive DLFM (P- or I-DLFM).	▪ Increase service offering to DSOs and TSOs	1
C03	Use advanced algorithms to increase the efficiency of market clearing	▪ Improve market clearing	1
C04	Use a combination of market clearing methods to improve market clearing	▪ Improve market clearing	1
C05	Reduce the number of contracts by connecting FlexSuppliers to different FlexBuyers	▪ Increase service offering to FlexSuppliers	2
C06	Improve the flexibility optimization by considering data from DSO FlexRequests	▪ Increase service offering to FlexSuppliers ▪ Increase service offering to DSOs and TSOs	2,3
C07	Facilitate TSO-DSO coordination of flexibility management	▪ Increase service offering to DSOs and TSOs	3

Table 29: Summary of MO business cases

ID	Business Case	Related Business Goal	HLUC
C08	Offer more value to customer with additional market offerings	▪ To improve the market competitiveness ▪ To improve the operation of their markets	1

Table 30: Summary of DSO business cases

ID	Business Case	Related Business Goal	HLUC
C09	Procure local flexibility in a market-based way to manage congestion problems and for voltage control	▪ Ensure QoS and SoS to end-users, ▪ Delay/avoid network reinforcement investment ▪ Reduce capacity payments to upstream grid operators through peak-shaving	1, 3
C10	Providing specific network data that would allow for more investment in Flex Assets	▪ Delay/avoid network reinforcement investment	2
C11	Detect congestion in real time by a simulation of load flow analysis considering generation and load forecasts	▪ Ensure QoS and SoS to end-users	3
C12	Coordinate the redispatch of a RES plants larger than 100 kW	▪ Regulated task in Redispatch 2.0 (Germany)	3
C13	To minimize the cost of imbalance cause by redispatching units connected at the distribution level	▪ Regulated task in Redispatch 2.0 (Germany)	3
C14	Provide daily generation forecasts for all generation units larger than 100 kW in a specific network area	▪ Regulated task in Redispatch 2.0 (Germany)	3
C15	Provide daily load forecasts of the whole network	▪ Regulated task in Redispatch 2.0 (Germany)	3
C16	Execute redispatch requests from the upstream network operator	▪ Regulated task in Redispatch 2.0 (Germany)	3
C17	Calculate the financial losses of affected generation units and financial settlements	▪ Regulated task in Redispatch 2.0 (Germany)	3

Table 31: Summary of TSO business cases

ID	Business Case	Related Business Goal	HLUC
C18	Operate and clear the DA reserve and balancing markets	▪ Minimise the reserve capacity procurement cost	1, 2
C19	Procure flexibility service on a distribution level flexibility market	▪ Minimise the reserve capacity procurement cost	3

Table 32: Summary of ESP/Aggregator business cases

ID	Business Case	Related Business Goal	HLUC
C20	Optimally schedule the consumption and production of Flex Assets to reduce the balancing costs	▪ To minimise balancing costs ▪ Reduce RES curtailment	2
C21	Improve the investment decision in new RES and Flex Assets	▪ To reduce CAPEX in new RES and FlexAsset investments	2
C22	Optimise the operation of Flex Assets considering their participation in different markets	▪ To maximise the profit gained from selling flexibility	2
C23	Optimize the aggregated Flex Asset portfolio to respond to a FlexRequest	▪ To maximize its profit earned from the operation of the aggregated portfolio of FlexAssets.	4
C24	Optimize the aggregated Flex Asset portfolio to make a FlexOffer	▪ To maximize its profit earned from the operation of the aggregated portfolio of FlexAssets.	4
C25	Use market-based incentives to optimize aggregated Flex Asset portfolio	▪ Maximise value to prosumers ▪ Minimise prosumer discomfort	4

Table 33: Summary of Prosumer business cases

ID	Business Case	Related Business Goal	HLUC
C26	Sell flexibility without taking an active role in the marketplace.	▪ To increase revenue from their FlexAssets	4
C27	Making Flex Asset available in local marketplace to obtain a financial reward	▪ To minimize their electricity bill ▪ To increase revenue from their FlexAssets	4
C28	Set comfort parameters to determine the value of the flexibility from FlexAssets	▪ To minimize their discomfort	4

3 Intermediate list of FLEXGRID Key Exploitable Results (KERs)

3.1 General overview of the Key Exploitable Results (KERs)

This chapter contains a general definition of each KER of the FLEXGRID project. The information provided here is linked to research work carried out in WP3, WP4 and WP5. Each KER is presented according to three criteria: a) description, b) value for the project and c) relation with other KERs. It is considered that each result can be individually exploited. However, the strategy in the FLEXGRID project is to integrate all the exploitable results into different modules integrated in one single FLEXGRID S/W platform in order to maximize its commercial/business impact, adding value/background knowledge to all partners after the end of the project's lifetime. Therefore, this chapter also shows the main relations between all the KERs to define the business dependencies.

The KERs identified within the FLEXGRID project are structured in accordance with the H2020 classification of results. In the context of the project, each type of result will have the following characteristics:

- Scientific or Technological R&D result including ICT Hardware: Algorithms developed to be integrated in the ATP platform (TRL 5) and to be used as a research innovation (TRL 3).
- ICT Software Digital solution: Main platform to integrate the developed algorithms.
- Policy Related Result: Alternative solutions to be integrated in future markets.
- Services: KERs orientated to improve current market solutions with the objective of increasing the service offering for flexibility market stakeholders.

3.2 Key Exploitable Results (KERs) description

This section provides links between each KER, using a graphical presentation in order to better understand the relation between the developed algorithms, models and the FLEXGRID products. For improved clarity, the KERs are grouped into subsections according to the module/main service they belong to.

3.2.1 Automatic Trading Platform (ATP)

The Automatic Trading Platform (ATP) is an ICT software solution described in detail in D2.2. The ATP provides a user-friendly front end to the users of the FLEXGRID services. The main feature of this platform is the possibility to integrate and operate flexibility markets in real time considering the needs of different stakeholders. The users of the ATP include different types of ESP/Aggregators, , DSOs, TSOs, FMOs and MOs. Using the ATP services, these stakeholders will have the opportunity to participate in different flexibility markets in a simple and effective way.

This exploitable service is connected to all the other FLEXGRID KERs, since the ATP is the main interface for all the algorithms and services developed in the project. For the seamless interaction between the platform components, it is necessary to develop the correct communication channels. For this, it is essential to have good interaction between the partners involved in the development of each module. The data model described in D6.1 explains how the different modules are linked with the ATP, and which FLEXGRID partners are responsible for their development. Here, we consider the different the stakeholders might use, or otherwise be interested in the FLEXGRID solution. This is described in the following dependency diagrams.

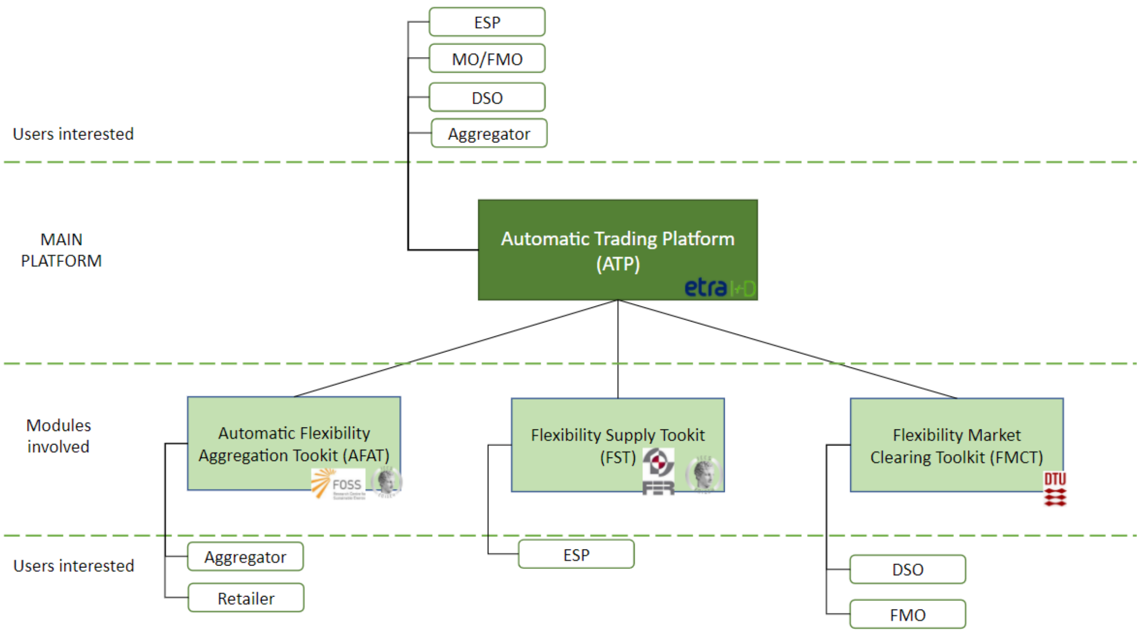

Figure 10: ATP dependency diagram.

3.2.2 Automatic Flexibility Aggregation Toolkit (AFAT)

The Automatic Flexibility Aggregation Toolkit (AFAT) is an ICT software solution developed in the FLEXGRID project which will be integrated in the ATP. The main functionality of AFAT is to manage the flexibility requests by enabling more optimal offers for the flexibility market. The service is composed of a series of modules that provide algorithms to help aggregators decide on the best FlexOffers from an aggregated portfolio of FlexAssets. For this, the AFAT can leverage the following KERs:

- Manage a FlexRequest,
- Create a FlexOffer,
- Manage a B2C flexibility market.

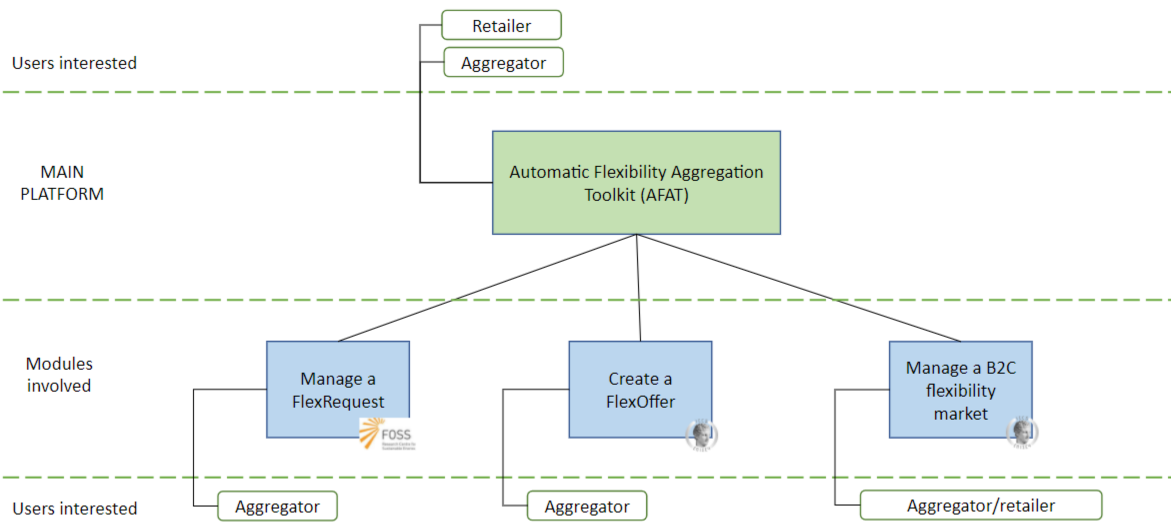

Figure 11: AFAT dependency diagram.

Each of the KERs related to the AFAT are in fact functionalities that are provided by the algorithms described in D3.1. For example, to deliver the "manage a FlexRequest" and "create a FlexOffer" functionalities, the AFAT uses the "Flexibility Aggregation Algorithm Module". Meanwhile, to perform the "manage a B2C flexibility market" service, the AFAT will use the "Retail Market Mechanisms Module". Additionally, the functionality of the AFAT relies on the FLEXGRID ATP's "Forecasting Engine", which is descried in D4.1. Note, the dependency diagram in Figure 11 does not include the back-end modules as it focuses on the functionalities provided by the AFAT. The link between the front-end functionalities and the back-end modules is shown in Figure 12.

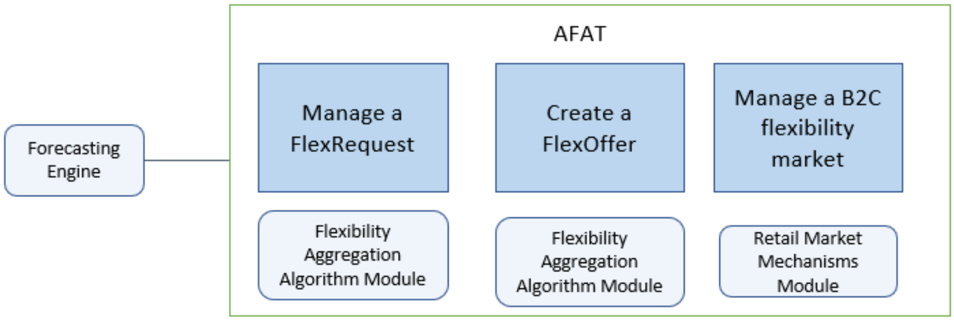

Figure 12: AFAT link between modules/algorithms (light blue) and functionalities (dark blue).

By means of the algorithms involved in the creation of the FlexOffer, the AFAT will do the optimization not only for demand to be scheduled but also in the most cost-effective way for the aggregator and the retailer through the "Retail Pricing Algorithm", the "Flexibility Aggregation Algorithm" and the "Forecasting Engine" involved in the calculation procedure. All the interactions between the modules and algorithms are given in the following paragraphs, and further explained in detail in D3.1 and D3.2.

Manage a FlexRequest

The "Manage a FlexRequest" KER is a Scientific/Technological R&D result with the main objective of successfully responding to the flexibility request made by the DSO, TSO or a BRP. A flexibility request can either be a request for activation of energy (upward or downward) for one or many specific timeslot(s) or a request for available capacity for one or many timeslot(s) with a potential activation request if required using the "Flexibility Aggregation algorithm".

In the different time periods, a request can have a variety of possibilities in payments (e.g., for capacity and energy), making it necessary to evaluate and analyse each flexibility requests in detail. This is important because new requests can be made to manage network challenges in near real-time, and FlexSuppliers involved in the activation will need tools for easy evaluation of the different possibilities.

Create a FlexOffer

The "Create a FlexOffer" KER is a Scientific/Technological R&D result with the objective of establishing a method for computing the upward and downward flexibility cost for a set of DERs by means of the "Flexibility Aggregation Algorithm". This KER can be leveraged in two modes of operation: offline operation mode and online operation mode – these are explained in detail in D3.1. In online operation, FlexOffers can be created to submit a bid in a near real-time energy market.

Manage B2C flexibility market

A B2C flexibility market is comprised of an aggregator/retailer and a set of end-users (i.e. end-consumers or end-prosumers). The "Manage a B2C flexibility market" KER facilitates the allocation of flexibility activations among end-user FlexAssets in an aggregated portfolio, while maximising the social welfare (ref. D3.1). For achieving this goal, the aggregator/retailer will be able to setup simulation scenarios in order to identify interesting business cases for operating a novel B2C flexibility market by means of the "Retail Market pricing" algorithm. The B2C flexibility market is not part of an actual energy market as of now and is a complete novel solution proposed. The innovative algorithms will be used in future new flexibility markets to accommodate individual assets or a combination of assets with the other functionalities the AFAT can provide.

3.2.3 Flexibility Supply Toolkit (FST).

The Flexibility Supply Toolkit (FST) is an ICT Software Digital solution developed in FLEXGRID which is integrated in the ATP. Its main functionality is to achieve optimal solutions to help the ESP enhance its business strategy considering all relevant objectives and constraints. For this the toolkit provides the following KERs:

- Minimize CAPEX,
- Minimize OPEX,
- Stacked revenue maximization,
- Market Price Forecasting.

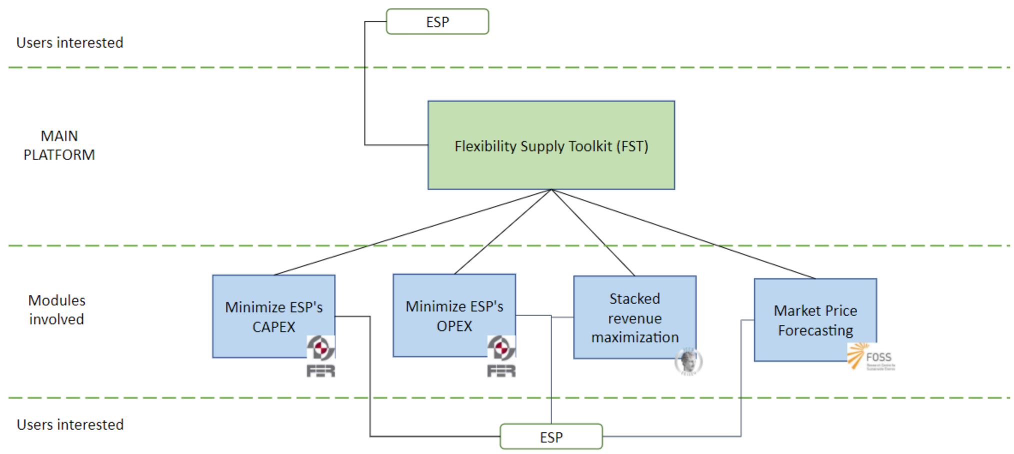

Figure 13: FST dependency diagram.

Each of the KERs related to the FST are in fact functionalities that are provided by the algorithms described in D4.1. For "Minimize CAPEX" the FST will run the "FlexAsset Sizing/Siting Algorithm Module". For the Minimization of the OPEX the "Optimal Scheduling Algorithm Module" should be run. If the ESP wants to use the "Stacked revenue maximization" function, the "Optimal Bidding Algorithm Module" will be used. Like the AFAT solution the FST has also use the "Forecasting Engine" module to have the Market Price forecasting in order to achieve the optimal solution for the ESP.

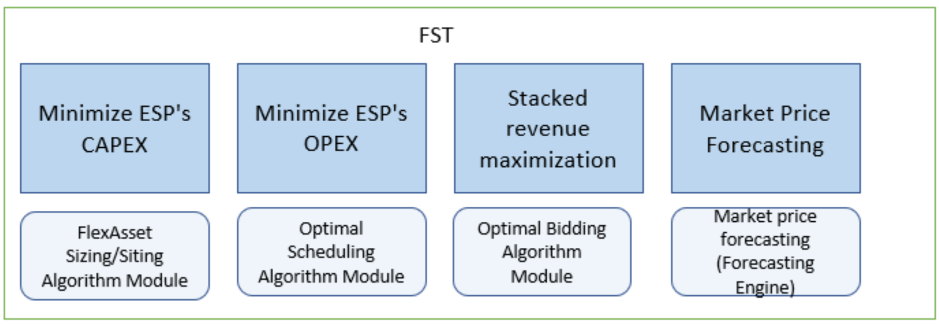

Figure 14: FST link between modules/algorithms (light blue) and functionalities (dark blue).

By means of the four algorithms given in Figure 14, the FST acts as the main interface for a FlexSupplier in the bidding process and dispatch once a FlexOffer has being created. All the interactions between the modules and algorithms mentioned are elaborated in D4.1 and D4.2 and in the following sections.

Minimize ESP's OPEX

Through this Scientific/Technological R&D KER integrated in the FST service, a minimization of the OPEX can be achieved. The algorithm to minimize the OPEX is the "Optimal FlexAsset scheduling" defined in detail in chapter 3 of D4.1. The main objective is to optimally schedule FlexAssets under an ESP's control considering a specific cost function (e.g., minimizing the RES curtailment).

Minimize ESP's CAPEX

Minimize ESP's CAPEX is a Scientific/Technological R&D results with the objective of sizing and siting of FlexAssets in an optimal manner according to the ESP's input parameters and existing grid constraints. This is achieved using the "FlexAsset Sizing/Siting" algorithm. The algorithm considers future scenarios to determine optimal FlexAsset siting and sizing options that will allow for lower lifetime OPEX of FlexAssets. This allows for improved investment decision in new FlexAssets, and thus a lower CAPEX.

Stacked revenue maximization

The Stacked revenue maximization is a Scientific/Technological R&D Results that is provided by the "Optimal Bidding Algorithm Module" defined in D4.1. Its objective is to improve an ESP's profits from making their FlexAssets available on different markets. It creates optimal bidding strategies according to a FlexAsset's constraints and provide the optimal schedule for the FlexAsset's operation. The model can be adapted to different cases, depending on specific market regulations, which may vary from country to country.

Market Price Forecasting

The "Market Price Forecasting" KER is a Scientific/Technological R&D Result with the main goal of offering a tool for ESPs/Aggregators to design a bidding strategy based on the optimal trade-off between risk and profit. The algorithm detailed in D4.1 is tightly linked to the FST as it is one of the backend tools that relies on future market price predictions to better optimise the ESPs bidding strategy.

3.2.4 Flexibility Market Clearing Toolkit (FMCT)

The Flexibility Market Clearing Toolkit (FMCT) is an ICT Software solution developed in the project and integrated in the ATP. It features advanced Optimal Power Flow (OPF) algorithms that help DSOs identify the need for flexibility. The FMCT also allows for efficient, network-aware market clearing of a Distribution Level Flexibility Market (DLFM) based on the FlexOffers and FlexRequests received. The toolkit provides the following KERs:

- Pay-as-bid DLFM clearing,
- Auction-based DLFM clearing.

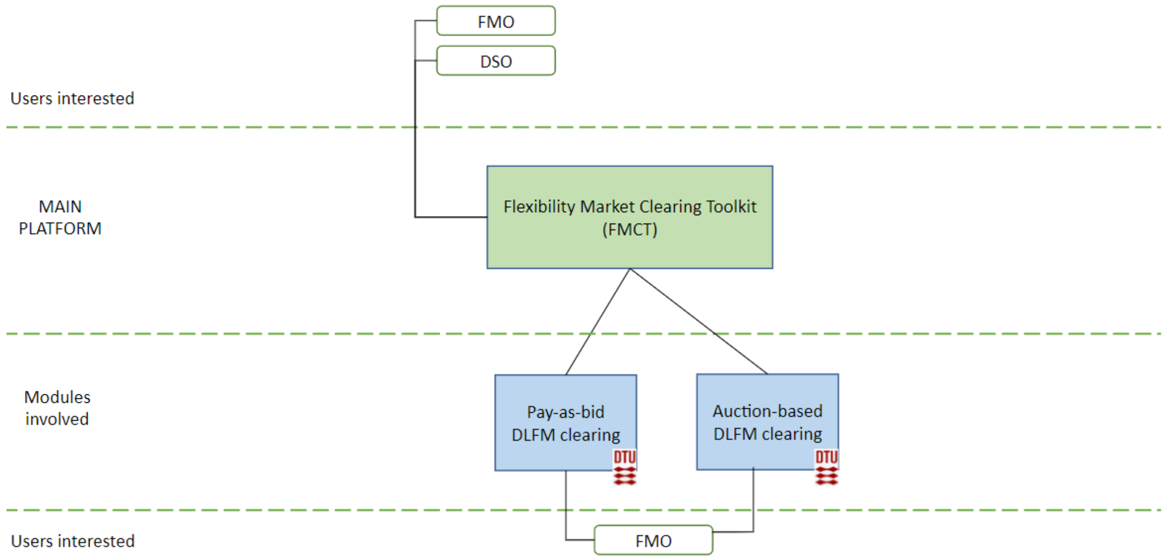

Figure 15: FMCT dependency diagram.

Each of the KERs related to the FST are in fact functionalities that are provided by the algorithms described in D5.1. To deliver the "Pay-as-bid DLFM clearing" functionality, the FCMT runs the algorithm in the "Market Clearing Module". For this module to successfully clear a flexibility market, it will run the two internal algorithms "Price Determination" and "Flexibility Schedule". To identify possible network congestions and voltage deviations, and to formulate FlexRequests by means of the "Auction-based DLFM clearing" the FCMT will run the "Identification of Flexibility Needs Module".

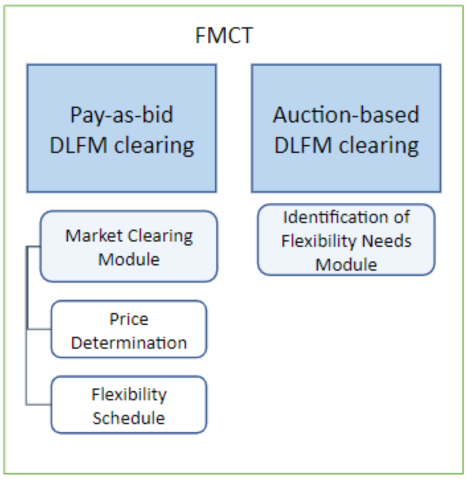

Figure 16: FMCT link between modules/algorithms (light blue) and functionalities (dark blue).

A full description of the internal algorithms of the FCMT can be found in D5.1 and D5.2. Here, we consider the following KERs.

<u>Pay-as-bid market clearing</u>

The Pay-as-bid market clearing is a Scientific/Technological R&D Result which tries to solve an optimization problem aimed at determining the best dispatch of generation assets and loads in an electrical network, so that all the physical and operational constraints are respected. The clearing algorithm includes network constraints and ensures that a feasible operating point exists with the cleared quantities while activating the assets with lowest price first.

This KER is the basis for the real value of the FMCT as it is the backend algorithms running to obtain the optimal solution. In addition, this KER is wholly related with the Auction-based in DLFM as both KERs are considering constraints in the grid.

Auction-based market clearing

The auction-based market clearing algorithm is a Scientific/Technological R&D Result with the objective of ensuring the feasible operation. Very closely related with the Pay-as-bid market clearing, the auction-based market clearing includes the network constraints to ensures that an operating point could exists with the cleared quantities and can also model network constraints on the cross-border intraday (XBID) market. This allows to increase the flexibility provision from small and decentralized resources to support the power system.

3.2.5 x-DLFM architectures

Although the "x-DLFM architectures" are consider as a KER within the FLEXGRID project, this is categorized as a Policy Related Result, due to the main objective is to recommend to policy makers about different market architectures.

Each DLFM architecture has its own characteristics targeting different future scenarios: The main advantage of the R-DLFM is that it is compatible with the existing regulatory framework and at the same time is capable of coping with forecast inaccuracies. The main advantage of P-DLFM model is that Distribution Network (DN) constraints are taken into consideration in a proactive way. Both the R-DLFM and the P-DLFM are not the most efficient solution in terms of social welfare. A main advantage of I-DLFM model is that it can maximize the social welfare and thus provide optimal network operation and market efficiency outcomes. These architectures are deeper explained along the document D5.1.

3.2.6 DSO Techno-Economic Analysis

The DSO analysis is a Policy Related Result focused on providing a techno-economic analysis, which develops a model that gives an optimal price for flexibility services in modern distribution system network considering electric vehicles, photovoltaic systems, battery energy storage systems, and demand side response providers. The sensitivity analysis will show results for which cases the flexibility providers are encouraged to provide their services, or in which cases for DSO is better to proceed with business-as-usual approach.

4 Value Proposition Analysis and Intermediate Business Modelling

4.1 Business Modelling Methodology

The objective of the business modelling activities in FLEXGRID, as presented in D8.1 is to "derive a set of business models, business cases and plan to support sustainable uptake of the FLEXGRID solutions in eventual commercial operation". Generally, a **business model** can be defined as "representation of the value logic of an organization in terms of how it creates and captures customer value"[52]. Different variations of this abstract definition exist, but the most important is the description of the key components of a business model, namely the target customer, value proposition, organizational architecture, and economics (cost and revenues).

For this, the efforts in WP8 are inspired by the lean start-up method[53], which promotes five key principles; two of which are very relevant for the work in FLEXGRID:

- **Validated learning**: building a sustainable business from a new venture is a learning process that can be validated scientifically. This usually requires running frequent experiments to test each element of the business.
- **Build-Measure-Learn:** the fundamental activity of building a sustainable business, which enables entrepreneurs to learn how clients respond to innovations and how they should adapt their business strategy. This is the basis of the FLEXGRID business model development process described in D8.1.

The first components of the business models that should be verified with this process are the value propositions: the benefits customers can expect from the FLEXGRID services[54]. The value propositions are analysed using the value proposition canvas presented in D8.1[55]. The intermediate version of the FLEXGRID value propositions presented here are derived from the business case analysis discussed in section FLEXGRID business ecosystem and business case analysis2. The customer-side of the value proposition canvas is updated considering the business goals and cases that the different actors are looking to carry out, and the value-side of the canvas is adjusted based on the outcomes of the research work proposed by FLEXGRID. This results in an intermediate, long-list version of the FLEXGRID value propositions which are used to create intermediate business models.

The intermediate business models presented here are deliberated qualitatively: the purpose is to describe the motivation, advantages and challenges of different business models that can utilise the project outcomes. This is the "build" step of the lean start-up process and will result in a set of business models that will need to be tested (i.e. measured) in the subsequent phase of the project. The business models are presented using the business model canvas introduced in D8.2.

These intermediate business models rely on certain hypotheses that need to be validated. Such hypotheses are highlighted in this report, and steps required for their verification will be discussed for the further work in the FLEXGRID project activities.

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[52] Fielt, E. 2014, 'Conceptualising Business Models: Definitions, Frameworks and Classifications', Journal of Business Models, Vol. 1, No. 1, pp. 85-105.

[53] Ries, E., 'The Lean Startup' (Currency, 2011)

[54] Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A., and Papadakos, T., *Value proposition design*. Hoboken, NJ: Wiley, 2014.

[55] https://www.strategyzer.com/canvas/value-proposition-canvas

4.1.1 Three Business Modelling Scenarios

FLEXGRID develops concepts, algorithms and functionalities that aim to deliver value to stakeholders in novel electricity market designs. For the most part, the technology, regulatory and market conditions required for the feasible deployment of the FLEXGRID results need further development. In order to imagine the commercialisation of these results, and develop business models that consider different market conditions, three scenarios are envisioned. This allows for a stepwise approach for developing business models that can progressively be embraced as market conditions evolve. The three scenarios considered are presented in Figure 17.

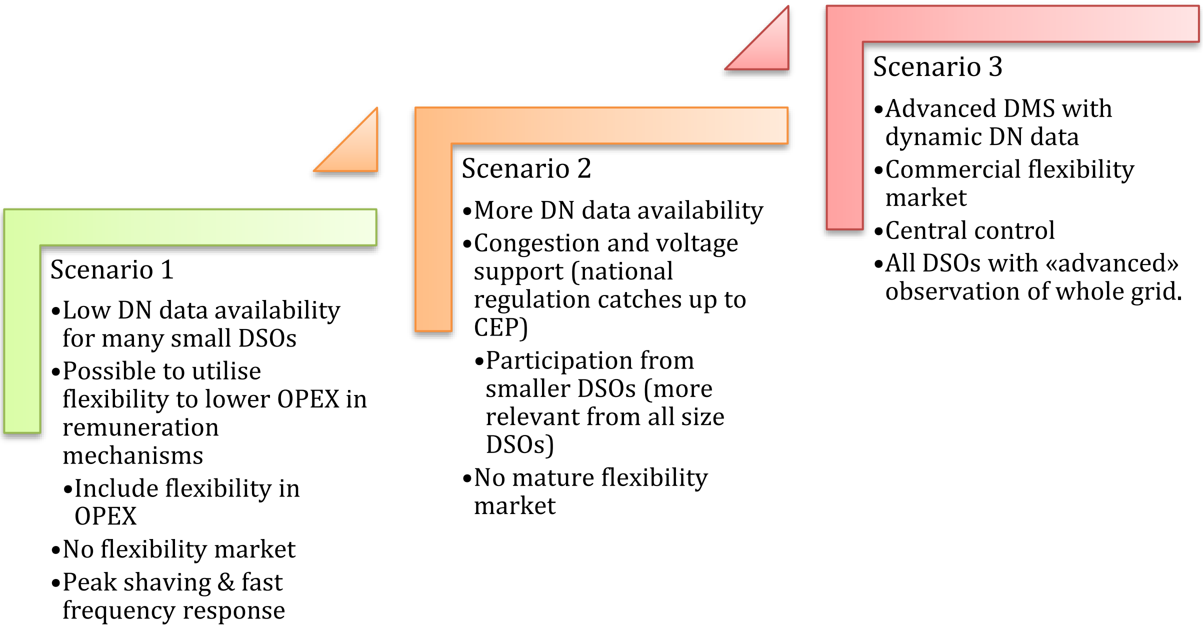

Figure 17: Three scenarios considered in the intermediate business modelling.

Scenario 1 considers developments in today's distribution networks in Europe. This is a context that varies widely across different member states, with DSOs operating in very different conditions. We consider here the most advanced existing markets and regulatory frameworks in Europe with regards to the use of flexibility in network operation.

Generally, there is a significant difference between the possibilities of large DSOs (e.g. serving over 100 000 customers) and what can be deployed by small DSOs. Large DSOs who have a higher capacity to invest in innovation and new infrastructure might have greater observability and DMS capability. This allows for deploying new solutions performing peak shaving and fast frequency response with dispatchable power. Smaller DSOs on the other hand often do not yet have this opportunity and most times lack the dynamic data available to perform advanced flexibility management to solve network constraints. Th

Scenario 2 looks at approximately a 2025-2030 time frame, where different member states have implemented the different provisions of the Clean Energy Package. In this scenario, congestion and voltage support with flexibility services are actively supported by DSOs who are encouraged to act as a facilitator for new energy services. The availability of dynamic data for the distribution network through advanced DMSs is also increasingly available for DSOs. However, this scenario does not include the presence of a mature commercial flexibility market as a clearly regulated entity in most member states.

Scenario 3 foresees a more distant situation, where the regulatory framework is quite different from today's reality. While it is impossible to accurately predict how market frameworks will end up in a distant future (i.e., beyond 2030), it is likely that highly integrated markets will be using high amounts of granular data to manage very distributed generation and storage assets rapidly and efficiently. This assumes that advanced DMSs is the norm among all DSOs, and centralised optimisation of network assets is effectively implementable. We therefore consider more of the low-TRL solutions being developed in WPs 3, 4 and 5.

4.2 Intermediate FLEXGRID Value Propositions

As was demonstrated in the business case analysis in section 2, FLEXGRID caters to stakeholders from across the electricity value chain, both across market and grid domains. It is therefore useful to group the value propositions – at least on a high-level – by the different target customers they address. This is presented in Table 34.

Table 34: High-level FLEXGRID Value Propositions

No.	High-level Value Proposition	Target customer
1	FLEXGRID ATP enables more efficient operation of a DLFM and its integration in today's market architecture and regulatory framework	FMO, MO
2	FLEXGRID enables DSOs to better leverage flexibility to accommodate a larger share of RES in the DN and also confront local congestion and voltage control issues	DSO
3	FLEXGRID enables TSOs to increase the available ancillary service capacity by procuring additional flexibility from DERs	TSO
4	FLEXGRID enables aggregators to improve business case of Flex Suppliers	ESP/Aggregator

Each of these high-level groupings can then be elaborated in a complete, long-list of the FLEXGRID value propositions. These are presented and analysed in the following subsections.

4.2.1 Long-list FLEXGRID value propositions to FMOs & MOs

One of the main target customers of the FLEXGRID components is the FMO. As shown in the business case analysis, the FMO is looking to develop and operate the DLFM in an optimal way, while increasing the service offering to its clients (FlexBuyers and FlexSuppliers). In a business context, it could also be relevant for a traditional MO to buy the services of the ATP for providing new services to their customers. The value propositions are given below.

Table 35: FLEXGRID value propositions for the FMO

No.	FLEXGRID ATP enables more efficient operation of a DLFM
1.1	FLEXGRID enables more efficient flexibility market operation by providing an improved market clearing process
1.2	FLEXGRID enables improved FMO service offering to DSOs and TSOs
1.3	FLEXGRID enables improved FMO service offering to Flex Suppliers

Generally, the FMO operates a flexibility market that is only feasible in scenario 3, but we discuss the potential opportunities for the FMO to provide some added value in scenario 2.

VP 1.1 FLEXGRID allows for more efficient flexibility market operation by providing an improved market clearing process.

FLEXGRID's first value proposition aims to improve the operation of the flexibility market. Here, the FMO's business concern is the operation of the flexibility market in a way that is both efficient and that is reflective of the network constraints. FLEXGRID proposes network-aware market clearing algorithms that work on an auction-basis as well as for continuous market clearing. These algorithms integrate in the FLEXGRID FMCT are described in detail in Deliverable D5.1.

In an auction-based market clearing scenario, the FLEXGRID's convexified AC Optimal Power Flow (AC-OPF) algorithm provides the best dispatch of generators and loads in an electrical network, so that all the physical and operational constraints are respected. The AC OPF algorithm can be adapted in order to achieve the desired cost function:

- Maximization of social welfare,
- Minimization of voltage deviations,
- Minimization of congestions,
- Empty objective function to evaluate the feasibility of a given dispatch.

A challenge to implementing the AC-OPF algorithm in the DLFM is to be able to retrieve meaningful locational marginal prices (LMPs) for active and reactive power.

When moving towards the real-time dispatch of FlexAssets, FLEXGRID provides continuous market clearing algorithms that ensure a low computational runtime while still considering the distribution network constraints. This ensures that bids are only matched if their activation respects the network constraints without saturating network elements and endangering operational security. These continuous, pay-as-bid algorithms provide high social welfare, and a high market utilization factor.

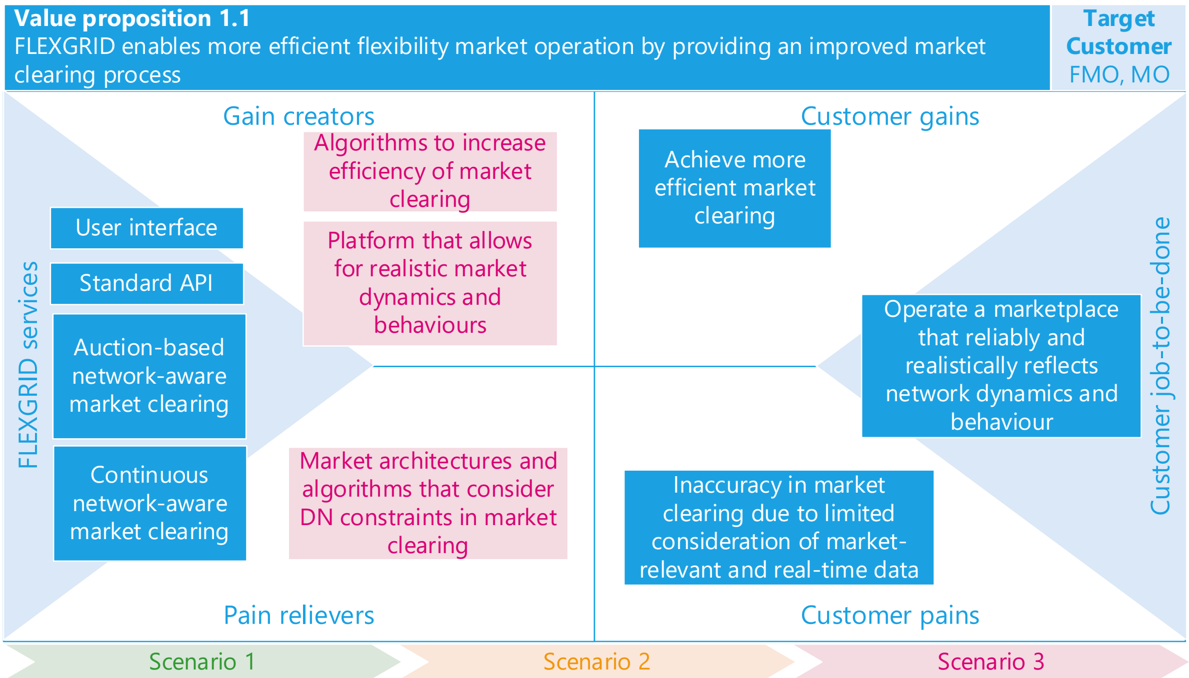

Figure 18: Value proposition canvas for VP1.1 (FLEXGRID enables more efficient flexibility market operation by providing an improved market clearing process).

VP1.2 FLEXGRID allows for improved FMO service offering to DSOs and TSOs.

FLEXGRID's second value proposition supports the FMO's service offering to grid operators. The FMO's main responsibility is to provide an intermediary for FlexBuyers to request and purchase flexibility services. In this context, the more added-value services that the FMO can provide FlexBuyers, the more they will be enticed to utilise the flexibility market to purchase flexibility services.

The FLEXGRID ATP first provides FlexBuyers with a single platform to interact with multiple FlexSuppliers. This is achieved through a standard API which greatly simplifies the integration work needed to obtain demand response services from multiple FlexSuppliers using bilateral contracts. FlexBuyers also are provided with a bespoke GUI that allows them to interact with the ATP and exchange relevant data with the other market actors.

Furthermore, FLEXGRID allows FMOs to clear their market considering the AC-OPF results from the distribution network. This network-aware Flex Market clearing provides DSOs with flexibility at the lowest cost based on market availability.

Finally, the advanced market-clearing algorithms aim to provide the maximal social welfare in the DLFM. This allows FMOs to provide the highest potential value for buying FlexServices on their market.

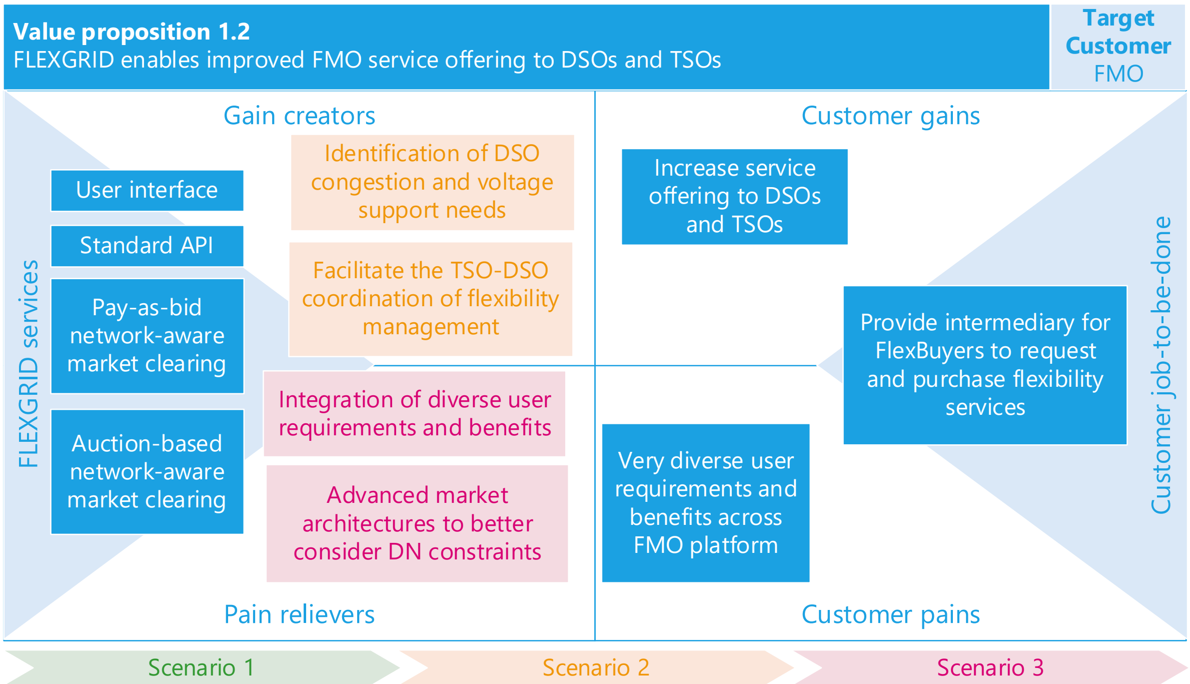

Figure 19: Value proposition canvas for VP 1.2 (FLEXGRID enables improved FMO service offering to DSOs and TSOs).

A major challenge to providing specific services to DSOs and TSOs is the diversity of requirements that this imposes on the FMO's platform.

VP1.3 FLEXGRID allows for improved FMO service offering to Flex Suppliers.

As mentioned in the business case analysis, the FMO can use the different FLEXGRID components to provide an increased value to FlexSuppliers offering flexibility on the market.

The FMO can notably use FLEXGRID's bespoke ESP and Aggregator GUIs to provide FlexSuppliers with a single platform where they can sell their flexibility to multiple FlexBuyers without the need to maintain multiple flex contracts. This lowers the barrier to enter for FlexSuppliers.

Moreover, the maximal social welfare achieved with the advanced market clearing provides an increased value to FlexSuppliers for their flexibility.

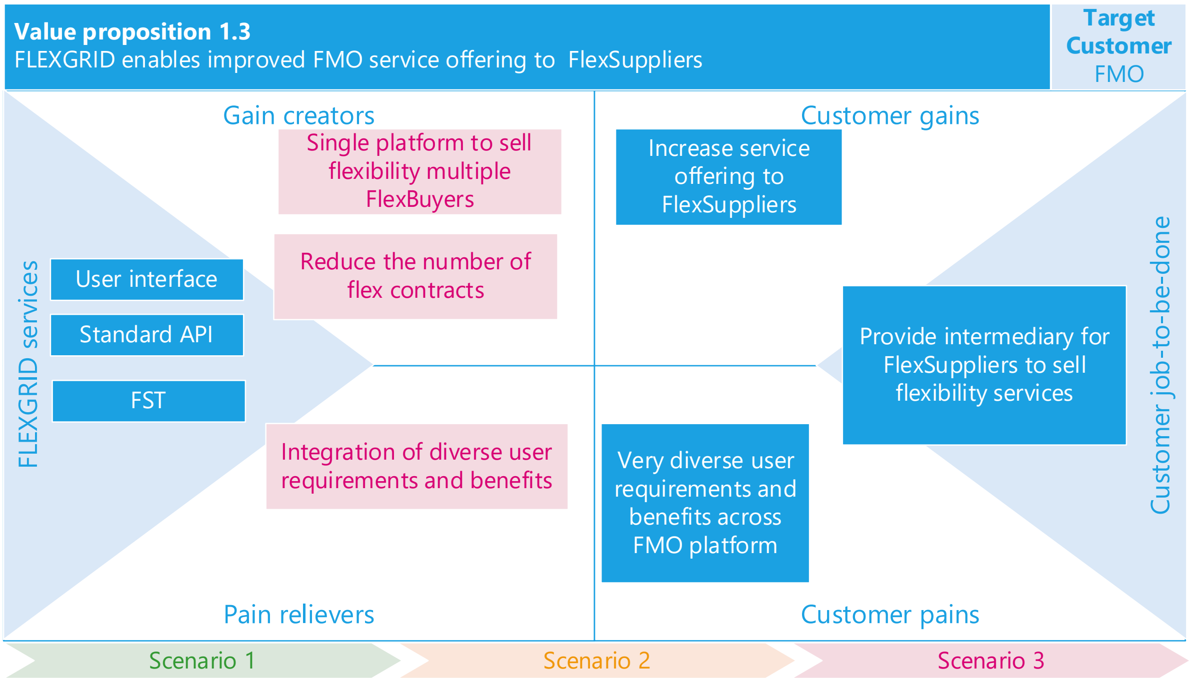

Figure 20: Value proposition canvas for VP 1.3 (FLEXGRID enables improved FMO service offering to Flex Suppliers).

4.2.2 Long-list FLEXGRID value propositions to DSOs

FLEXGRID provides the DSO with specific services that improves its ability to manage the increased presence of RES and other DER assets in its grid. DSOs will effectively be able to plan and operate their grid in this context by utilising Flex Services in a cost-competitive way.

The intelligent FLEXGRID services that are targeted to DSOs are integrated in the FMCT, which can be used as a stand-alone software toolkit for DSOs to identify its flexibility needs. It can also be integrated as a plug-in to another platform such as the FLEXGRID ATP. The value that the aforementioned FLEXGRID services promises to deliver to DSOs can be grouped in the value propositions described in Table 36.

Table 36: FLEXGRID Value Propositions to DSOs

No.	Value Proposition
2.1	FLEXGRID enables DSOs to reduce the capacity payments to upstream network operators through peak shaving
2.2	FLEXGRID enables DSOs to detect and identify congestion and voltage problems in their network
2.3	FLEXGRID enables DSOs to easily procure flexibility services to support the operation of their network
2.4	FLEXGRID enables DSOs to delay or avoid investment in network reinforcement infrastructure by procuring flexibility services
2.5	FLEXGRID enables a coordinated TSO-DSO procurement of flexibility

The following subsections provides a look at each value proposition.

VP2.1 FLEXGRID enables DSOs to reduce the capacity payments to upstream network operators through peak shaving

FLEXGRID enables DSOs to reduce capacity payments to upstream grid operators through peak-shaving. The FLEXGRID platform allows the DSO to model their network and predict the power peaks in the grid. This is highly relevant for DSOs where regulatory frameworks require them to pay capacity tariffs to upstream grid operators. For example, German DSOs pay a tariff based on the highest 15-minute power peak of the year; the ability to accurately predict and shave the power peaks translates in direct savings to the DSO.

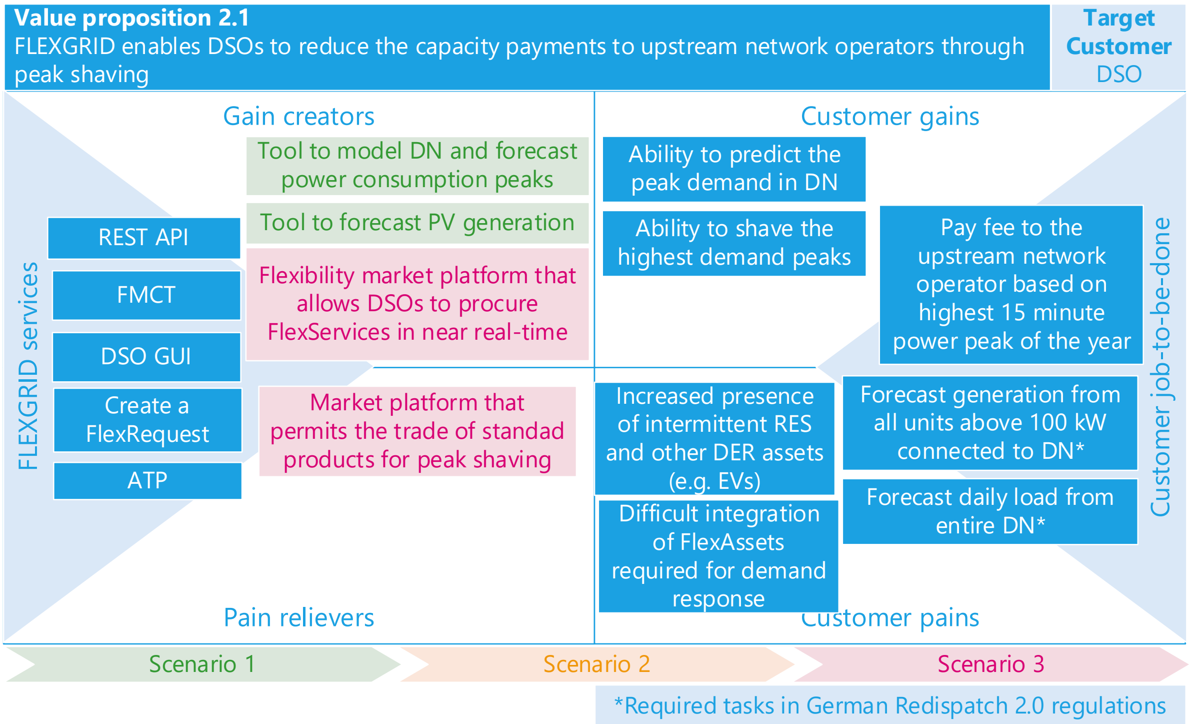

Figure 21: Value proposition canvas for VP 2.1 (FLEXGRID enables DSOs to reduce the capacity payments to upstream network operators through peak shaving).

The main challenge of this peak-shaving value proposition is to accurately forecast the consumption peaks and effectively manage the flexibility in the network to shave them at the right time. The difficulty in predicting the peak power consumption is the fact that these power peaks are generally outliers and are difficult to predict using historical consumption data. Meanwhile the guarantee of activation of dispatchable capacity is required for a DSO to rely on flexibility services for this peak shaving.

In scenario 3, where a DLFM can operate close to real time, FLEXGRID's ATP can be deployed for the DSO to procure peak shaving services in a DLFM that is using the FMCT's continuous market clearing algorithm. While there is a risk that there may not be sufficient liquidity in the market to provide peak shaving when consumption peaks are predicted, a flexibility market with high liquidity could potentially reduce the risk of not shaving the peak compared to relying on a single FlexAsset through a bilateral contract.

Finally, besides its importance for peak shaving to reduce capacity payments, German DSOs will need to produce a daily generation forecast for all units above 100 kW as well as a daily load forecast for their entire network under new Redispatch 2.0 regulations described in section 1.2.2.

VP 2.2 FLEXGRID enables DSOs to detect and identify congestion and voltage problems in their network.

FLEXGRID enables DSOs to identify potential line congestions and voltage problems in their network in the context of an increased share of intermittent RES connected at the distribution level. To achieve this, FLEXGRID's "identification of flexibility needs" module allows a DSO to use the AC-OPF algorithm to identify potential line congestions and voltage deviations in their network.

This can provide value to a DSO in different contexts depending on the maturity of their network infrastructure. For example, in scenario 1, this could give the DSO an opportunity to conduct an analysis with static data to determine its flexibility needs in the long-term future. This could provide the DSO insight into the need for flexibility to operate the grid infrastructure in specific scenarios.

This can also be utilized by DSOs to identify potential congestions and voltage problems in their network on a day-ahead timeframe. This provides the DSO with information on the flexibility needs to make a day-ahead FlexRequest.

Last, in more distant scenarios 2 and 3 where more dynamic network data is available from advanced DMS, the DSO could use this functionality to identify their flexibility needs in near real-time.

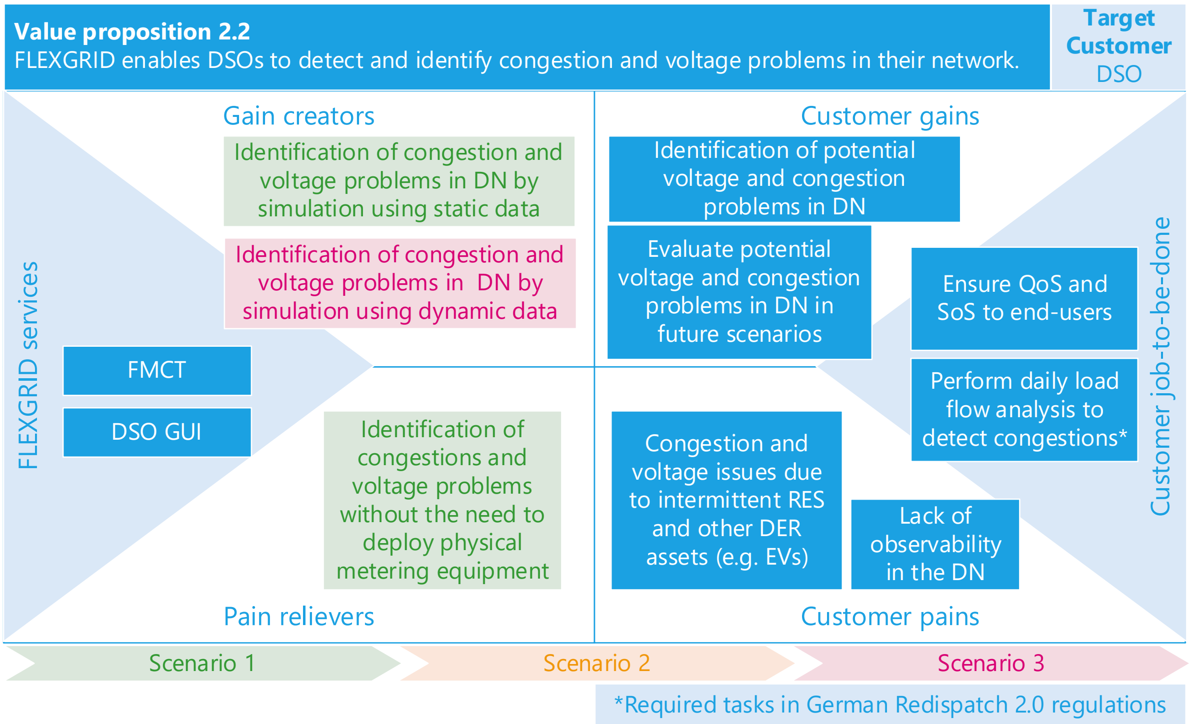

Figure 22: Value proposition canvas for VP 2.2 (FLEXGRID enables DSOs to detect and identify congestion and voltage problems in their network).

The ability to achieve greater observability at in DN level – especially in LV levels – has been increasingly relevant with the uptake of intermittent RES in the system. For this reason, the simulation-based identification of congestions and voltage problems using the relaxed AC-OPF algorithms together with generation and load forecasts can be very valuable for DSOs looking to achieve increased observability in the grid without the need to deploy extensive metering infrastructure. This is notably one of the tasks that is mandated to DSOs in Germany under the Redispatch 2.0 regulations described in section 1.1.2.

On the other hand, the specific issue of voltage quality is considered a local problem in the DN: the value of monitoring this from a central platform like the FMCT is unsure. It might not necessarily be more beneficial than integrating the voltage control functionalities locally, for example directly in PV inverters.

VP 2.3 FLEXGRID enables DSOs to easily procure flexibility services to support the operation of their network.

Building on the previous value proposition, FLEXGRID provides a platform for DSOs to easily procure flexibility services in a market-based way to support the operation of their network. The FMCT's Create a FlexRequest functionality transforms the DSO's flexibility needs into FlexRequests directly in the web-based dashboard. The integrated FLEXGRID ATP then integrates all FlexRequests and FlexOffers and clears the market while considering the DN constraints. This network-aware Flex Market clearing provides DSOs with flexibility at the lowest cost based on market availability.

FLEXGRID's integrated architecture also facilitates the DSOs technical and operational flexibility management with FlexSuppliers compared to bilateral flexibility service exchange. The ATP reduces the integration burden for DSOs – and FlexSuppliers – who utilize the standard FLEXGRID REST API to handle information exchange. This also simplifies the contract management for the DSO which does not need to maintain multiple contracts with many different FlexSuppliers.

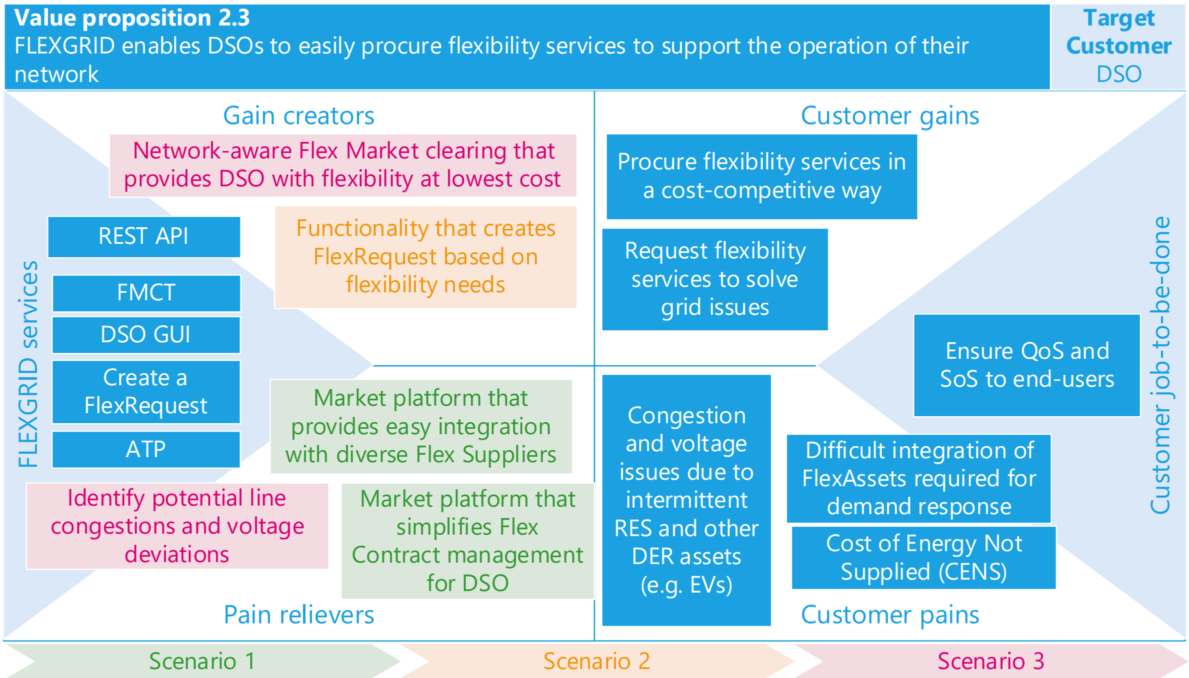

Figure 23: Value proposition canvas for VP 2.3 (FLEXGRID enables DSOs to easily procure flexibility services to support the operation of their network).

This value proposition depends on the DSO's capacity to implement flexibility management solutions in their operations. First, the availability of dynamic network data is needed to make accurate FlexRequests that can be used to support grid operation. This might be most feasible in an intermediate scenario 2, where advanced DMSs are adopted by most DSOs. Meanwhile, the use of the flexibility platform in a DSO's operations depends on the guaranteed availability of flexibility in the specific feeders where line congestions and voltage issues are expected.

VP2.4 FLEXGRID enables DSOs to delay or avoid investment in network reinforcement infrastructure by procuring flexibility services.

The DSO can utilise the FLEXGRID services to develop an effective strategy in planning for new investments in its network. This is highly beneficial for DSOs that expect a rapid increase in installed RES and intermittent DER in their grid.

Building on VP2.2, the FMCT provides the opportunity to perform scenario analysis to identify potential voltage and congestion problems in the future. With this information, DSOs can evaluate the feasibility of delaying or minimising CAPEX investment in new infrastructure by procuring flexibility services. This enables DSOs to:

- increase the hosting capacity of existing infrastructure, avoiding the need to invest in new infrastructure where possible.
- delay infrastructure upgrades where flexibility can be utilized until new infrastructure is planned.
- evaluate the optimal investment strategy in CAPEX in new infrastructure and OPEX in procurement of flexibility to support the network operation.

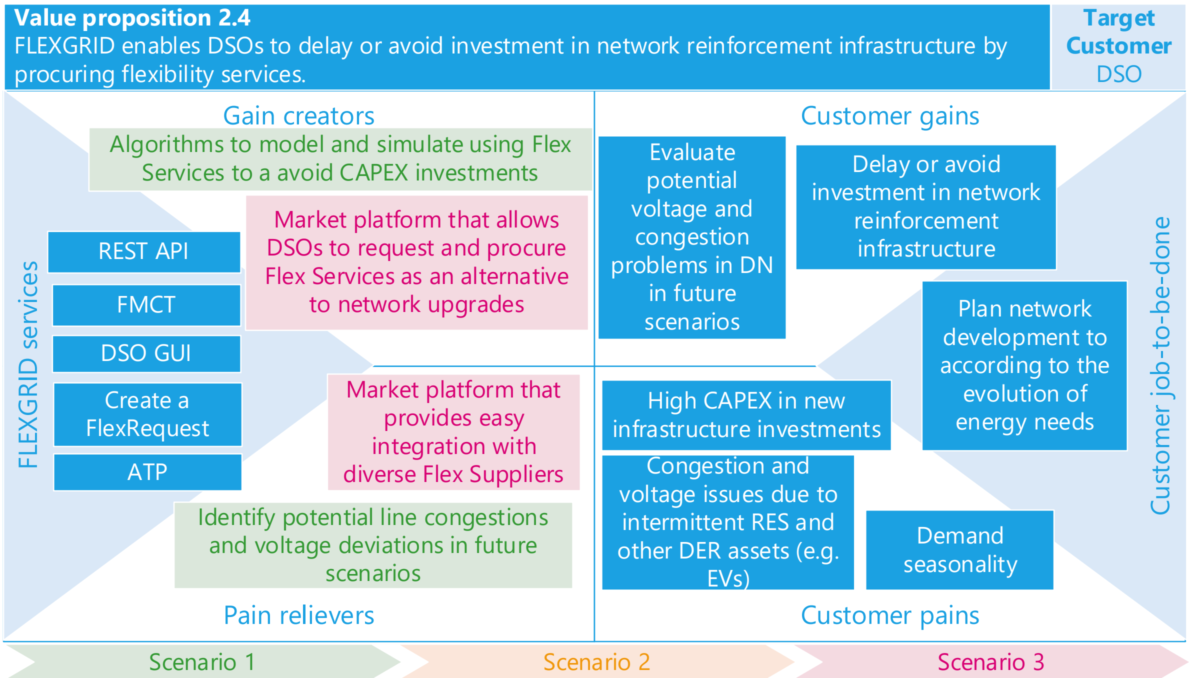

Figure 24: Value proposition canvas for VP 2.4 (FLEXGRID enables DSOs to delay or avoid investment in network reinforcement infrastructure by procuring flexibility services).

This value proposition could be performed in scenario 1 using static network data, where a DSO can evaluate their infrastructure development needs considering the possibility to use flexibility to support network operations. In more mature scenarios, where dynamic network data is available through advanced DMS, the ATP can be deployed as a platform to request flexibility as an alternative to network upgrades.

VP2.5 FLEXGRID enables a coordinated TSO-DSO procurement of flexibility

With the increase in penetration of RES in the electricity network, DSOs and TSOs are expected to compete for procuring flexibility services from the same FlexAssets connected at the distribution level. FLEXGRID allows for a coordinated procurement of flexibility between DSOs and TSOs, where the flexibility settlement is allocated to where it has the highest value on the market. The FLEXGRID ATP provides this possibility via its standard REST API in which interactive message exchange can be realised.

Furthermore, the auction-based market clearing algorithms consider the DN constraints when settling the market so that flexibility will only be activated if it can be delivered without saturating network elements and endangering operational security.

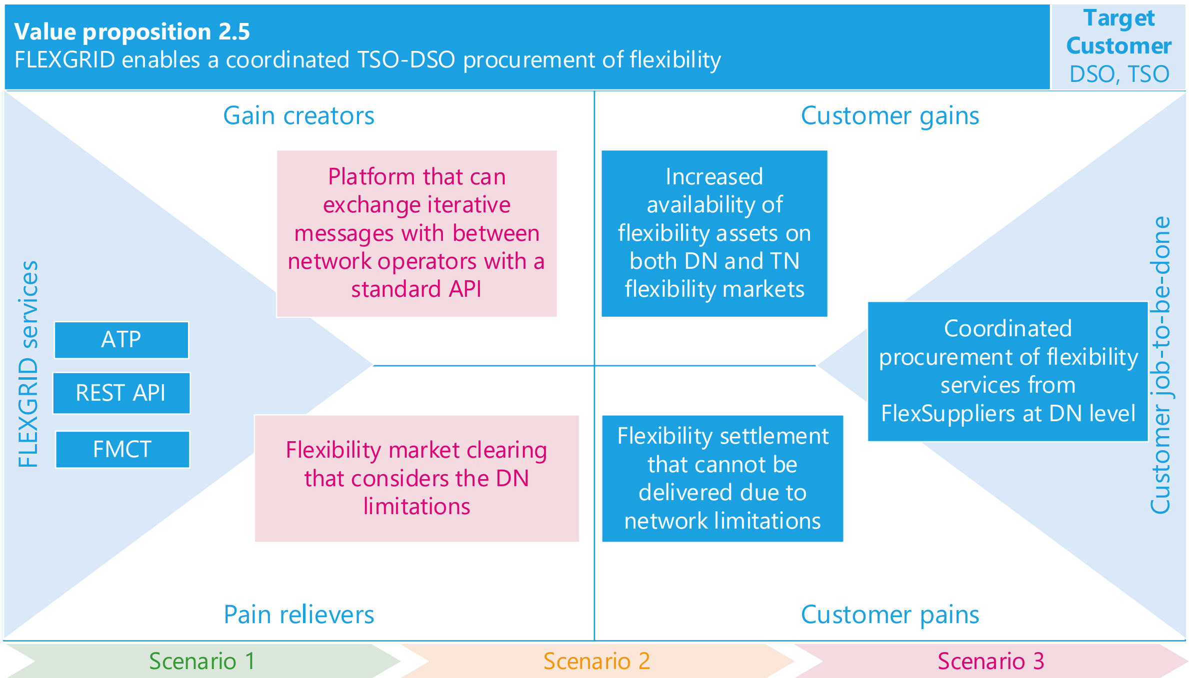

Figure 25: Value proposition canvas for VP 2.5 (FLEXGRID enables a coordinated TSO-DSO procurement of flexibility).

This is more relevant in the more futuristic scenario 3. It requires a well-established DMS and ICT infrastructure by the DSO as well as a commercial DLFM. It also requires a coordination centre (i.e. IT infrastructure and platform) for the TSO-DSO collaboration.

4.2.3 Long-list FLEXGRID value propositions to TSOs

While the FLEXGRID FMCT's components are designed to provide intelligence to the DSO, the ATP does provide value to the TSO as well, as listed in Table 37.

Table 37: FLEXGRID Value Propositions to TSOs

Number	FLEXGRID allows TSOs to increase the available ancillary service capacity
2.6 (ref. Table 36)	FLEXGRID allows for a coordinated TSO-DSO procurement of flexibility
3.1	FLEXGRID allows TSOs to reduce the reserve capacity procurement cost by procuring flexibility from the distribution level

VP3.1 FLEXGRID enables TSOs to reduce the reserve capacity procurement cost.

FLEXGRID provides TSOs an access to buy flexibility from the distribution level when there is a lack of reserve capacity in the TSO markets or when the prices for flexibility is lower on the distribution level than at the transmission level. This allows TSOs to reduce their reserve capacity procurement costs.

With an access to the DLFM through the FLEXGRID ATP, the TSO can purchase flexibility products that respect the TSO ancillary product requirements from FlexSuppliers connected at the distribution level. This single connection to the ATP notably simplifies the TSO's process of qualifying FlexSuppliers.

It also lowers the administrative barrier for FlexSuppliers, who can provide flexibility services to DSOs and TSOs without having to manage multiple contracts. In turn, for the TSO, this supports an increase in FlexSuppliers capable of providing them with reserve capacity – thus lowering the cost of reserve capacity due the increased offer.

Last, the integrated ATP provides TSOs with a single platform to interconnect with using a standard API. This simplifies the ICT infrastructure that the TSO needs to maintain in order to procure flexibility from distributed FlexAssets.

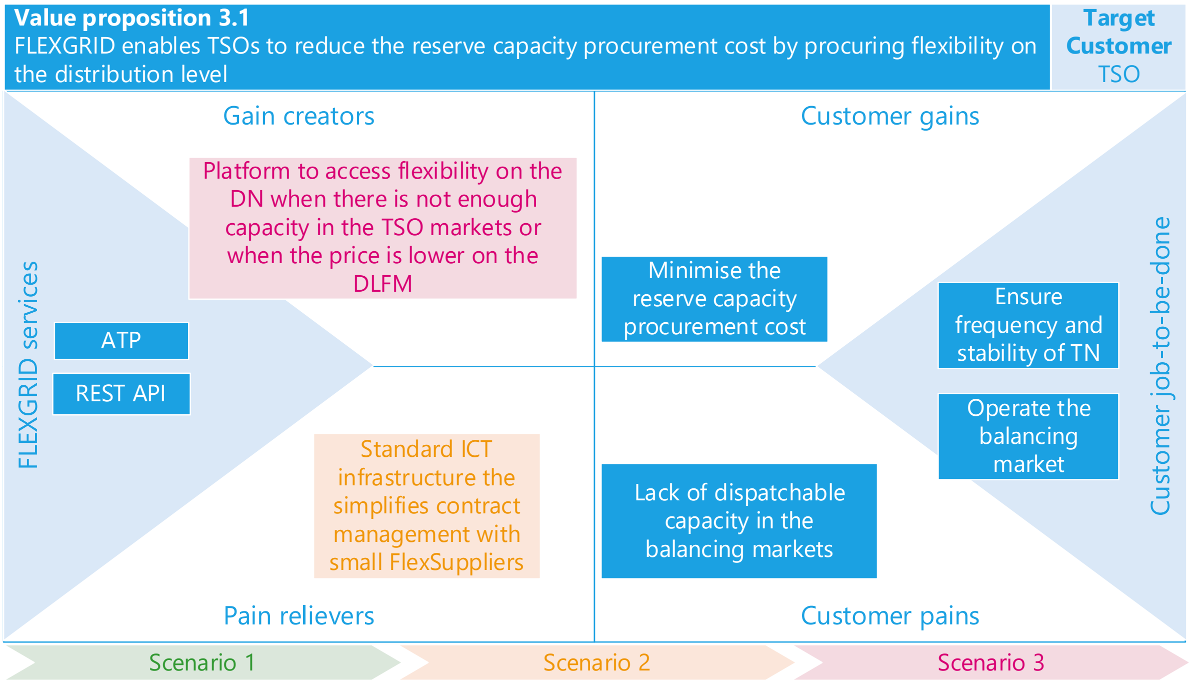

Figure 26: Value proposition canvas for VP 3.1 (FLEXGRID enables TSOs to minimise their reserve capacity procurement cost).

In order for the TSOs to be able procure flexibility from the DLFM, the market architecture should allow the TSOs to bid on the DLFM. Furthermore, the DLFM should contain flexibility products that respect the ancillary service requirements. This requires a prequalification process for the FlexSuppliers in order for them to sell FlexServices to the TSO.

4.2.4 Long-list FLEXGRID value propositions to FlexSuppliers

ESPs can utilise the FLEXGRID services to improve how they operate FlexAssets to obtain an increased profit. This includes increased revenues from selling FlexServices, reducing OPEX, and improving the business case in new asset investment.

FLEXGRID provides services specifically aimed at improving the business of Aggregators. This gives aggregators the capacity to formulate FlexOffer, react to FlexRequests, and provide market-based incentives to prosumers for the provision of flexibility in an aggregated portfolio. These functionalities are included in the AFAT.

Table 38: FLEXGRID value propositions for FlexSuppliers

Number	FLEXGRID enables aggregators to improve business case of FlexSuppliers
4.1	FLEXGRID enables FlexSuppliers to increase the profit from selling flexibility on one or multiple markets (i.e. revenue stacking)
4.2	FLEXGRID enables BRPs to reduce portfolio imbalance
4.3	FLEXGRID enables RES suppliers/Aggregators to reduce RES curtailment
4.4	FLEXGRID enables improved investments in FlexAssets
4.5	FLEXGRID enables aggregators to maximise their profits from managing a portfolio of FlexAssets
4.6	FLEXGRID enables aggregators to maximise social welfare in a portfolio of prosumer FlexAssets
4.7	FLEXGRID enables aggregators to minimise prosumer discomfort in an aggregated portfolio

In the scenario with a commercial DLFM (scenario 3), an ESP benefits from all of the functionalities of the FST and can use the ATP's GUI to directly offer flexibility on the DLFM. However, the FLEXGRID services can also provide value to ESPs in scenarios 1 and 2. This described in the following subsections.

VP4.1 FLEXGRID allows FlexSuppliers to increase the profit from selling flexibility

FLEXGRID provides the possibility for FlexSuppliers to increase their assets' profitability from selling flexibility on different markets. For this, the FLEXGRID FST provides the "Stacked revenue maximisation" functionality which optimises the bidding strategy that a FlexSupplier should carry out to maximise the profits that can be obtained considering the following markets.

- Day-ahead Energy market: energy market operated by a NEMO,
- Intraday Energy market: energy market operated by a NEMO,
- TSO Balancing markets (Primary, Secondary and Tertiary),
- Day-ahead Distributed Local Flex Market: R-DLFM proposed by WP5.

The "stacked revenue maximization" function is performed by the "optimal bidding algorithm" described in D4.1. This algorithm considers the market price forecasting, energy prosumption forecasting and information on the network topology to derive an optimal schedule for the FlexAssets and a bidding strategy that maximizes profits.

The optimisation also considers the reduction of RES curtailment where a RES generation unit might lose revenue when curtailed.

In scenario 1, a FlexSupplier can use historical market price data to make a statistical analysis in order to improve investment decisions or, for example, to decide in the best markets where selling flexibility might return the highest profits.

In scenario 2, a FlexSupplier with access to dynamic data can use this dynamically to improve operational profit margins by optimally bidding on the different markets.

In a business context, with unbundling requirements between DSOs and other market actors, it is unsure how much dynamic network data will be available to commercial FlexSuppliers that can be used in their optimal scheduling. We therefore consider that this value proposition might be available to FlexSuppliers in a more distant scenario 3.

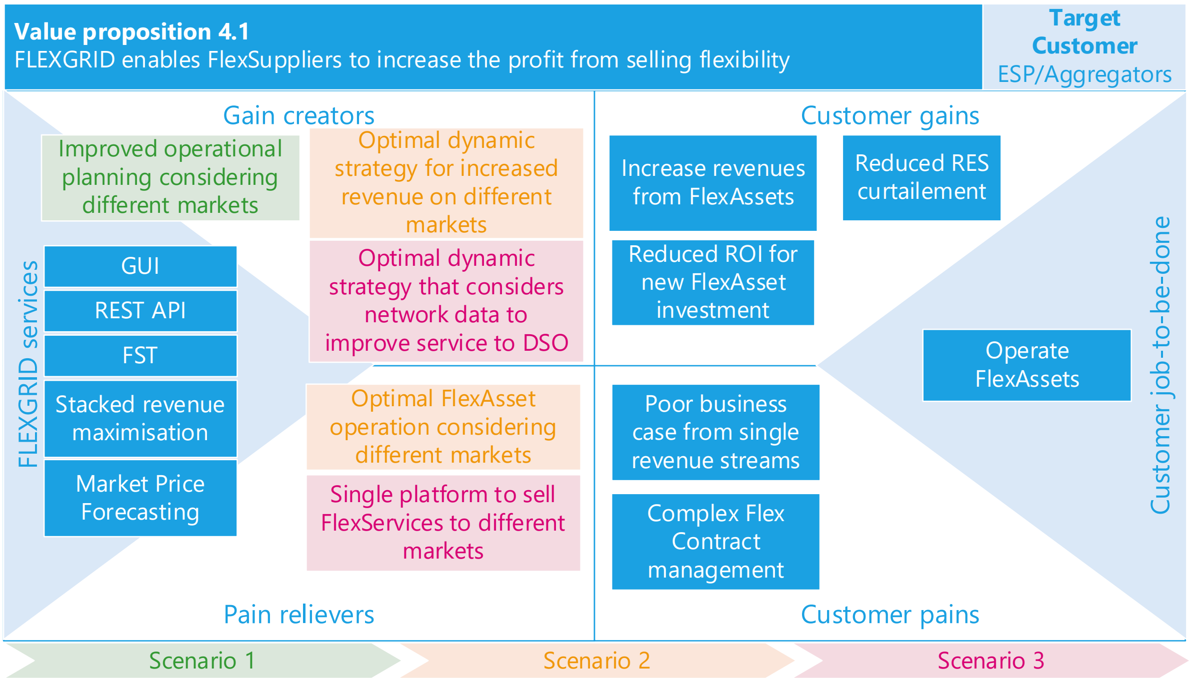

Figure 27: Value proposition canvas for VP 4.1 (FLEXGRID enables FlexSuppliers to increase the profit from selling flexibility).

The possibility to use dynamic data to implement the optimisation algorithm in operations makes this value proposition, but a challenge in implementing for FlexSupplier operations is the ability to accurately forecast FlexAsset prosumption profiles. An inaccurate forecast might completely ruin the business case for an ESP/aggregator trying to exploit this value proposition. This evaluation of the forecasting algorithms will be evaluated in the context of the bnNETZE pilot in the WP7 activities.

Furthermore, FlexAssets are often used for multiple purposes in order to make their investment case more attractive. For instance, a battery storage system (BSS) might be used to provide multiple stacked services which might not be related to Flexibility – e.g., as a backup power unit for a hospital. In many cases, the main purpose of the FlexAsset is not related to energy – e.g., smart charging of EVs. In the worst case, a FlexAsset can be dispatched for a FlexService that might hinder its primary functionality. However, an ESP/aggregator could generally set a priority or failsafe mechanism to avoid this.

VP4.2 FLEXGRID enables BRPs to reduce portfolio imbalance

FLEXGRID enables ESP/aggregators that are BRP to the FlexAssets they operate, to reduce their portfolio imbalance. The FLEXGRUD FST includes the "Minimise ESP's OPEX" which provides cost minimizing schedules to FlexAsset portfolios.

This optimisation described in D4.1 considers improved battery models with realistic charging and discharging characteristic to achieve more accurate prosumption forecasting. This improved forecasting reduces the error and corrective actions that result to undesired balancing costs.

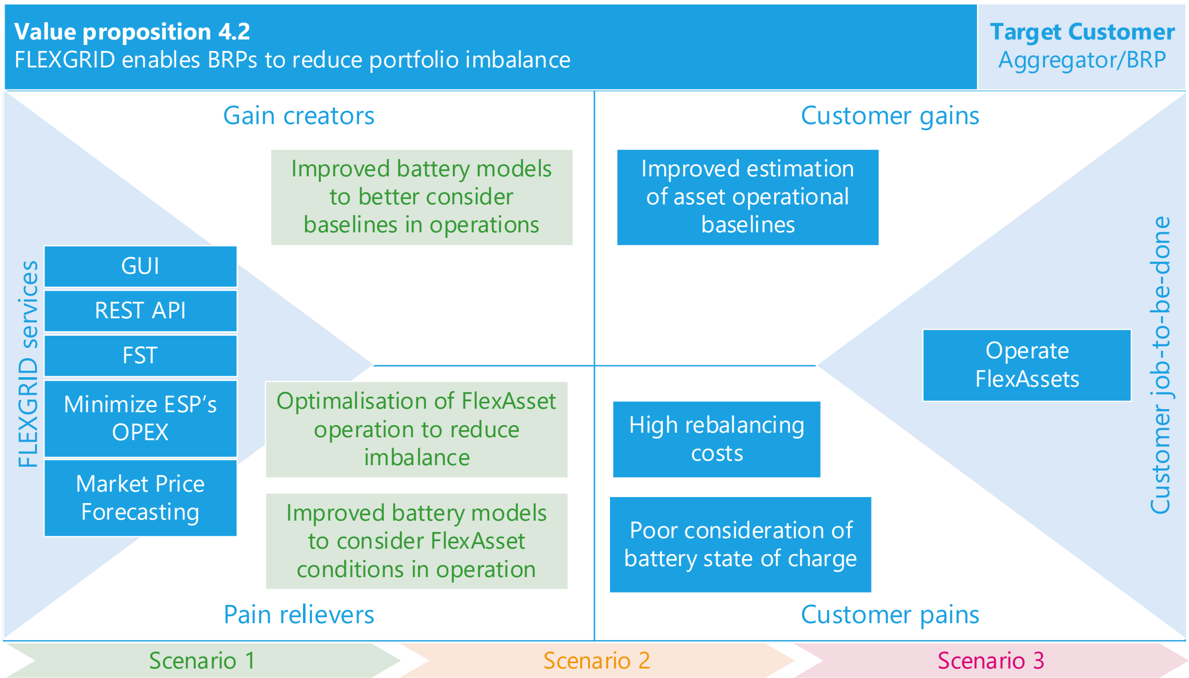

Figure 28: Value proposition canvas for VP 4.2 (FLEXGRID enables BRPs to reduce portfolio imbalance).

VP4.3 FLEXGRID enables Retailer/Aggregators to reduce RES curtailment

FLEXGRID can enable retailers/aggregators to reduce the curtailment of RES assets. This provides financial value where RES curtailment translates to lost revenue from generation assets. It also provides value towards achieving a more sustainable energy system, where RES assets can be prioritised instead of fossil fuel generation.

Both the optimal bidding algorithm and optimal scheduling algorithm modules consider the reduction of RES curtailment. A retailer/aggregator can therefore dynamically dispatch FlexAssets in order to reduce RES curtailment.

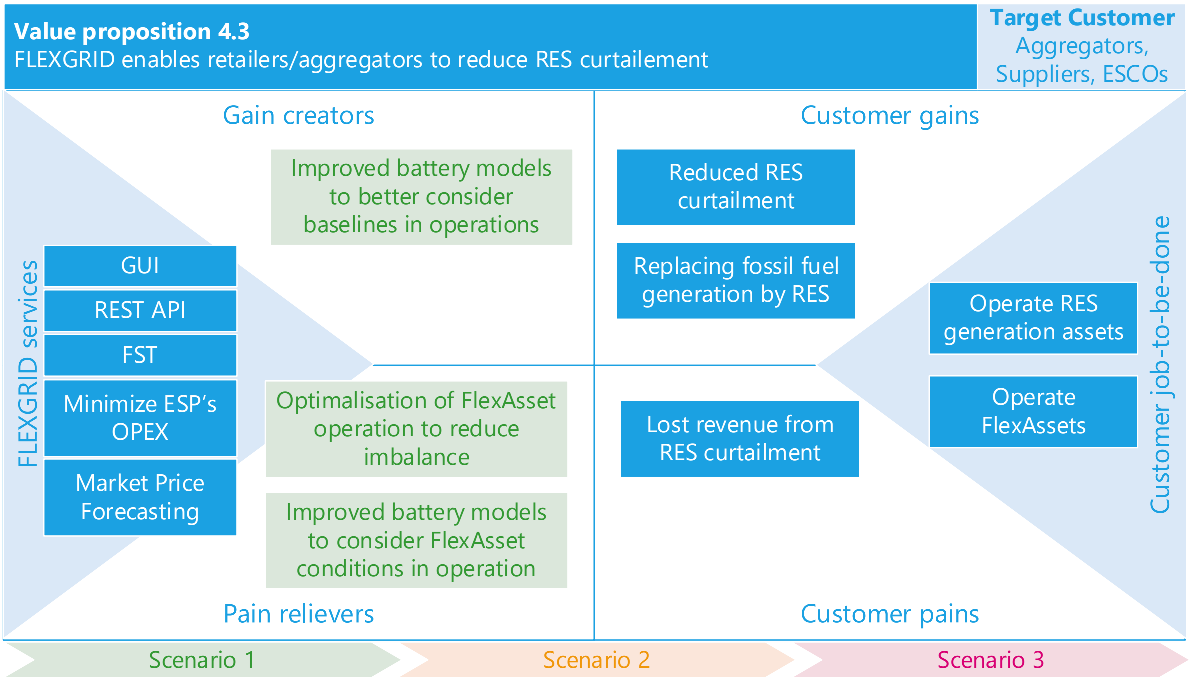

Figure 29: Value proposition canvas for VP 4.2 (FLEXGRID enables retailer/aggregators to reduce RES curtailment.

VP4.4 FLEXGRID enables improved investments in FlexAssets

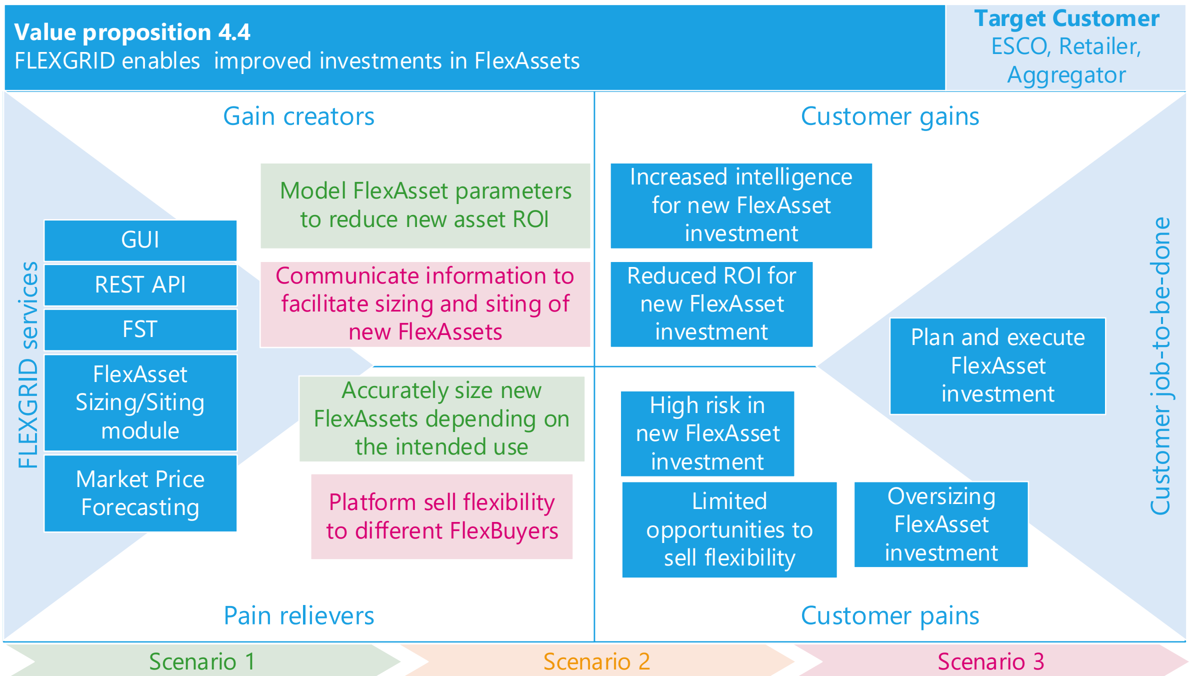

Figure 30: Value proposition canvas for VP 4.4 (FLEXGRID allows for improved investments in FlexAssets).

FLEXGRID assist in planning and investing in new FlexAssets. For this, FLEXGRID proposes the FlexAsset sizing/siting module which a FlexSupplier can use to determine the optimal parameters that can reduce the ROI of a new FlexAsset. This algorithm aims to find the best siting configurations, sizing configurations, asset characteristics and revenue streams that can help the investment case of a new FlexAsset.

Different types of ESPs (e.g., ESCOs, retailers, aggregators) can therefore consider multiple factors that might improve or hinder the performance of FlexAssets over their operational lifetime. Such factors include technological characteristics, design characteristics, market prices and forecasted generation and consumption curves. This can be performed using historical data available.

Furthermore, in a case where information on the network topology could be communicated to FlexSuppliers, this information could be used to facilitate the sizing and siting of new FlexAssets in order to provide better support to DSOs in operating their network. As discussed in section 0, this is a rather futuristic business case for DSOs and is relevant for more the more futuristic scenario 3.

VP4.5 FLEXGRID enables aggregators to maximise their profits from managing a portfolio of FlexAssets

FLEXGRID helps aggregators optimise the dispatch of FlexAssets in their portfolio in order to maximise their own profits. This can be performed either reactively, allowing an aggregator to react to a FlexRequest from a FlexBuyer or proactively, where an aggregator creates a FlexOffer based on the optimal dispatch of FlexAssets at a given time. These strategies are carried out using the "Manage a FlexRequest" and "Create a FlexOffer" functionalities in the AFAT.

When responding to a FlexRequest, the flexibility aggregation algorithm module in the AFAT aims to find the optimal activation of FlexAssets in its portfolio considering the revenues that the aggregator gains from the activation payments as well as the cost of acquiring and activating flexibility from end-users. This cost considers both the "actual" costs (i.e., market and retail price) and costs determined by prosumers' preferences.

On a proactive basis, the "Create a FlexOffer" allows to automatically compose optimal FlexOffers to bid into different markets. These FlexOffers are designed to be:

- Concise: preserving the privacy of FlexAsset constraints and end-user information,
- Informative: providing enough information about FlexAssets needed to provide a FlexService,
- General: allowing for different types of FlexAssets (e.g., batteries, EVs, thermal storage, heating, ventilation, and air conditioning (HVAC) systems, etc.)
- Real-time: allowing aggregators to use the algorithm online in operations to dynamically create FlexOffers.

The ATP also proposes "B2C flex market" mechanisms which allow aggregators to incentivise prosumers to provide more flexibility to the portfolio. These mechanisms use intelligent agents that respond to iterative auctions, and financial reward each end-user for providing flexibility.

While using the functionalities online in the dynamic management of portfolio assets requires a mature communication infrastructure that exchanges high amounts of data, an aggregator can perform offline analysis with historical data the simulates different pricing schemes in order to propose new contracts to prosumers that incentivise them to make their flexibility available.

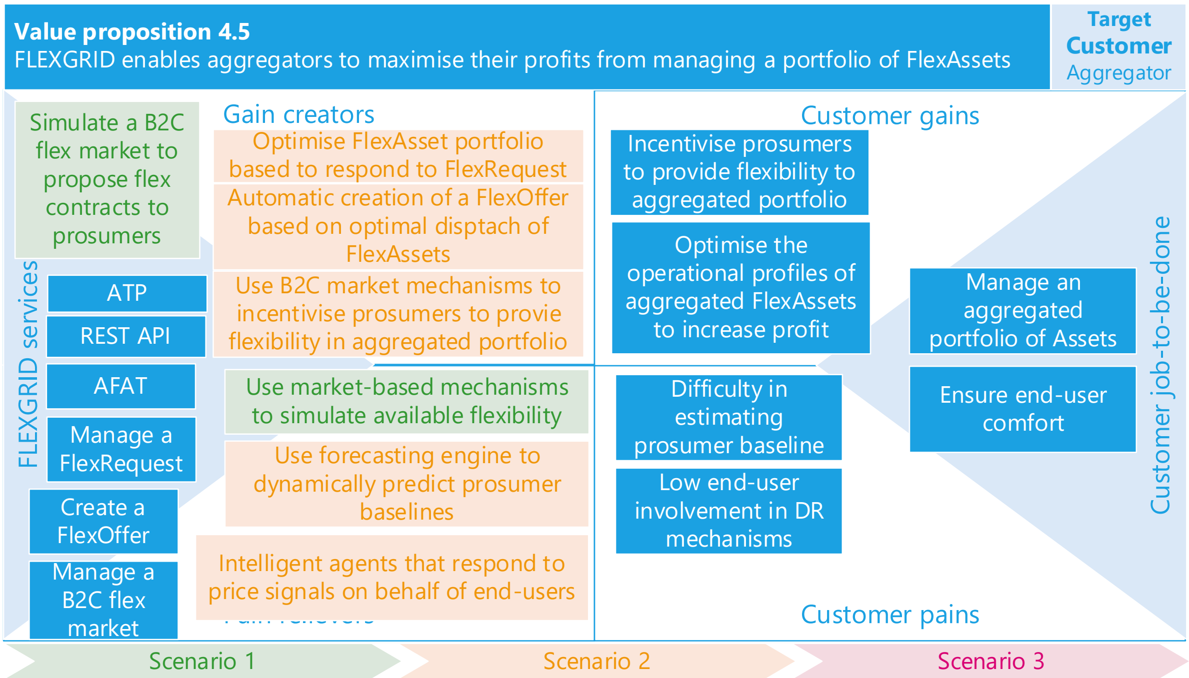

Figure 31: Value proposition canvas for VP 4.5 (FLEXGRID enables aggregators to maximise their profits from managing a portfolio of FlexAssets).

VP4.6 FLEXGRID enables aggregators to maximise social welfare in a portfolio of prosumer FlexAssets

The “manage a B2C flexibility market” functionality included in the FLEXGRID AFAT enables aggregators to provide the maximum payoff to all participants in the aggregated portfolio. This is particularly relevant to aggregators because it allows them to do so without knowing the local functions (consumption habits and comfort levels) of each user – which are often private information.

In this case, the aggregator carries out an iterative auction-based mechanism where each prosumer is rewarded for allocating flexibility in the B2C market. This way, the aggregated portfolio is optimised for social welfare maximisation. The approach is incentive-compatible, and also allows for a scalable implementation.

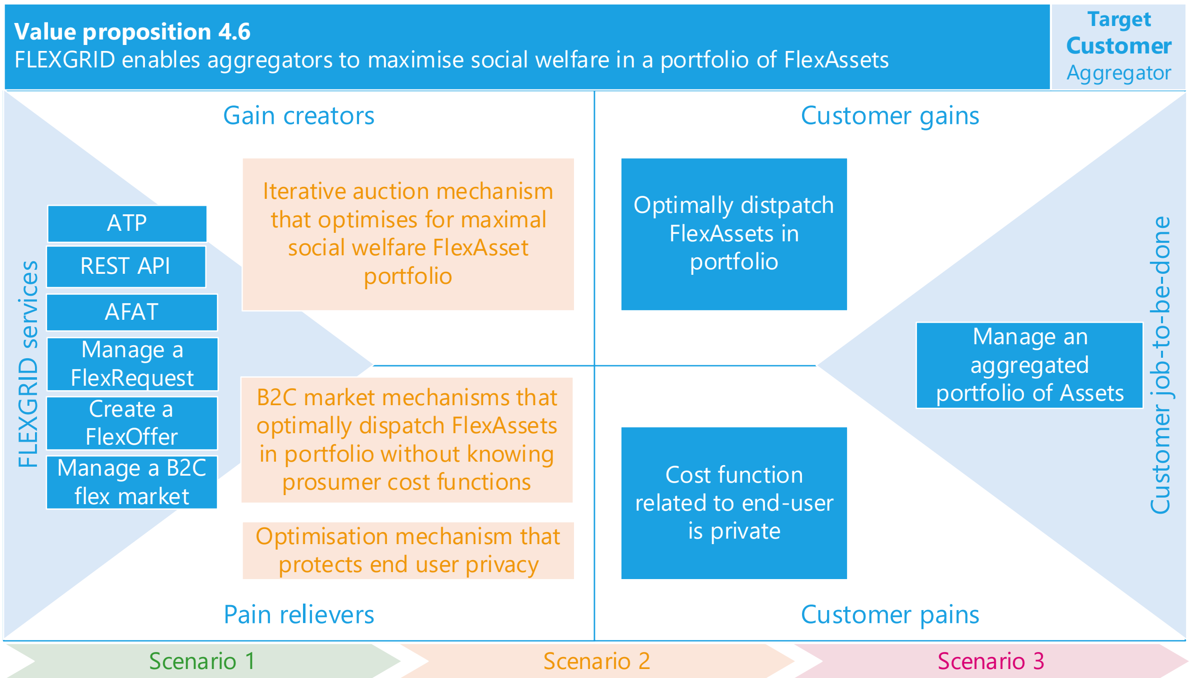

Figure 32: Value proposition for VP 4.6 (FLEXGRID enables aggregators to maximise prosumer welfare in a portfolio of prosumer FlexAssets).

VP4.7 FLEXGRID enables aggregators to minimise prosumer discomfort in an aggregated portfolio

In many cases, FlexAssets serve a primary purpose that is not related to energy – e.g., smart charging of EVs, HVAC systems. Using the flexibility from these assets to sell in FlexServices risks causing a certain level of discomfort to end-users. Different types of FlexAssets have varying levels of discomforts caused by having to interrupt their primary function, ranging from minor inconvenience to major failure. The FLEXGRID AFAT's flexibility optimisation algorithms allow to minimise the prosumer discomfort in the aggregated portfolio.

This is considered in the flexibility contracts in the "Manage a FlexRequest" functionality, where end-users define their own comfort parameters. It is also considered in the auction-based optimisation in the B2C flexibility market function, where prosumer discomfort parameters are kept private.

This is particularly valuable for aggregators who might struggle to incentivise risk-averse prosumers to make their flexibility available. In this case, the aggregator could simulate a B2C flex market that considers the desired (or necessary) comfort parameters. This could be used as a basis for proposing flexibility contracts to the end-users that guarantee their comfort levels (i.e., quality of service) required to participate in the aggregated portfolio.

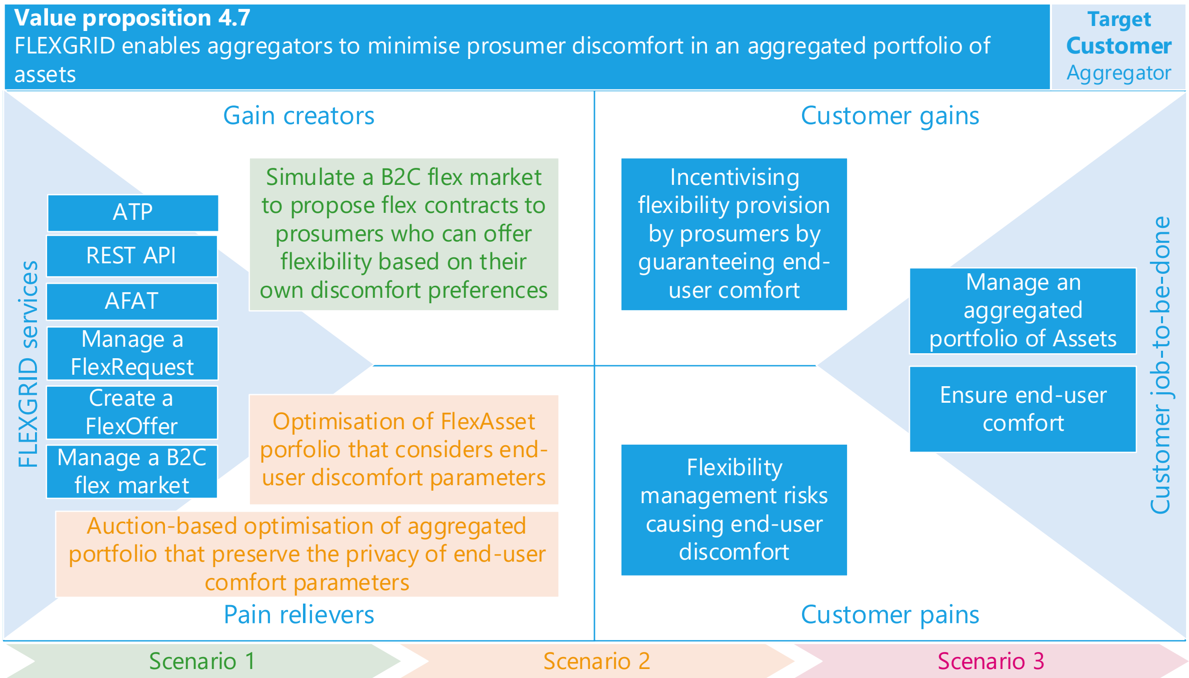

Figure 33: Value proposition canvas for VP4.7 (FLEXGRID enables aggregators to minimize prosumer discomfort in an aggregated portfolio of assets).

4.3 Intermediate Business Models

The FLEXGRID value propositions described in the previous subsection provide the basis for certain highly relevant business models. These business models are suggested as grounds for commercial exploitation of some of the FLEXGRID KERs, and a way to provide new, valuable services in the electricity domain. Each business model is briefly summarised and presented with alongside a business model canvas to give an overview of the structure of the different components.

Table 39: List of intermediate business models

	Intermediate Business Models
1	FLEXGRID platform for flexibility market operation
2	Flexibility Market Operator (FMO) – using the FLEXGRID functionalities to provide increased value to prosumers
3	FLEXGRID platform for DSOs
4	FLEXGRID platform for FlexSuppliers
5	Aggregator – using the FLEXGRID functionalities to provide increased value to prosumers

Each business model is discussed qualitatively to provide a basic understanding of the potential for value creation based on the FLEXGRID KERs. As is core to the build-measure-learn process described in the methodology (section 4.1), and indications are given about certain value hypotheses which should be tested in the subsequent work in WP8. Steps required for this validation is explored to be considered for the further activities.

4.3.1 Intermediate business model: FLEXGRID platform for flexibility market operation

The foremost challenge that the FLEXGRID concept was designed to address is the interaction of different energy sector stakeholders in order to effectively exchange energy services that allow a smooth management of an electricity grid with a high penetration of RES.

The first business model presented here is that of a software provider that sells the FLEXGRID software platform (i.e., the ATP and is functionalities) to flexibility market operators in order to improve the operation of flexibility markets. The target customer of this business model is therefore the FMOs, who could buy the FLEXGRID software components using a software-as-a-service (SaaS) to use the FLEXGRID functionalities to support the flexibility market operation. The FLEXGRID services could also be sold to a traditional MO who could therefore propose a flexibility market themselves (i.e., taking the role of the FMO).

The important distinction for this business model compared to that of the FMO (presented in section 4.3.2) is that the software platform provider does not carry out the operation of the market. The platform provider could then also sell the same platform and functionalities to a competing market operator. While it might be strategic for an FMO to integrate some of the FLEXGRID functionalities into its core business and provide them exclusively to its market participants, FMOs might also prefer to rely on third-party platform providers like the one proposed by this FLEXGRID business model. This would allow the FMO to reduce the cost of obtaining the FLEXGRID functionalities (by purchasing the platform as a service, instead of developing the functionalities in-house).

The FLEXGRID ATP therefore provides FMOs (and MOs) with a modular platform that allows for easy integration with FlexBuyers and FlexSuppliers through a standard API that exchanges necessary information for the operation of a DLFM. Furthermore, the FLEXGRID platform provides more efficient flexibility market operation through the improved market clearing process described in section 4.2.1 (ref. VP1.1).

Figure 34 provides an overview of the FLEXGRID platform provider's business model.

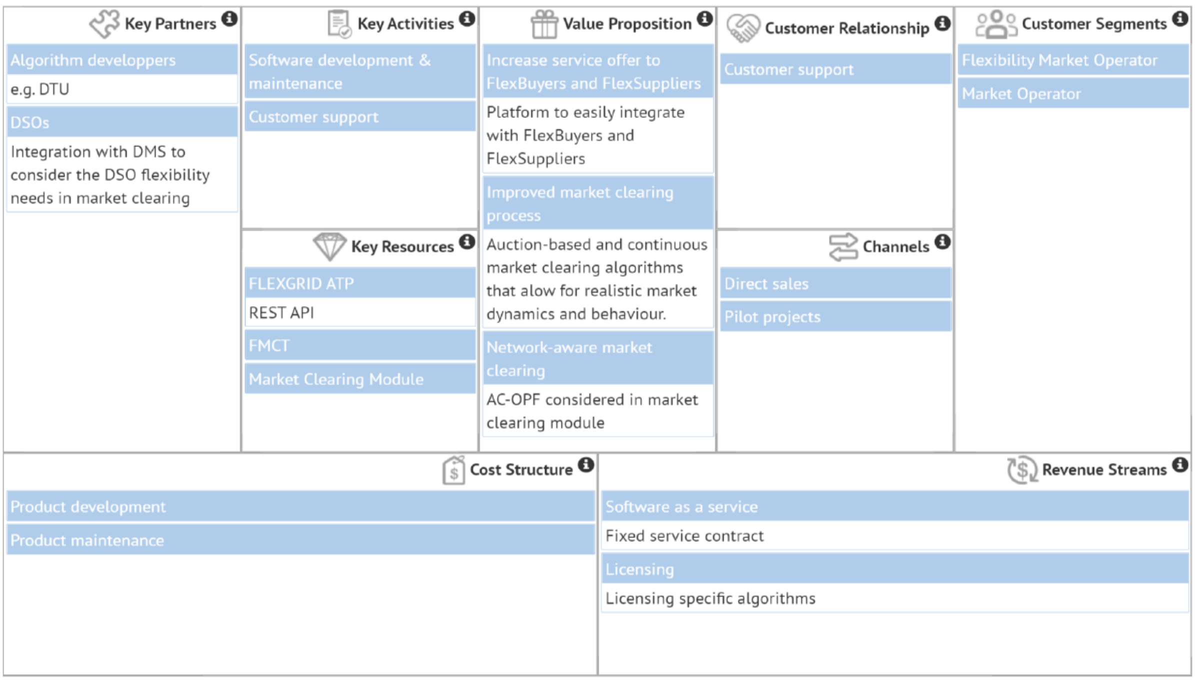

Figure 34: Business model canvas for the provider of the FLEXGRID platform for flexibility market operation.[56]

[56] Business Model Canvas layout by strategyzer.com (CC BY-SA 3.0)

The FLEXGRID platform is built as a modular set of toolkits that can easily be integrated together with the standard REST API. Different types of users have bespoke GUIs tailored to their needs. With this, the FLEXGRID platform can be used by market operators to facilitate data exchange between FlexBuyers, FlexSuppliers and a central market platform. This functionality can be utilised in a medium-term scenario 2, where FlexBuyers can announce the need for flexibility on a single local platform. Moreover, market operators can also use the market clearing module to improve their market clearing. Last, market operators can use the ATP and the integration in advanced distribution management systems in order to carry out market clearing that considers the AC-OPF in the grid. This is most relevant for scenario 3.

Further activities in WP8 will evaluate the value and interest of an FMO to purchase the FLEXGRID functionalities from a third-party platform provider versus integrating the functionalities in its own platform. Furthermore, an assessment of financial sustainability of the platform provider business model will be performed considering the cost and revenue structure that could be included in a service offering on a commercial level. An indicative list of costs and revenue streams is included in the intermediate business model canvas in Figure 34.

4.3.2 Intermediate business model: Flexibility Market Operator (FMO)

The second business model proposed here is that of the FMO as the operator of the flexibility market. The objective of this business model is to assess how an FMO could best leverage and implement the FLEXGRID functionalities to improve its operations and provide increased value to FlexBuyers and FlexSuppliers.

In this context, it is important to consider strategic implications of how to practically implement the FLEXGRID functionalities in the FMO's business model. One option could be for the FMO to purchase the FLEXGRID functionalities as a service from a third-party software provider whose business model is described in section 4.3.1. This could reduce the cost of implementing the FLEXGRID functionalities in the FMO operations, as they could be purchased as a service from a single platform provider – avoiding the need for different FMOs to develop and maintain the functionalities themselves. On the other hand, FMOs might make a strategic investment to acquire the FLEXGRID functionalities and integrate them directly into their market platform to use them as a strategic advantage over competing market operators.

Both of the aforementioned options could be carried out by the FMO business model described here. The fundamental distinction between the FMO business model and the one presented in section 4.3.1 (software platform provider for flexibility market operation) is that the FMO has a responsibility in operation of the flexibility market. A company embracing the FMO business model could eventually have a defined role in future regulatory frameworks, just as NEMOs have a regulated role today.

As the operator of a DLFM, the FMO provides FlexBuyers and FlexSuppliers with a platform to buy and sell flexibility services. In a first scenario, the FMO could utilise the ATP's standard API to facilitate the integration of FlexBuyers and FlexSuppliers, who could submit bids to the flexibility market directly through bespoke ATP GUIs.

In a second scenario, the FMO could utilise the different market clearing algorithms provided by the FLEXGRID FMCT (auction-based and continuous) to improve the efficiency of the DLFM market clearing. Last in scenario 3, the FMO could achieve a close integration with the DSO to use network-aware market clearing.

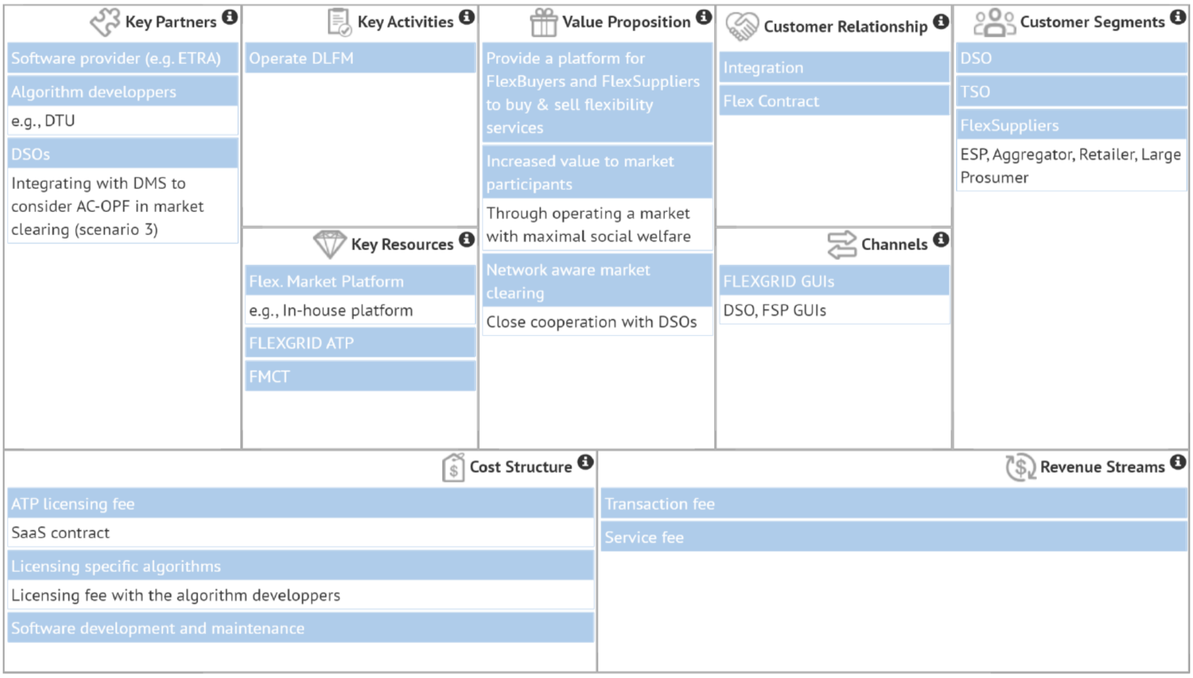

Figure 35: Business model canvas for the FMO.

As for the previous business model, further activities in WP8 will evaluate the value and interest of an FMO to purchase the FLEXGRID functionalities from a third-party platform provider versus integrating the functionalities in its own platform. Furthermore, an assessment of financial sustainability of the FMO business model will be performed considering the cost and revenue structure that could be included in a service offering on a commercial level. An indicative list of costs and revenue streams is included in the intermediate business model canvas in Figure 35.

4.3.3 Intermediate business model: FLEXGRID platform for DSOs

The third intermediate model is that of a software provider that sells the FLEXGRID software services to DSOs. This company could provide a software solution exploiting the intelligent services in the FMCT, and eventually the opportunity to integrate with a DLFM and other market actors through the ATP.

The DSO could use the FLEXGRID services for rapid peak shaving by forecasting power peaks and requesting flexibility from FlexSuppliers. Such services require DSOs to have advanced DMSs, but this is already achievable in the case of larger DSOs who have access to such systems.

Secondly, in a medium-term scenario 2, DSOs could utilise the FMCT to detect and identify network congestions and voltage problems in their network. Assuming that DSOs could generally have access to advanced DMS, they could use the ATP to formulate FlexRequests to FlexSuppliers support their network operations. In a first step, DSOs could feed static data to make FlexRequests for the day-ahead markets. In a second step, the DSO could use dynamic data from the DMS to make FlexRequests in near real-time.

In the final scenario 3, the DSOs might exchange more data with the FMO through the ATP in order to improve the DLFM's capacity to FlexServices that reflect the needs of the DSO.

Moreover, the DSO could use the FMCT to evaluate their future flexibility needs to better plan their network reinforcements. This could be a service where the DSO uses static network data to evaluate the potential to delay or avoid investment in network reinforcement by procuring flexibility services.

Finally, FLEXGRID's services could be used by DSOs to coordinate with TSOs to optimally dispatch FlexServices from assets at the distribution level.

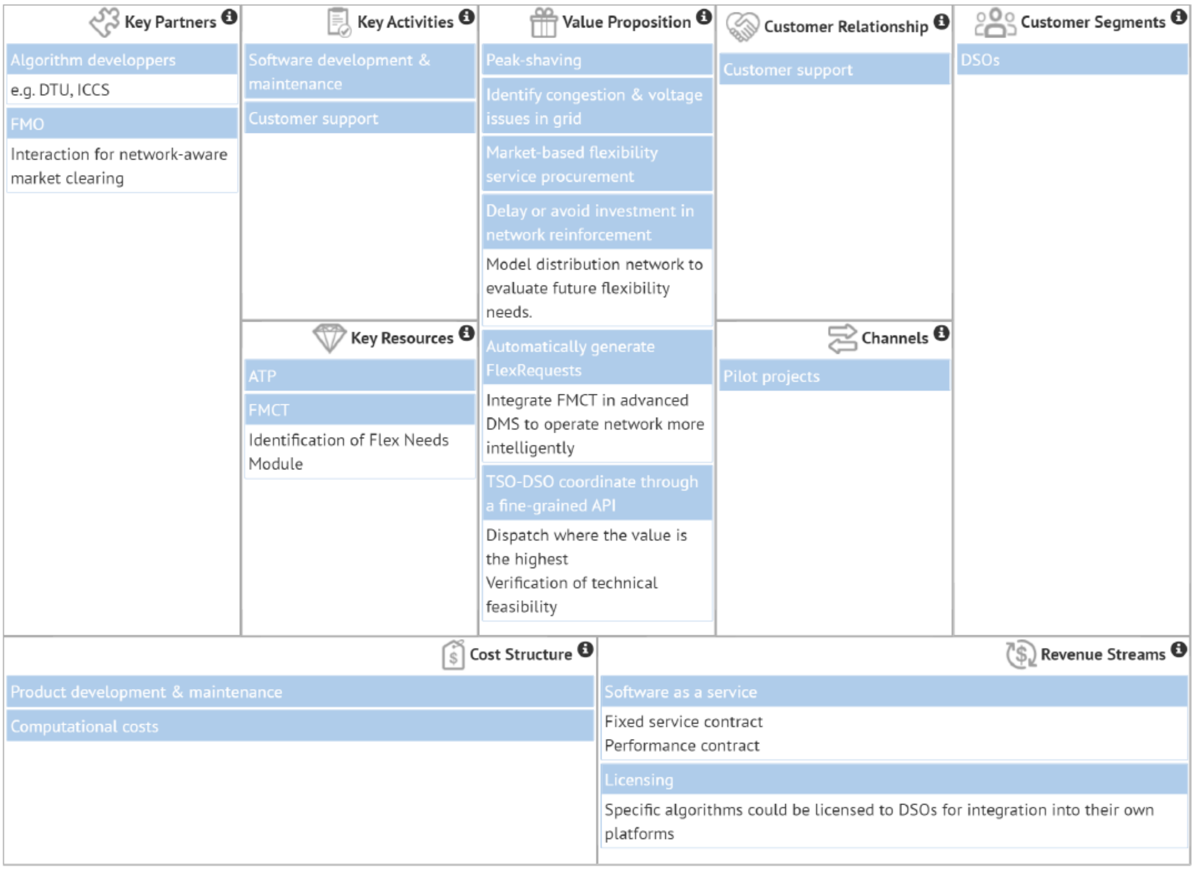

Figure 36: Business model canvas for the provider of the FLEXGRID platform for distribution network operation.

The different services may be provided to DSOs in a modular way in order to address the most relevant needs of DSOs in a specific situation. In fact the maturity of DSO network management varies tremendously across Europe – and even in a same country. As described in the stepwise scenario approach in section 4.1.1, a small DSO might have very limited access to network data and therefore could leverage only some basic functionalities of the FLEXGRID services, while a (typically larger) DSO with more advanced data management system might be able to integrate the FLEXGRID services directly into their DMSs in order to operate their grid intelligently. The value of the FLEXGRID DSO services should be further evaluated and quantified for different types of DSOs, in order to adjust this business model for the most promising business cases.

A financial assessment will be carried out to evaluate the potential sustainability of the business model, considering cost and revenue structures that could be included in a service offering on a commercial basis. Results from this analysis will be included in D8.3. An indicative list of costs and revenue streams is included in the intermediate business model canvas in Figure 36.

4.3.4 Intermediate business model: FLEXGRID software for FlexSuppliers

The fourth intermediate model is that of a software provider that sells the FLEXGRID software services to FlexSuppliers. The target customers in this case are different ESPs, aggregators, retailers, ESCOs and BRPs who could utilise the intelligence from the FST and the AFAT in order to carry out different FlexSupplier business cases described in

Table 32.

The first purpose of the FLEXGRID solution in this case is to increase the FlexSupplier's profit from selling flexibility in different markets. Initially this can be accomplished by providing statistical analysis functionality using static historical data in order to determine the best bidding strategy in different to increase the profit from a certain set of FlexAssets. In a second step, this functionality can be deployed using dynamic data to improve operational profits by optimising the bidding on different markets. Finally, in a more distant scenario 3, the FLEXGRID ATP can receive relevant network data that could help FlexSuppliers provide better FlexServices to the DSO.

The FLEXGRID software can also be used by aggregators who are BRP for a set of FlexAssets in order to reduce their portfolio imbalance by generating optimized schedules for FlexAssets in the balance portfolio. Retailer/aggregators who operate renewable generation assets can use the dynamic optimisation functionalities to reduce RES curtailment and avoid lost revenue. These functionalities could be achievable in scenario 1.

Furthermore, FLEXGRID can provide functionality for FlexSuppliers looking to improve their investment and planning of new FlexAssets. This enables for optimal planning of technological characteristics that can improve the financial performance of FlexAssets over their operational lifetime. In a more distant scenario 3, where the consideration of network data might be more feasible, grid topology could be taken into account for optimal sizing and siting to improve the ROI of a FlexAsset from selling services to the DSO.

FLEXGRID also provides a set of services to aggregators that help them improve their profits by optimally managing their portfolio of assets. This includes the possibility to:

- Optimally dispatch FlexAssets to improve their profits when responding to FlexRequests,
- Automatically create FlexOffers in real-time to bid on different markets,
- Incentivize prosumers to make their flexibility available through iterative auction-based mechanisms.
- Maximize the value provided to prosumers,
- Minimize the prosumer discomfort,
- Simulate different pricing schemes to design optimal contract for prosumers.

Figure 37 provides an overview of how the FLEXGRID software provider's business model could be organised.

This business model provides multiple services to different types of FlexSuppliers that may be adjusted to fit a specific target customer. Each value proposition requires further testing to quantify the value that can be provided to each customer.

Furthermore, the business model's value proposition is strengthened over the course of the stepwise scenarios, fits allowing FlexSuppliers to utilise the functionalities at first with static historical data, and eventually with dynamic data in online operations. Eventually the FLEXGRID platform could facilitate interactions with network operation and flexibility markets.

The assessment of the financial sustainability of the business model will be carried out and documented in D8.3, considering cost and revenue structures that could be included in a service offering on a commercial basis. An indicative list of costs and revenue streams is included in the intermediate business model canvas in Figure 37.

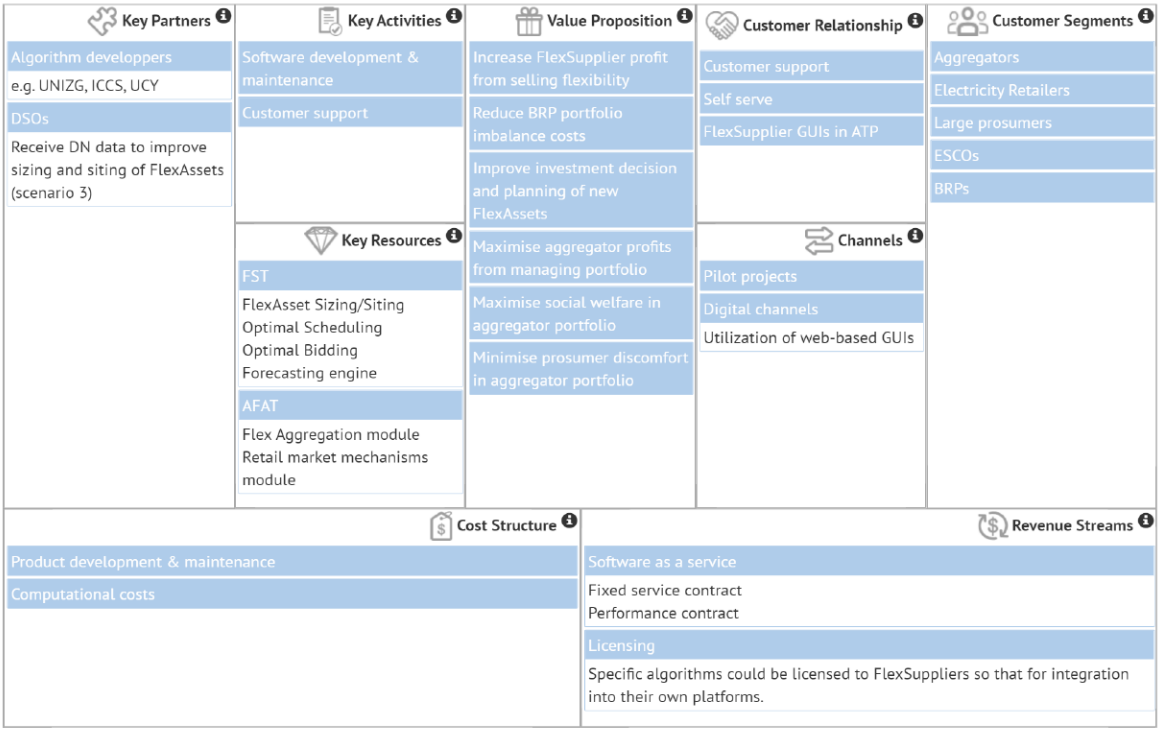

Figure 37: Business model canvas for the provider of the FLEXGRID platform for FlexSuppliers.

4.3.5 Intermediate business model: Aggregator utilising the FLEXGRID functionalities to provide increased value to prosumers

The last business model presented here is that of an aggregator who utilises the FLEXGRID components to provide increased value to prosumers. The aggregator is the business actor that is active in the trade of flexibility as described in section 2. This business model is different from that presented in section 4.3.4 (software provider for FlexSuppliers) in that it is an active market participant who sells flexibility to FlexBuyers and provides complimentary services to prosumers. The aggregator may very well be a customer of the software company selling the FLEXGRID services in section 4.3.4. Alternatively, the aggregator might choose to license specific FLEXGRID algorithms to integrate them in its own aggregator platform. This distinction is a strategic one for the aggregator: an aggregator might want to deliver some of the FLEXGRID services as an exclusive offer that could differentiate them from a competitor. However, using a third-party SaaS provider could reduce the cost of developing and maintaining the functionalities, allowing the aggregator to focus its resources on the core of its business.

The aggregator business model presented here is a multi-sided business model, where there is a service exchange both towards prosumers looking to sell flexibility, as well as towards FlexBuyers who want to buy FlexServices to support their own operations (e.g., DSOs, TSOs). The provision of FlexServices to FlexBuyers allows DSOs and TSOs to carry out business cases summarised in Table 30 and Table 31. The value provided to the FlexBuyers depends on how much dispatchable capacity is available at a given time and location. The revenue of the aggregator directly depends on its ability to deliver FlexServices that meet the FlexRequests from FlexBuyers. Such services are already carried out today, for example in TSO balancing markets where aggregators are already present as balancing service providers. In later scenarios (2 and 3) the aggregator could achieve increased interaction with FlexBuyers to improve their service offering, for example by considering network data and by automatically making FlexRequests communicated through the FLEXGRID ATP.

On the prosumer side, FLEXGRID provides functionalities that improve the value that aggregators can provide to the prosumers in their portfolio. First, in scenario 1, aggregators could simulate the auction-based optimization of FlexAsset dispatch in their portfolio in order to design prosumer FlexContracts. This simulation is described in detail in D3.2. Such contracts could include incentives for prosumers, enabling them to receive increased rewards for making flexibility available.

In scenario 2, where we imagine increased availability of dynamic prosumer data, the aggregator can perform dynamic optimisations to strategically offer flexibility in different market, thus increasing the revenue for prosumer FlexAssets.

In cases where prosumers own RES assets, the aggregator can also optimise the dispatch of FlexAssets to reduce the curtailment of RES generation. This is valuable to prosumers who could otherwise loose revenue from selling energy. It is also important for prosumers who invest in RES infrastructure due to environmental considerations: these prosumers specifically want to make the best use of RES and avoid using fossil fuel alternatives.

Moreover, aggregators can provide aggregation services which consider the comfort (i.e., quality of service) parameters of the prosumers. This is valuable for prosumers whose FlexAssets often serve another primary purpose. Prosumers can therefore set specific comfort parameters in FlexContracts which are taken into account in aggregated portfolio management.

Last, the aggregator can deploy the auction based B2C flexibility market functionality in order to dispatch FlexAssets based on the value attributed to the flexibility by each prosumer. Yet, as prosumers are unlikely to want to take an active role in accepting or rejecting each activation request in the iterative approach, the intelligent agents respond on the prosumers' behalf and the settlement is reached considering the end-user comfort while guaranteeing the privacy of each customer.

An overview of the aggregator business model is provided in Figure 38. Note, the different colours refer to the different sides of the multi-sided business model.

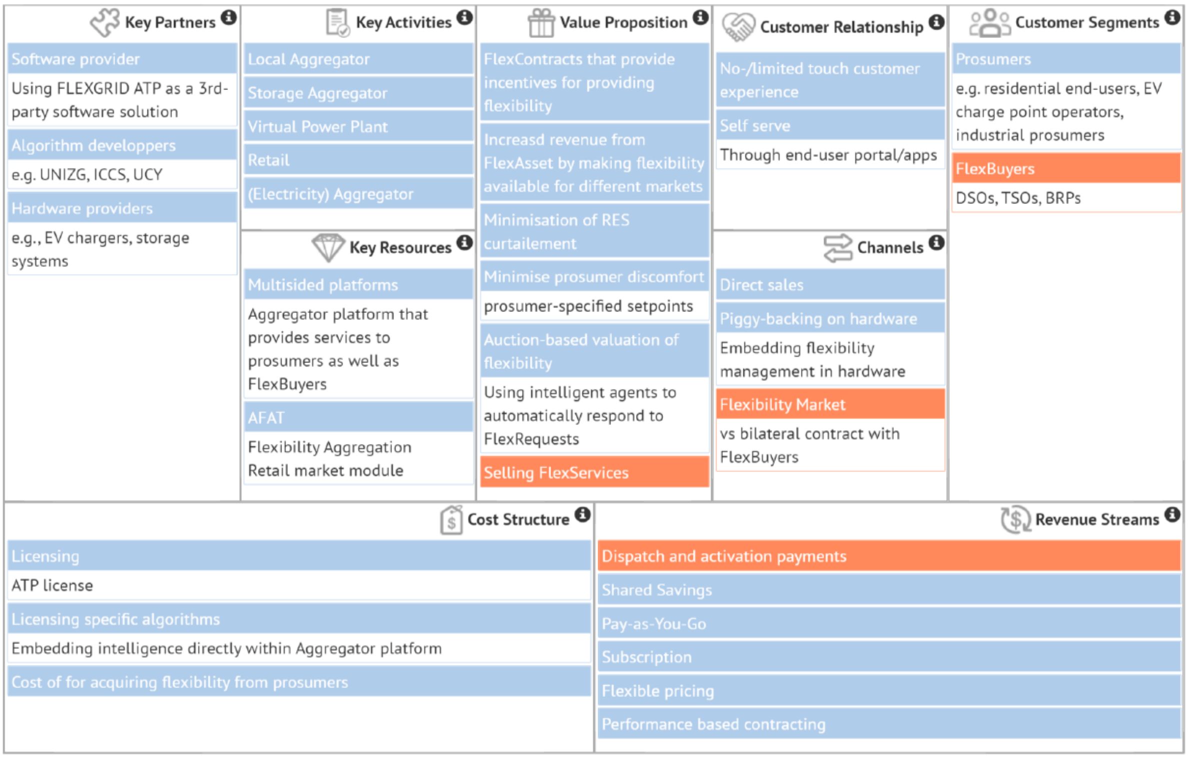

Figure 38: Business model canvas for the aggregator.

The aggregator business model can be further described, where special considerations could be detailed in some cases (e.g., whether the aggregator is also BRP for the FlexAssets). Such considerations will be evaluated and discussed in subsequent WP8 activities. The different value propositions should also be further tested and quantified.

The assessment of the financial sustainability of the business model will be carried out and documented in D8.3 considering cost and revenue structures that could be included in a service offering on a commercial basis. Different type of aggregator-prosumer FlexContracts should also be considered depending on the type of service being offered. An indicative list of costs and revenue streams is included in the intermediate business model canvas in Figure 38.

5 Impact Analysis and Innovation Management

5.1 Methodology for impact analysis

The Joint Research Council (JRC) presented a unique framework for assessing the innovation impact in the national member states of the EU: The Regional Innovation Impact Assessment (RI^2A) framework[57] was introduced to monitor the innovation developed through the research and its impact in the Europe. The assessment focuses on four main categories:

- Education and Human development
- Research, technological development, and commercialization
- Entrepreneurship and support to enterprise development
- Regional orientation, strategic development, and knowledge infrastructure

Figure 39 highlights the process of taking into account challenges from the society concerning environment and economy. These challenges become the basis for various EU policies and in particular the objectives of the Horizon framework. The FLEXGRID project directly connects with the primary objectives of the Horizon work programme focused on secure, clean, and efficient energy. The impact analysis will specify the various inputs and outputs of the project, while presenting the methodology of mapping the key performance indicators (KPIs) to impact of the FLEXGRID project.

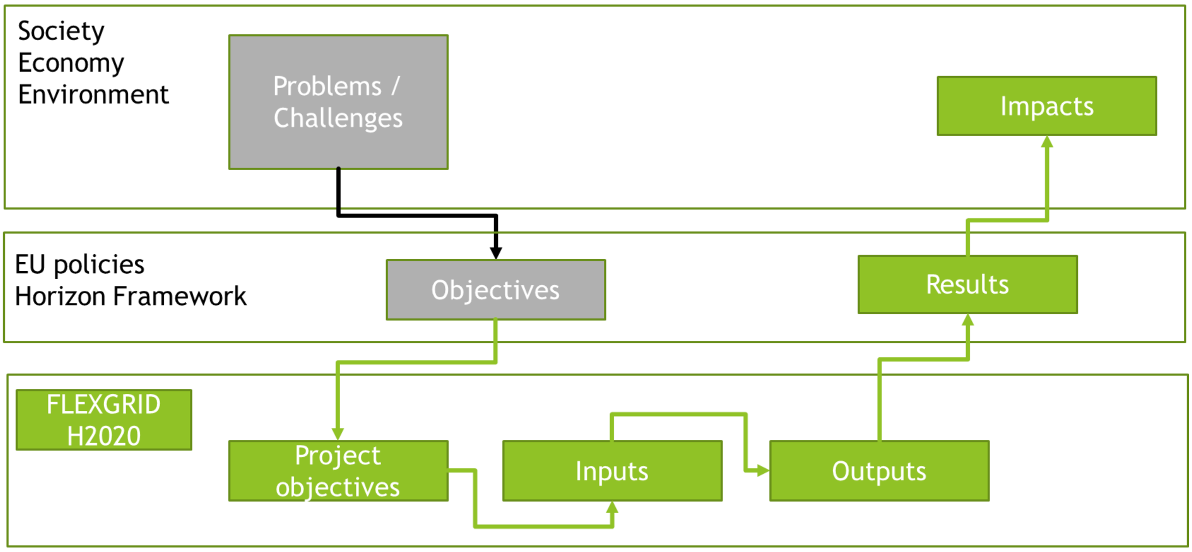

Figure 39: Adapted Impact process from Technopolis Group (2004) and JRC (2018).

Another aspect that is important to consider in order to capture the holistic impact of the project, is to further expand the above picture and connect it to key societal actors. To do this, the project uses the Quintuple Helix Approach of the European Union[58], where each project impact will be connected to the contribution it makes into the 5 helices (Academia, Government, Civil Society, Industry and Environment).

The FLEXGRID project methodology for conducting impact analysis is inspired by the Regional Innovation Impact Assessment (RI^2A) framework, where first the project objectives and

[57] A regional Innovation Impact Assessment Framework for Universities by JRC (2018)

[58] Franc, Sanja & Karadžija, Deniza. (2019). Quintuple helix approach: The case of the European Union. 5. 91-100. 10.32676/n.5.1.8.

corresponding impacts in the Grant agreement are reviewed and the Key Performance Indicators (KPIs) are analysed. Second, each of the inputs from the research WPs being carried out in the project is mapped to the project outputs KPIs. Finally, all the KPIs are connected to the impacts mentioned in the project Grant Agreement and expanded to the broader impacts (Quintuple helix) that the project is contributing to.

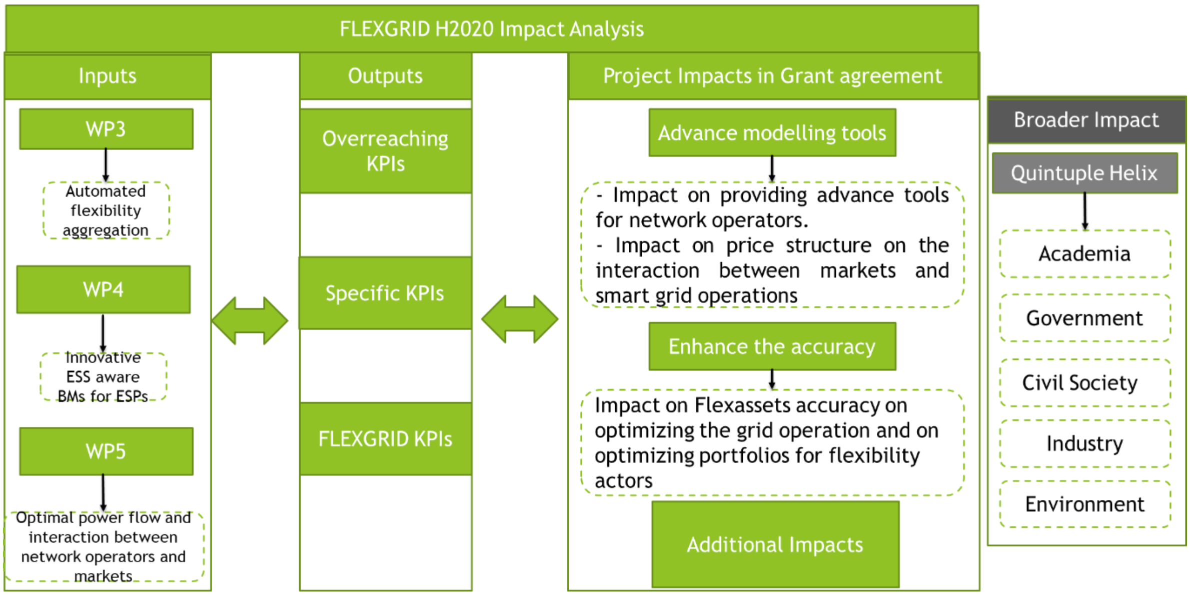

Figure 40: FLEXGRID H2020 Impact analysis flow.

5.2 Review of FLEXGRID Impacts and Key Performance Indicators (KPIs)

The following sections builds on the methodology of the impact analysis discussed above, where first the FLEXGRID impacts and KPIs are reviewed, followed by the discussion on the impacts and KPIs for each research and innovation topic of the FLEXGRID project.

5.2.1 Review of project impacts and KPIs

FLEXGRID provides value to several stakeholders in the energy market, where it facilitates the automated and optimal trading of FlexAssets for the FlexDemand generated by different stakeholders. This enables a more effective and efficient energy market supporting the activities of various stakeholders in the most optimal manner.

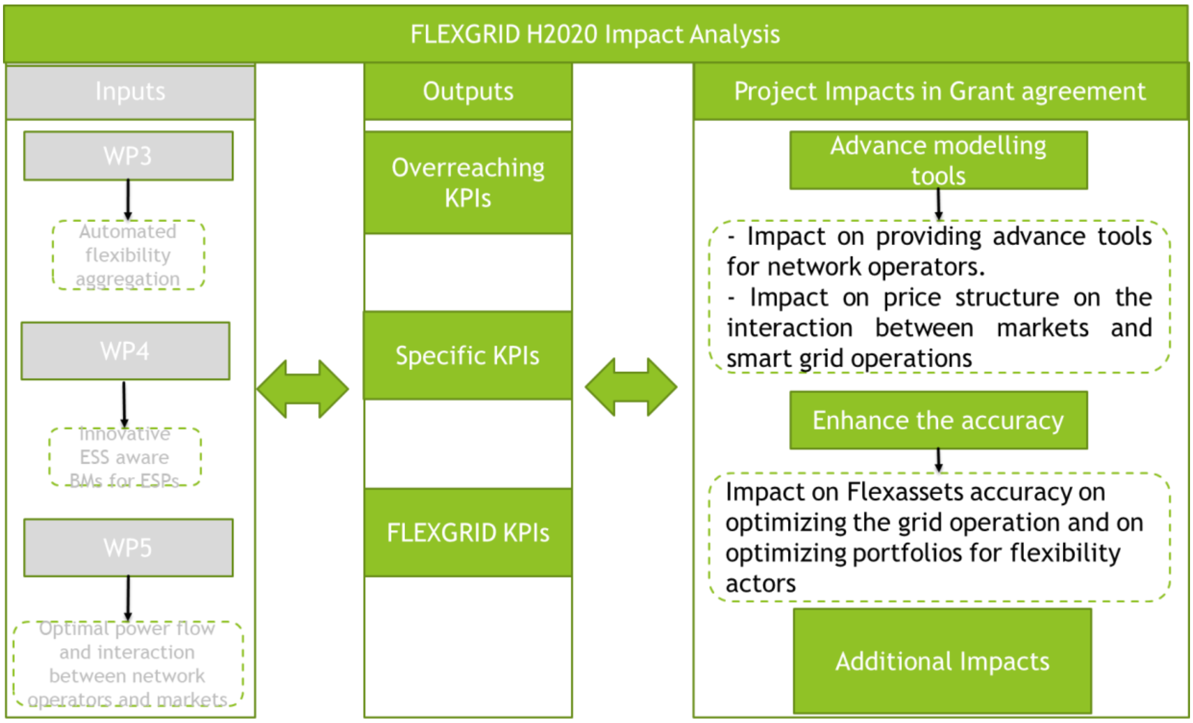

Figure 41: Direct impacts of FLEXGRID project.

Project impacts highlighted in the proposal phase, focused on providing improvements to various sections of the flexibility market. The advance modelling tools will help in knowledge increase for design of price and magnitude of electricity infrastructure and the new developments appearing in the flexibility markets. FLEXGRID project gives a detailed overview of various impact points that can facilitate the current and future operations of network operators (TSOs and DSOs), while also providing value to commercial players such as ESPs (in various roles). For enhancing the accuracy of different flexibility assets, several new methods and algorithms are proposed. These algorithms will help in optimizing the grid operation and in enhancing the flexibility potential from different DERs and VRES.

To support the achievement of the project impacts different Key Performance Indicators (KPIs) are considered according to three main categories of KPI classification:

1. Overreaching KPIs
2. Specific KPIs by Smart Grid related projects
3. FLEXGRID specific KPIS

All the three classification of KPIs enlist specific indicators that will be addressed using the research and innovation carried out under the project research work. Several of these KPIs will be addressed by single or multiple research KPIs mentioned in detail in other deliverables (D3.1, D4.1 and D5.1).

5.2.2 Impacts and KPIs specific to automated flexibility aggregation, energy market development and management as a service

The FLEXGRID research work for the automated flexibility aggregation, energy market development and management aims to support the efficient operation of an ESP acting as an aggregator or an independent aggregator. The aim of developing new algorithms and models is not only to support aggregator operations, but also to facilitate the overall functioning of flexibility markets. The following are few impact points observed associated with the research work documented in D3.1:

- Facilitate the operations of an aggregator by optimally orchestrating its aggregated flexibility portfolio of end prosumers,
- Maximizing the profits of an aggregator by optimally participating in several energy markets,

- Facilitating participation of the end prosumers in flexibility markets keeping in view the benefits for an aggregator by providing an ad-hoc B2C flexibility market for end prosumers,
- Supporting the aggregation services by providing an Automated Flexibility Aggregation Toolkit (AFAT).

There are several of the Key Performance Indicators (KPIs) listed in the D3.1 for automated flexibility aggregation and the research work being carried out in the FLEXGRID project. The KPIs primarily focus on the value addition for two stakeholders *i) aggregators* and *ii) end-user/prosumers.* In addition, several of the KPIs also focus on evaluating the performance of the algorithms and tools developed. This will help in quantifying the impact of the research work towards the overall FLEXGRID project impacts (mentioned above) and contribution to overall society (Quintuple helix). The following process will be used to conduct the impact analysis later in the project for the research work on automated flexibility aggregation, energy market development and management. Each impact point of the research work will be connected with the research KPIs (in D3.1), which will be evaluated and quantified under the piloting work of the FLEXGRID project. These research KPIs will then be mapped to overall project KPIs and corresponding impact points as per the methodology defined in section 5.1.

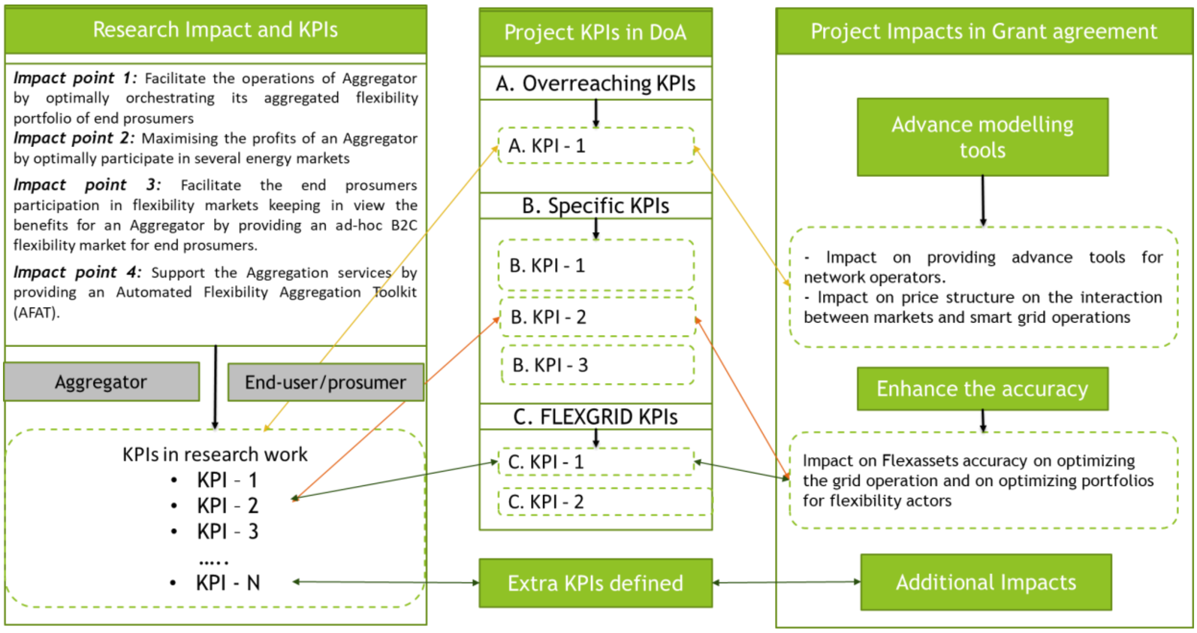

Figure 42: Automated flexibility Aggregation impact and KPI analysis.

5.2.3 Impact and KPIs specific to innovative ESS aware BMs for ESPs and interaction with advanced RES & Market Forecasters

In sections 1 & 2, various new market developments and business cases were discussed related to ESPs. Several research topics in the FLEXGRID project aim to further facilitate the services and offerings of an ESP in different forms (ref. section 2). The innovation developed for ESPs and interaction of RES with Electricity markets will help in creating valuable contributions to an ESP business. The following are some of the impact points identified for the research work carried in D4.1 on ESS aware business models for ESPs and interaction with advance RES and Market forecasters:

- Supporting the forecasting services of an ESP to better predict market prices and production of FlexAssets (e.g., solar PV),
- Minimize the OPEX of an ESP by better scheduling consumption and production in the portfolio,
- Minimize the CAPEX of ESP business by creating optimal investment strategies for FlexAssets,

- Facilitate the business of an ESP by optimizing participation in several energy markets,
- Support of an ESP bidding process by offering market-aware and network aware bidding process,
- Increase in ESP offerings by developing leasing option of storage assets for flexibility purposes.

Each of the above-mentioned impacts have their own corresponding indicators. The KPIs listed in D4.1 document the various performance parameters of the FlexAssets and the accuracy of the forecasting algorithms. The minimisation of the OPEX and CAPEX are quantified with multiple indicators specifying the benefit for an ESP. As per the methodology of the impact analysis, the innovative business models for ESPs and interaction of RES and market forecasting will be analysed first with the project classified KPIs, then mapped to the project impacts, and finally to the societal contribution using the Quintuple Helix model. The quantification and evaluation of each research KPI will be carried out with the piloting work in WP7, where few more KPIs will be added to conduct an overall impact assessment of the FLEXGRID research on ESP operations.

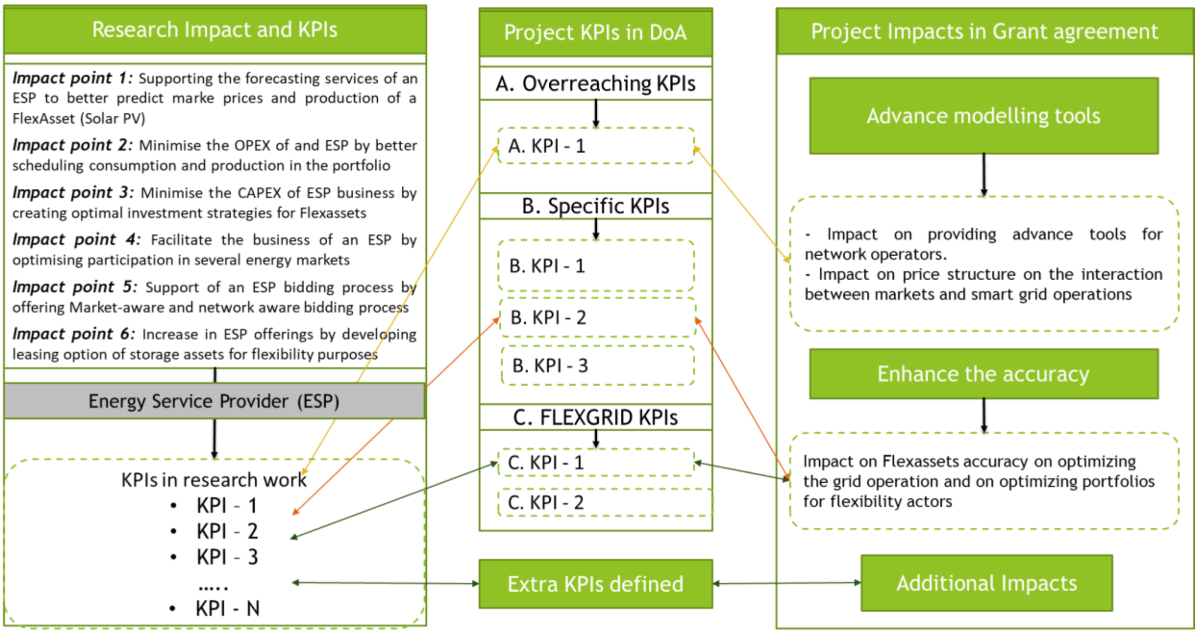

Figure 43: Innovative BMs for ESP and Forecasting impact analysis.

5.2.4 Impact and KPIs specific to optimal Power Flow and interaction between network operators and markets

With the increase in RES penetration in the electricity network, the network operators (TSOs & DSOs) are trying various new schemes to accommodate maximum RES and DERs in their respective parts of the network. FLEXGRID project proposes new coordination schemes between TSO and DSOs where different market clearing mechanisms can help in unlocking the best value flexibility from different FlexAssets. The research work carried out in the project with initial research motivations discussed in D5.1, helps in providing a detailed analysis of various market architecture and new algorithms to support better functioning of the overall electricity network. Several of the impact points identified from D5.1 are listed below:

- Enable unique TSO-DSO coordination schemes and efficient market clearing process
- Support the market clearing process with enhanced optimal power flow algorithms
- Execute most optimal coordination schemes and facilitate the DSO operations by accounting various constraints of the distribution grid

- Minimize the network investment costs of the DSO by providing best value flexibility for the grid.

The DLFM architectures proposed by FLEXGRID provide three main market clearing process *i) P-DLFM, ii) I-DLFM* and *iii) R-DLFM*. All the architectures take into account the operations of TSO and DSO while also ensuring an efficient market operation. In addition, to support the immediate needs of the DSO in terms of flexibility, the OPF algorithms aim at supporting the everyday operations of the distribution grid. To quantify the impact on the operations of a DSO, several KPIs are proposed in the D5.1. The impact analysis methodology will be applied to the research KPIs for the OPF and additional KPIs will be proposed for quantifying the impact of the different DLFM architectures.

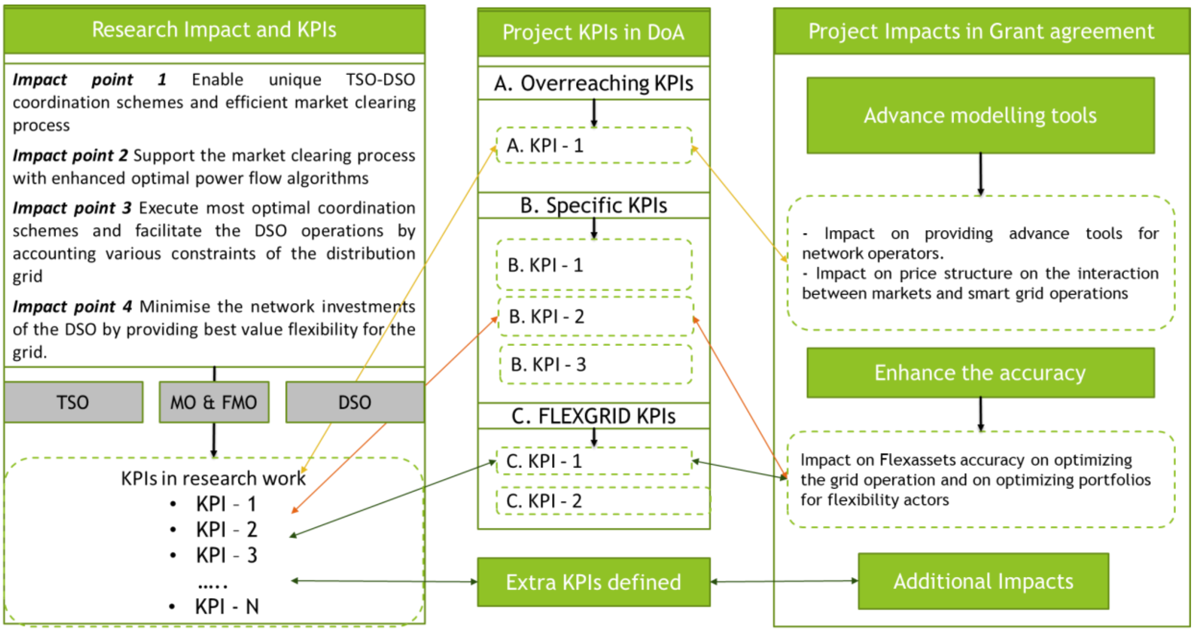

Figure 44: Impact analysis for TSO-DSO coordination, DLFMs and OPF

5.2.5 Next Steps: Overall Impact Analysis Towards the Broader Society

The impact analysis methodology above highlights the importance of expanding the research and innovation work and connecting it to its contribution to society. In order to capture the value addition of the research and innovation of FLEXGRID project, the quintuple helix model (Carayannis & Campbell, 2010) is adopted. The quintuple helix model is a framework which provides quality-based methods for sustainable innovation development. To involve different stakeholders and the value addition of the innovation for each stakeholder and its interaction with FLEXGRID innovation. The various project impacts will be mapped with the 5 helices proposed in literature as shown in Figure 45.

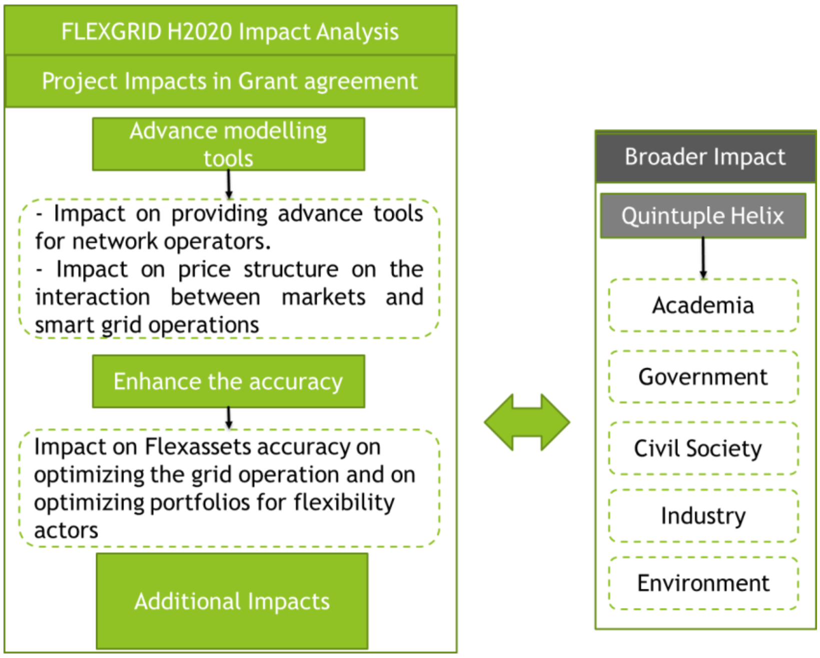

Figure 45: FLEXGRID impacts to Quintuple Helices.

The knowledge addition to the community and interaction of different stakeholders in the flexibility markets can be well documented using the Quintuple Helix model. Using the piloting results of the FLEXGRID project, evaluation of the KPIs and conducting the relative impact mapping as per the sections shown in Figure 45. The overall project impact analysis will be then further expanded by using the business case analysis and the business modelling work detailed in sections 2 and 4. Finally, the circularity of the knowledge addition will help in capturing the true value of FLEXGRID innovation and its relevant impacts. The circulation of knowledge approach proposed in literature will be used to conduct the highlight the concrete contributions of the project in the society and its impact beyond the project objectives.

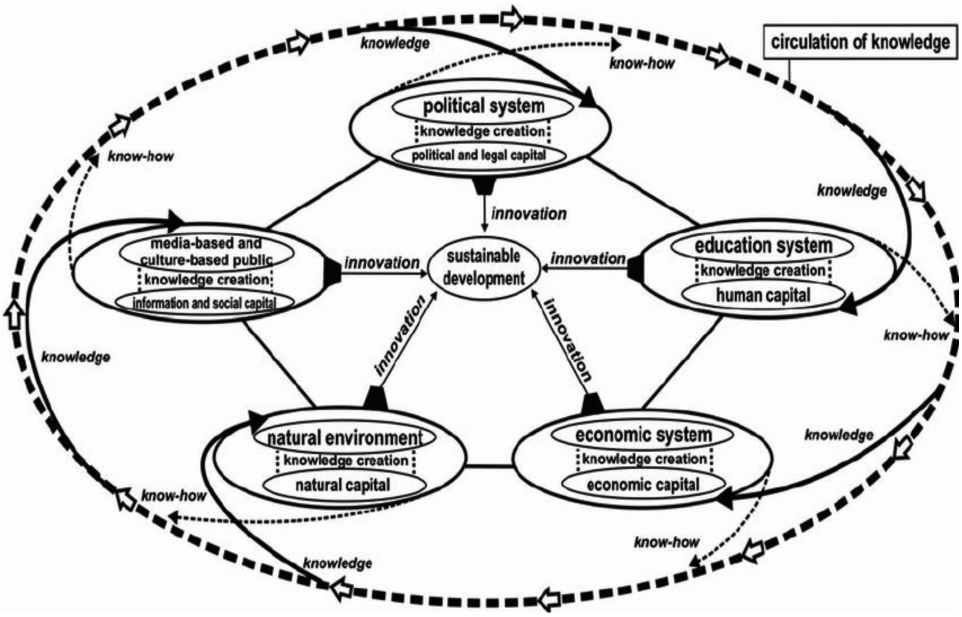

Figure 46: Quintuple helices circulation of knowledge modified from Etzkowitz and Leydesdorff (2000), on Carayannis and Campbell (2006, 2009, 2010), and on Barth (2011a).

6 Conclusions

FLEXGRID carries out tasks aimed at increasing the potential impact of the project results. These tasks guide the work pertaining to market analysis, business modelling, exploitation planning, communication, and dissemination. WP8 activities collaborate closely with other work packages, first taking the concepts and use cases defined in WP2 (Use cases/services and architecture design) and projecting them in a context of future commercialisation. The work is carried out with the involvement of all consortium partners alongside developments in the research work packages WP3, WP4 and WP5.

Initial results delivered by the research WPs in M12 (D3.1, D4.1 and D5.1) provided some first insights into the potential benefits and important KPIs that should be considered when evaluating the FLEXGRID results. These initial results were extensively discussed in a series of digital workshops to gather the perspectives from both academic and industrial partners as to understand the business and exploitation potential of the FLEXGRID KERs.

The intermediate results from the WP8 activities provide holistic understanding of the societal, business, and regulatory contexts that pertain to the FLEXGRID project. First, many developments have been observed in commercial and research solutions addressing the challenges relevant to FLEXGRID. Companies have been developing new business models that provide services exploiting flexible energy assets and aiming to support the smooth operation of the electricity network. FLEXGRID is evaluating innovative trends in this area to design a set of business models that could be crucial to a future commercialisation of the FLEXGRID results.

In the set of intermediate business models proposed here, a qualitative discussion provided some understanding into the drivers and factors that could guide the decision-making of different business stakeholders. A long list of the value propositions proposed by the FLEXGRID components has been expanded to provide an overview of the possibilities that could be carried out by the different FLEXGRID solutions providers. The subsequent activities in WP8 will aim to quantify the potential value that could be delivered by the business models in order to provide an assessment of the theoretical potential of the business models. The objective of these activities is to refine and describe the most promising business models that could support the sustainable development of the FLEXGRID solutions.

Meanwhile, regulatory frameworks continue to be a major factor in the feasibility of new flexibility services used in the electricity domain. While European legislation has set some guidelines in the directives included in the Clean Energy Package, national regulations are being developed in different directions in the FLEXGRID topics. For this reason, the project has described different sets of architectures as well as a modular product design that could be tailored to different future regulatory frameworks. The project foresees a model for the electricity domain that could deliver optimal social welfare in a long-term future (i.e., 2030 and beyond). However, to make this vision a reality, WP8 considers a stepwise approach that could deploy different components of the modular FLEXGRID architecture in a way that brings value to stakeholders on a shorter time frame and allows for a progressive development of market solutions that could evolve together with regulatory frameworks.

In the next phase of the project, the first versions of the FLEXGRID ATP components will be developed in WP6 and deployed/tested in WP7. This will provide WP8 with many important KPI results that can substantiate and complement the analysis work performed in WP8. In addition to a quantitative analysis of the hypotheses presented in the intermediate business models, these practical simulation and pilot testing results will be utilised in the impact analysis carried out by WP8. This analysis, whose method is described in Section 5, will assess how the FLEXGRID KERs can be adopted and supported by stakeholders from the greater society, considering the quintuple helix model adopted in FLEXGRID: academia, government, civil society, industry, and the environment. The outcome of this analysis will point to potential impact targets that are achievable considering initial results from the project and assessments considering future scenarios. This will be formulated as a roadmap to European policy makers for the development of future market architectures that support new services in an intelligent electricity system that maximises social welfare (i.e. the benefits of all involved market stakeholders).