**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

# Final version of business modeling, dissemination, and exploitation of results

## Deliverable D8.3

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# Glossary of Acronyms

Project management terminology

| Acronym | Definition |
|---|---|
| D | Deliverable |
| DoA | Description of Action |
| EC | European Commission |
| HLUC | High Level Use Case |
| KER | Key exploitable result |
| MS | Milestone |
| WP | Work Package |
| UCS | Use Case Scenario |
| KPI | Key Performance Indicator |

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 |
| ACER | Agency for the Cooperation of Energy Regulators |
| 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 |
| CBA | Cost Benefit Analysis |
| CEP | Clean Energy Package |
| CHP | Combined Heat and Power |
| CPO | Charging point operator |
| 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 |
| ICS | Industrial Control System |
| ICT | Information and Communication Technology |
| IEGSA | Interoperable European Grid Services Architecture |
| IPR | Intellectual Property Rights |
| LMP | Locational Marginal Price |
| MVP | Minimum Viable Product |
| (NE)MO | (Nominated Electricity) Market Operator; FMO stands for Flexibility MO |
| (NBM) | Nordic Balancing Model |
| 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 |
| SOC | State of charge |
| S/W | Software |
| SWOT | Strengths Weaknesses Opportunities Threats |
| TRL | Technology readiness level |
| VPC | Value Proposition Canvas |
| VPP | Virtual Power Plant; IPP stands for Independent Power Plant |
| VRE | Variable Renewable Energy |
| HEMS | Home Energy Management System |
| (ZTOEE) | Zakon o Tržištu Električne Energije |

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**Table 1: Document History Summary**

| Revision Date | File version | Summary of Changes |
|---|---|---|
| 23/09/2021 | v0.1 | Initial draft ToC circulated with consortium partners, along with writing task delegation and schedule |
| 15/05/2022 | v0.2 | First contributions from partners |
| 10/06/2022 | v0.3 | Main contributors evaluated first contributors and make requests for additional contributions |
| 30/06/2022 | v0.4 | Second contributions from partners |
| 26/08/2022 | v0.5.1 | Ready for 1st review |
| 02/09/2022 | v0.6 | 1st review provided by NPC |
| 09/09/2022 | v0.7 | Main contributors addressed all comments from 1st review |
| 16/09/2022 | v0.8 | 2nd review provided by NPC |
| 26/09/2022 | v0.9 | Main contributors addressed all comments from 2nd review, and forwarded the final version to the coordinator (ICCS) |
| 27/09/2022 | v1.0 - Final | Submitted to ECAS portal by coordinator (ICCS) |

# Executive Summary

This deliverable presents the final results from FLEXGRID's Work Package (WP8) – *Business modelling, dissemination, exploitation, and management of innovation impact.* Most of the WPs have already been finalized, except WP7 and WP8 that will close the project. The research WPs submitted their final deliverables D3.3, D4.3, and D5.3 in November 2021. The results have been integrated into WP6's software platform, the FLEXGRID Automated Trading Platform (ATP). D3.3 presented the final version of research work that later has been included as services in the Automated Flexibility Aggregation Toolkit (AFAT), D4.3 results have been integrated as the Flexibility Supply Toolkit (FST), and D5.3 results are the core of the Flexibility Market Clearing Toolkit (FMCT). WP6 also ended in June 2022, delivering the software platform[1] (D6.3) that has been used during the pilot phase of the project as part of WP7. Finally, WP7 D7.2 was submitted in June 2022, reporting on the validation activities of the FLEXGRID systems and research tools. Meanwhile, the energy domain has changed significantly with the Russian war in Ukraine, and the flexibility domain has also seen a significant progression with new local flexibility market projects and new flexibility platforms. It is in these circumstances that D8.3 provides the conclusion to FLEXGRID's business modelling and exploitation efforts at the month 36, notably describing:

- The final version of the FLEXGRID business ecosystem,
- An updated overview of the EU – and national German, Croatian and Norwegian - policies and regulation on flexibility,
- The final business models of the FLEXGRID services,
- A quantitative evaluation of the potential FLEXGRID revenue through business case analyses,
- The final business and exploitation plan for FLEXGRID's ATP platform and its associated services,
- The impact analysis of the project results.

*FLEXGRID business ecosystem*

The business ecosystem proposed in D8.3 has been refined and narrowed down to show in the most concise and precise way the multiple actors in FLEXGRID's ecosystem and their interactions. All actors included could benefit from one or more of the FLEXGRID services to reach their business goals. However, FLEXGRID shows its maximum potential when being implemented as an integrated solution where all the actors interact by using the FLEXGRID ATP.

The final version of FLEXGRID's business ecosystem presented in D8.3 has defined in more detail the stakeholders within the ecosystem. The roles of the prosumer and independent aggregator have been included within the energy service provider (ESP) role, and the relation between the ESP and its clients are shown in a more explicit manner. Additionally, the direct interaction between flexibility suppliers and ancillary services markets has also been added. Lastly, all interactions between actors and markets have been updated to show a more complex level of flexibility exchange where some actors can be buyers and sellers of flexibility according to their needs.

*EU policy and regulatory development*

Since the delivery of D8.2 some changes have happened in the regulatory framework for flexibility; however, the major impact on the electricity system has been caused by Russia's invasion of Ukraine, which is accelerating EU's drive for an energy transition. On the **Save Gas for a Safe Winter** package the EC acknowledges the potential role of demand side flexibility to help reduce and optimize energy consumption, encouraging member states to "**open all markets to flexible demand-side resources**

[1] FLEXGRID ATP - Available on: FLEXGRID ATP GUI (etra-id.com)

**to enable their participation."** In parallel Agency for the Cooperation of Energy Regulators (ACER) has recently initiated (a task demanded by the EC) a public consultation process with the aim to establish a guideline for Demand Response Network Codes.

At the member state level, the latest regulatory developments in Germany, Croatia and Norway are presented in this deliverable. Regarding **Germany,** Redispatch 2.0 entered into force on 1st of October 2021, assigning new responsibilities for grid operation to DSOs, and significantly lowering the threshold for units eligible for redispatch from 50 MW to 100 kW. Therefore, not only DSOs are affected by Redispatch 2.0 but also the owners of distributed generation assets. In **Croatia** the new Electricity Market regulation became effective on 22 October 2021, transposing the directives and regulations of the Clean Energy Package. Furthermore, according to the Croatian regulation Zakon o Tržištu Električne Energije (ZTOEE) in the end of 2022 the new Rules on Balancing the Electric System should be ready, allowing the Croatian TSO HOPS to join the European balancing energy exchange platforms. Finally, **Norway's** regulatory framework has been updated and the Nordic Balancing Model (NBM) is introduced which is a collaboration between the Nordic TSOs to improve the balancing model in the Nordic countries and create new markets to face the challenges of the grids of the future.

Overall, the latest regulatory developments show an increasing willingness from regulatory bodies to include the active management of distribution grids in their legal frameworks. This is mostly attributed to European directives and regulations, but also to the evidence of a power system with higher challenges at the distribution level.

*Business models and Business cases of FLEXGRID services*

The intermediate business models presented in D8.3 have been refined to correspond with the final business cases analyzed. The reduction in the number of analyzed business cases has been done through a consultation process with the industrial partners to identify those services with the highest exploitation potential. The final list of business models and business cases is:

- BM - FLEXGRID platform for flexibility market operation
  - BUC - FMO using advanced algorithms to increase market clearing efficiency
- BM - FLEXGRID platform for DSOs (and TSOs)
  - BUC - DSOs use the FLEXGRID ATP to predict peak power demand and request flexibility (Peak Shaving)
  - BUC - DSOs avoid grid enhancement by requesting flexibility from a local market
  - BUC - Long-term economic analysis of TSO using Distribution Network (DN)-level flexibility through a Distribution Level Flexibility Market (DLFM)
- BM - FLEXGRID platform for FlexSuppliers
  - BUC - ESPs optimize their performance in day-ahead and intraday markets
- BM - Aggregators use the FLEXGRID functionalities to provide increased value to prosumers
  - BUC - Aggregators optimize aggregated FlexAsset portfolios to sell flexibility to capacity markets

The business case analysis provides valuable insights on the viability of FLEXGRID services as standalone products. This approach allows to deploy the FLEXGRID platform in different stages. First, starting with those services that can already be offered in the market, while increasing the maturity of the services that are currently lacking the regulatory framework and/or the necessary infrastructure to be market ready. The progressive addition of these services in FLEXGRID's portfolio is considered within the business plan as a modular process that will eventually lead to offer the ATP as an integrated solution for flexibility provision at distribution level.

The results presented in the business case analysis have shown how all FLEXGRID services can create added value to power system actors. However, during the process relevant regulatory barriers, technology alternatives, and overall threats for the FLEXGRID innovative services have also been identified. One relevant example is the business case where DSOs avoid grid enhancement by requesting flexibility from a local market. In this case study the analysis has shown how the viability of the service heavily relies on the needs for flexibility by the DSO, and its willingness to pay in the market. In other words, flexibility procurement can jeopardize the viability of the local flexibility market. This observation does not exclude DLFMs as an alternative to grid deferral, but it is able to show how challenging the flexibility ecosystem can be. On the other hand, some of the business cases analyzed have shown great potential for profitability. This is the case, for instance, of a *DSO using FLEXGRID ATP to predict peak power demand and request flexibility.* During the analysis, the potential revenue of this service has been shown, together with its potential for replicability.

*FLEXGRID business and exploitation plan*

This section builds on top of the business case analysis results to define the final exploitation strategy and business plan for the FLEXGRID ATP, and its individual modules. To do so, it starts by presenting the target market of the developed solutions, then the go-to-market plan is defined, and finally future funding sources are explored together with potential partnerships with industrial actors to foster the implementation of the FLEXGRID ATP. Overall, the section shows the envisioned steps to go from a current Technology Readiness Level (TRL) 5 to a higher TRL, describing the pathway to develop the FLEXGRID product to reach market ready maturity.

*Impact analysis of FLEXGRID's results*

The FLEXGRID impact analysis methodology is taken further in this document where the different KPIs related to the overall project are discussed. We start by providing an overview of the specific and overreaching KPIs that the FLEXGRID project addresses. These KPIs are then mapped against the various research KPIs which are summarized in this deliverable as part of the overall research summary of the project. The FLEXGRID KPIs are defined per research topic that is investigated in the research work of the project. Afterwards the particular impact contribution of these KPIs from the FLEXGRID project is described. These impact points include the contribution of the project towards advanced modelling tools where the market interaction and benefits of FLEXGRID research towards grid operation is discussed. The ESP unique business cases that are allowed using the novel FLEXGRID x-DLFM architecture and the contribution of algorithms for reducing Operational Expenditures (OPEX) costs and optimizing capital expenditures (CAPEX) investment are included. The FLEXGRID impact related to the aggregators' increase in profits is discussed and the impact on overall social welfare for end users is increased using the novel B2C Flexibility market that an aggregator can run. The network-aware market clearing processes also contribute significantly to the overall flexibility value chain, where the cost for the DSOs and the impact on reduction of costs related to grid operation are highlighted. Finally, the broader impact towards the society is discussed using the Penta helix approach, where the FLEXGRID contribution to the academia, industry, civil society, government, and environment is described.

# 1 Introduction

This deliverable is a continuation of D8.2[2] which updates the FLEXGRID business models, business cases, value propositions, and the project's business and exploitation plan. It includes an updated version of the dissemination and exploitation plans, and the impact analysis of the overall project. Additionally, it includes sections devoted to intellectual property rights management and policy and regulatory developments within the electricity flexibility framework.

This deliverable document the results of WP8 activities around four main topics, all of them related to the business, exploitation, and impact potential of the FLEXGRID research outcomes:

- FLEXGRID business models
- FLEXGRID business and exploitation plan
- FLEXGRID impact analysis and innovation management
- FLEXGRID communication and dissemination activities

The document presents a comprehensive overview of FLEXGRID's work on business modelling and exploitation, together with an evaluation of the impact of the project. Chapter 1 (**SIN**) includes the final version of FLEXGRID's business ecosystem, together with a recap of the Key Exploitable Results (KER) presented in D8.2 (relevant for the exploitation plan), and the state of the art of flexibility policies and regulations at EU and national level. The final outcomes of the business modelling process are presented in Chapter 2 (**SIN**). The final list of selected business cases has been achieved through an interactive and iterative process with the industrial consortium partners. As a result, the scope has been narrowed down to mainly focus on four business models and six business cases. Chapter 3 (**ETRA**) presents the business and exploitation plan for individual FLEXGRID modules and the ATP. This chapter is complemented by the CBA analysis that can be found in the Annex (**ETRA**). Chapter 4 (**ETRA**) is devoted to Intellectual Property Management and presents the IP management plan for FLEXGRID' services, along with the contributions in the Innovation and Exploitation Committee. Then, in Chapter 5 (**SIN**) it is presented the impact analysis and innovation management for the project. Where the overall project research results are summarized, the impact according to the project objectives and the broader societal contribution is discussed. Finally, Chapter 6 (**ICCS**) reports on the communication and dissemination activities of the project results, and Chapter 7 (**SIN**) includes the conclusion of the FLEXGRID final business modelling, exploitation, impact, and innovation management work.

## 1.1 FLEXGRID architecture and business ecosystem

In this deliverable the stakeholders and actors considered in FLEXGRID's business ecosystem have been narrowed down, and the results can be seen in **Error! Reference source not found.**. FLEXGRID's business ecosystem covers a broad segment of the electricity value chain, including TSOs, DSOs, distributed loads and generators through the role of the (ESP) and its included actors (Supplier, Aggregator and Prosumer). Finally, it also includes the electricity markets through the roles of the Flexibility Market Operator (FMO) and Market Operator (MO).

FLEXGRID's business eco-system illustrated in **Error! Reference source not found.** highlights the interactions and value addition of implementing an integrated flexibility solution, such as the FLEXGRID ATP. The services developed during the project allow different stakeholders to reach their

[2] FLEXGRID Deliverable 8.2 - Intermediate version of business modelling, dissemination, and exploitation of results. Available on: [Deliverables | FLEXGRID (FLEXGRID-project.eu)](Deliverables | FLEXGRID (FLEXGRID-project.eu))

business goals, while the integrated ATP solution creates a single marketplace where flexibility sellers and buyers can easily interact.

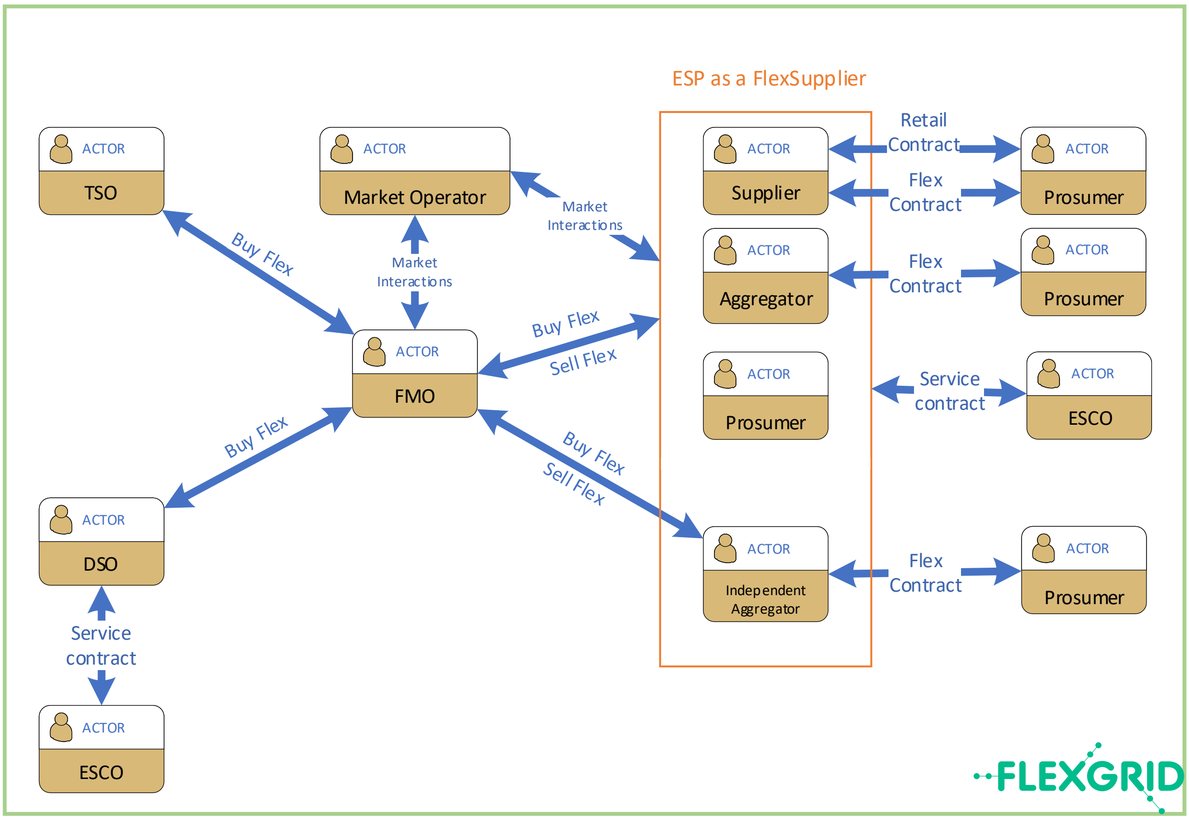



**Figure 1: Actors considered in the FLEXGRID business ecosystem**

The following paragraphs analyze the identified actors and their interactions within the FLEXGRID ecosystem. First, prosumers are defined as flexible asset owners; two types of prosumers are shown **Error! Reference source not found.Error! Reference source not found.**. One is an independent or large prosumer[3] who can participate via an energy supplier or act as a direct market participant. The other type of prosumers refers to end-users that are not able to participate in energy markets themselves. These prosumers are offered the opportunity to deliver flexibility and getting compensated using intermediate actors such as an ESP. As a dependent prosumer, there are flexibility contracts with the aggregator and independent aggregator in addition to the retail contracts with the energy provider.

An aggregator is a market actor who combines energy users' (prosumers) and producers' flexibility for the purpose of selling it to various stakeholders or through flexibility markets. Aggregators can be existing BRPs or energy retail companies adding new functionalities to their daily business. Additionally, aggregators can act as ESPs and optimize energy consumption of end-users in periods of low flexibility needs. In the FLEXGRID ecosystem, ESCOs are defined as companies providing energy services to all the stakeholders but that are not actively involved in the procurement or provision of flexibility. From this perspective, most FLEXGRID developed services could be implemented as independent business models for ESCOs. From the system operator's perspective, FLEXGRID envisioned ecosystem will allow DSOs and TSOs to procure flexibility from distributed assets to preserve the stability and effectiveness of the energy grid. Furthermore, the integration of services in a centralized tool/space (ATP) should ease the provision of flexibility from the distribution side, and therefore increase the available liquidity for procurement. Finally, the last actor to be considered are market operators. FLEXGRID has mainly developed solutions towards procurement and provision of

[3] Large prosumer – Power system actor with enough flexibility to participate by itself in ancillary services markets.

flexibility from DERs. The FMO is the actor envisioned to operate the local flexibility market in FLEXGRID. Additionally, if the ATP will be implemented as an integrated solution, the FMO is also considered the best actor to be managing the additional services. Finally, the role of MO within FLEXGRID is considered because part of the services developed (e.g. stacked revenue maximization) could also be used by different stakeholders to interact with other markets such as ancillary services markets or wholesale electricity markets. At the same time, innovations such as network aware algorithms for local flexibility markets, could allow a more extensive integration between different electricity markets (see D5.3 discussion on x-DLFM architectures)

## 1.2 Description of the key exploitable results

The final list of KERs has no major changes compared to the intermediate list reported on D8.2. The following paragraphs provide an overview of the identified KERs from D8.2 and include some new KERs identified during the latest stage of the project.

**Scientific or Technological R&D Result**

- **Manage a FlexRequest (Dispatch optimization)** – The aggregator maximizes its profits by optimally selecting the dispatch/activation of its distributed FlexAssets (WP3). It is focused on the aggregator as the main user, the service is integrated in the ATP (through UCS 4.1) and it is included in the (AFAT) module.
- **Create a FlexOffer** – The aggregator maximizes its profits by dynamically orchestrating distributed FlexAssets (WP3). It is focused on the aggregator as a main user, the service is integrated in the ATP (through UCS 4.3) and it is included in the AFAT module.
- **Manage B2C flexibility market** – The aggregator operates an ad-hoc B2C flexibility market with its end energy prosumer customers (WP3). It is focused on the aggregator as the main user, the service is integrated in the ATP (through UCS 4.4) and it is included in the AFAT module.
- **Minimize ESP's OPEX** - The ESP minimizes its operational expenses by optimally scheduling end user consumption (WP4). It is focused on the ESP as the main user, the service is integrated on the ATP (through UCS 2.1) and it is included in the FST module.
- **Minimize ESP's CAPEX -** The ESP minimizes its capital expenditures by making optimal investments (WP4). It is focused on the ESP as the main user, the service is integrated on the ATP (through UCS 2.2), and it is included in the FST module.
- **Stacked revenue maximization -** The ESP maximizes its profits by co-optimizing its participation in energy, reserve, and local flexibility markets (WP4). It is focused on the ESP as the main user, the service is integrated in the ATP (through UCS 2.3), and it is included in the FST module.
- **Market Price Forecasting –** The service is a reliable forecasting tool that will be used to forecast the day-ahead electricity prices (WP4). It is focused on aggregators and ESPs as the main users, the service is integrated on the ATP (through UCS 4.4) and it is included in the FST module.
- **Pay-as-bid market clearing** – Market design and clearing algorithm for local flexibility markets including network constraints (WP5). It is focused on the FMO as the main user, the service is integrated in the ATP through UCS 1.1, 1.2 and 1.2 depending on the type of product to be cleared (active power, active reserve, or reactive reserve) and it is included in the (FMCT) module.
- **Auction-based market clearing** - Market design and clearing algorithm for local flexibility markets including network constraints (WP5). It is focused on the FMO as the main user, the service is integrated on the ATP through UCS 1.1, 1.2 and 1.2 depending on the type of product to be cleared (active power, active reserve, or reactive reserve) and it is included in the FMCT module.

In a Figure 2 a schematic representation of FLEXGRID's ATP modules and services can be seen. On it the business actors and consortium partners that have developed the services are also represented. The ATP integrated KERs are not the only results from FLEXGRID that have further potential either for exploitation or to give inputs for new regulations. The following are the results from FLEXGRID that have not been integrated on the ATP but in the consortium's view possess future exploitation potential.

**External Services**

- **PV forecast** - Focused on aggregators and ESPs as the main users and integrated on the ATP through UCS 4.4-PV. This KER is being exploited and developed by UCY on their specific PV forecasting platform. The main achievements will be added to the UCY service to improve their tool.
- **Load Forecast** - Forecasting algorithms are not a novel idea but being able to forecast and focus specifically on flexibility management techniques is. The load forecast algorithm performs an evaluation and improvement of different forecasting algorithms in the fields of PV generation, physical load flows, and wholesale prices. The service has been developed by AIT in collaboration with bnNETZE and its performance results can be seen in D7.3.
- **Novel consulting services mostly based on ATP** - Industrial partners will take advantage of the ATP developed services to provide consulting services. Markets for flexibility are currently discussed in many parts of the world. For example, NPC receive requests from North America to Asia to discuss and provide solutions for utilizing the potential of distributed assets in lower than transmission grid levels. Many countries need assistance to analyze the problem and define possible solutions.

**Policy Related Results**

- **x-DLFM architectures** - Recommendation to policy makers about different market architectures. Not included in the ATP and focus on policy makers as CEER, ACER, DSOs, TSOs, and the EC.
- **DSO Techno Economic Analysis** - Simulation results that make a recommendation to policy makers about trade-offs in using flexibility markets. Not included in the ATP and focus on market actors as DSOs, TSOs, Aggregators, ESPs, and FlexSuppliers.

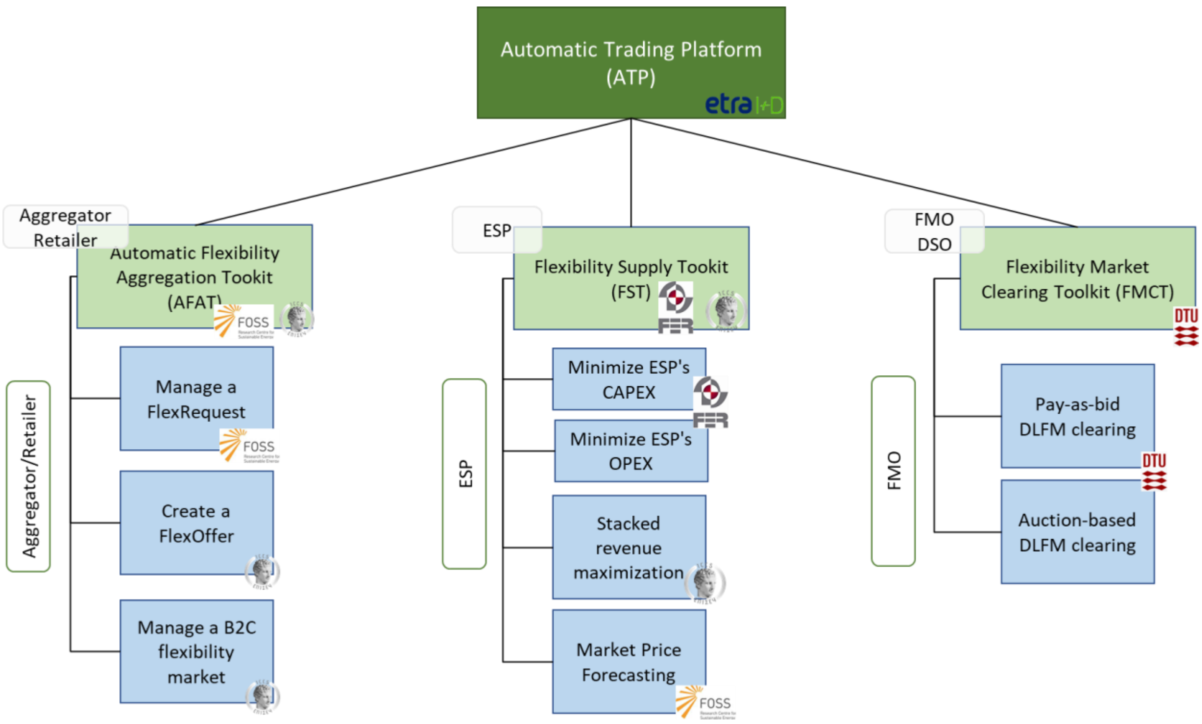



**Figure 2: FLEXGRID ATP integrated modules and services**

### 1.2.1 FLEXGRID KER #1: Automated Trading Platform (ATP)

The ATP provides a user-friendly frontend to all users of the FLEXGRID services. Therefore, it integrates the rest of the FLEXGRID KERs and all their services in it, and a central database. The following are the core components of FLEXGRID ATP backend:

- Flexibility Market Clearing Toolkit – KER #2
- Flexibility Supplier Toolkit – KER #3
- Automated Flexibility Aggregation Toolkit - #4
- FLEXGRID Central Database

The main feature of the platform is the possibility to integrate and operate flexibility-related services in real time considering the needs of the various stakeholders. Potential ATP users include: i) (FMOs), ii) (DSOs), iii) (ESPs), iv) aggregators/retailers, and v) administrative users. Using the ATP services, these stakeholders will have the opportunity to use different flexibility services in a simple and effective way and interact with each other. More specifically, the FMO user can manage various flexibility market parameters and visualize how FlexDemand and FlexSupply are matched. The DSO users can easily create a FlexRequest and generally manage their flexibility needs. ESP users can manage their available flexibility and offer it to the market in the most efficient way. Aggregator users can manage a portfolio consisting of many end users (i.e. energy prosumers) and thus efficiently represent their interests in the energy/flexibility markets. Finally, the administrative user is able to manage many ATP user accounts and allocate various combinations of access rights to each one of them. The relevant feature about the ATP as a KER, is that the different market actors/stakeholders can effectively interact with each other through the FLEXGRID ATP, thus facilitating optimized business contexts. For example, when a flexibility market is cleared, the dispatch results are communicated to all FlexBuyers and FlexSuppliers. Moreover, when an ESP runs a "what-if" simulation scenario about a new FlexAsset investment, they can easily share these results with other stakeholders (e.g. the local DSO), who might be interested in this information. In general, the FLEXGRID ATP can bring closer the various stakeholders' business interests, which can be very useful for the smart grid ecosystem and help EU's energy transition by enhancing social welfare related KPIs for the sake of EU citizens (i.e., end users).

Apart from the ATP's frontend services, a central database (DB) is included in the ATP offering. Thus, all types of users can use the ATP's web services to insert new data into the DB, update and delete data from it. This is also very useful for the interaction between two or more stakeholders, because they can agree on specific datasets to be used for "what-if simulations" and then be able to discuss the results (via the use of ATP GUIs) towards agreeing on possible new future business partnership.

FLEXGRID ATP has been deployed by ETRA in the context of WP6. ETRA, being a software platform provider, aims at exploiting the ATP by identifying new business opportunities related to the establishment of new flexibility markets via the participation of at least one FlexBuyer (e.g. DSO, TSO or BRP), one FlexSupplier (ESP or aggregator) and one FMO. ETRA could also provide ATP services to an FMO actor (e.g. NODES), who already operates a flexibility market and already has a portfolio of clients from both FlexDemand and FlexSupply sides. More details about ATP's cost-benefit analysis (CBA) and Intellectual Property Rights (IPR) management are provided in section 3 and 4.

### 1.2.2 FLEXGRID KER #2: Flexibility Market Clearing Toolkit (FMCT)

The FMCT includes several market clearing algorithms and mathematical models that are part of the WP5 work done by DTU. There are two major types of algorithms that have been integrated in the FMCT, namely:

- Auction-based flexibility market clearing
- Continuous flexibility market clearing

These two main types of algorithms have been integrated in three main flexibility "services" to deal with corresponding business scenarios (i.e., flexibility needs of a DSO), namely:

- Active power (energy) product [UCS 1.1]
- Active power reserve (up/down) product [UCS 1.2]
- Reactive power reserve (up/down) product [UCS 1.3]

These algorithms have been integrated into the FMCT. Hence, the FMO user can run "what-if" flexibility market clearing scenarios to find efficient market equilibria that match FlexRequests (made by a DSO) and FlexOffers (made by ESPs). The FMO user is also able to visualize important KPIs such as: i) social welfare, ii) cost of flexibility procurement (for the FlexBuyer), iii) volume of flexibility that has been traded, iv) flexibility price, v) list of accepted bids, etc. Via this process, FLEXGRID proposes another possibility where an FMO user can compare various flexibility market clearing algorithms and thus decide in which market/system contexts a possible introduction of a flexibility market can have a positive impact for all involved stakeholders and most importantly for end users.

The auction-based flexibility market clearing algorithm is a scientific/technological R&D result with the objective of ensuring the feasible operation of the DN. Very closely related with the continuous flexibility market clearing (also a scientific/technological R&D result), they include the DN constraints to ensure that an operating point could exist with the cleared quantities and has the potential to model network constraints on the cross-border intraday (XBID) market. This allows to increase the flexibility provision from small and decentralized resources, in constrained grids, which can be helpful to support the EU's energy transition.

Finally, the DSO user can use the FMCT to identify any possible network constraints (e.g., local congestion, voltage control issues). After identifying its need for flexibility, the DSO user can create a FlexRequest (price/quantity pairs for given timeslots) and submit it to the ATP. Then, both FMO users and ESP/aggregator users are informed about this FlexRequest and can thus further process it. FLEXGRID FMCT has been deployed by DTU in the context of WP5, while ETRA was responsible for the integration of FMCT algorithms in the ATP. More details about FMCT's (CBA) and IPR management are provided in section 3 and 4.

### 1.2.3 FLEXGRID KER #3: FlexSupplier's Toolkit (FST)

The FST includes several algorithms and mathematical models that are part of WP4 research work provided by UNIZG-FER, ICCS and UCY. This research work is targeted at ESP users. There are four main algorithms that have been integrated in the FST, namely:

- Minimize ESP's capital expenditures (CAPEX) [UCS 2.1],
- Minimize ESP's operational expenditures (OPEX) [UCS 2.2],
- Maximize ESP's stacked revenues by co-optimizing its participation in multiple markets [UCS 2.3],
- Market price forecasting and PV forecasting [UCS 4.4].

These algorithms have been integrated into the FST. Hence, the ESP user can run "what-if" simulation scenarios to identify the best strategy for its business. More specifically, regarding the UCS 2.1 functionality, the ESP user can run an optimal scheduling algorithm to investigate how its OPEX can be minimized in various scenarios. Regarding UCS 2.2's functionality, the ESP user is able to run an optimal FlexAsset sizing and siting algorithm to determine its optimal investment strategy. The ESP user can run exhaustive "what-if" simulation scenarios assuming various mixes of FlexRequests and FlexAsset portfolios and providing as input parameter an OPEX reduction target (e.g. 5%) that should be satisfied when the new FlexAsset investment will be made. Regarding UCS 2.3 functionality, the

ESP user can run an optimal bidding algorithm to determine its energy and flexibility offers in four different markets. Via the ATP, the ESP user can fill in various input parameters and thus calculate its stacked revenues from its co-optimized market participation strategy. Finally, regarding UCS 4.4, the ESP user can run a market price forecasting algorithm that tries to minimize the mean absolute percentile c (MAPE), which helps the ESP to efficiently bid in all the available markets.

FLEXGRID's FST has been developed by UNIZG-FER (cf. UCS 2.1-2.2), ICCS (cf. UCS 2.3) and UCY (cf. UCS 4.4) in the context of WP4, while ETRA was responsible for the integration of FST algorithms in the ATP. More details about FST's (CBA) and IPR management are provided in section 3 and 4.

#### 1.2.4 FLEXGRID KER #4: Automated Flexibility Aggregation Toolkit (AFAT)

The AFAT includes several algorithms and mathematical models that are part of WP3 research work done by ICCS and UCY. This research work is targeted for the aggregator user. There are three main algorithms that have been integrated in AFAT, namely:

- Manage a FlexRequest [UCS 4.1],
- Manage a B2C flexibility market [UCS 4.2],
- Create a FlexOffer [UCS 4.3].

The "Manage a FlexRequest" algorithm aims at successfully responding to the FlexRequest made by a DSO, TSO, or BRP. A FlexRequest can either be a request for activation of energy (upward or downward) for one or more timeslot(s) or a request for available capacity for one or more timeslot(s) with a potential activation request if required using the "Flexibility Aggregation algorithm". In different time periods, a request can have a variety of payment options in (e.g., for capacity and/or energy), making it necessary to evaluate and analyze each flexibility requests in detail. This is important because new requests can be made to manage grid challenges in near real-time, and FlexSuppliers involved in the activation will need tools for easy evaluation of the different possibilities. Secondly, there is the B2C flexibility market. FLEXGRID's envisioned 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" algorithm facilitates the activation of flexibility among end-user's FlexAssets in an aggregated portfolio, while maximizing social welfare. For achieving this goal, the aggregator/retailer user can setup simulation scenarios 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 proposed as a complete novel solution.

Finally, the "Create a FlexOffer" algorithm aims to establish a method to compute the upward and downward flexibility cost for a set of DERs by means of a "Flexibility Aggregation Algorithm". The aggregator user can visualize the expected revenues for each of the timestamps that are considered in the execution of the algorithm. The expected revenue is calculated by first aggregating the individual FlexOffers to a single aggregated FlexOffer. Then, the resulting FlexOffer is matched with a given FlexRequest. For each timestamp, a price and a quantity value are calculated. Thus, the aggregator may run different scenarios with different FlexOffers and FlexRequests and see how the different FlexOffers should be clustered to produce the optimal expected revenues for the aggregator's business.

FLEXGRID's AFAT has been developed by ICCS (cf. UCS 4.2-4.3), and UCY (cf. UCS 4.1) in the context of WP3, while ETRA was responsible for the integration of AFAT algorithms in the ATP. More details about AFAT's (CBA) and IPR management are provided in sections 3 and 4.

## 1.3 Policy and regulatory developments at European and national level

This section focuses on advances in distributed flexibility regulations. First, it presents the relevant policy developments at European level, whereas in the subsequent sections the national regulations of Germany, Croatia and Norway are updated to show today's situation of flexibility.

### 1.3.1 EU - Policy and regulatory developments

The recent invasion of Ukraine by Russia has led the EU to further accelerate the energy transition by reducing the dependency of Russian gas. According to the IEA, the EU purchased 155 billion cubic meters of natural gas from Russia in 2021, accounting for about 40 percent of the continent's total gas consumption and nearly half (45%) of its gas imports. Energy prices were already rising due to post-lockdown increased energy demand, and now Russia's attack on Ukraine has led to even more uncertainty and price instability in the energy markets which is affecting all EU citizens. The EU has responded to these challenges with multiple measures and initiatives all of which can be encompassed within the **REPower EU**[4] plan. The **REPower EU** plan builds on top of the European Green Deal's **Fit for 55 plan**[5], increasing its funds with 225 billion €, and it is oriented to accelerate a sustainable, just and beneficial energy transition for all Europeans. Some of the relevant measures promoted in the plan are:

- Improved permitting of RES projects (to accelerate RES deployment)
- Increase the European renewables target for 2030 from 40% to 45%
- EU-coordination demand reduction plans in case of gas supply disruption
- Investments in an integrated and adapted gas and electricity infrastructure network

As can be observed in the listed objectives above, due to the current situation the EU has decided to accelerate its energy transition plans, and to do so it is promoting an increased adoption of RESs together with investments in new infrastructure, but also it is acknowledging the power of demand response and flexibility for a more resilient system. Furthermore, in the **Save Gas for a Safe Winter**[6] package, the EU explicitly mentions the potential role of demand side flexibility to reach the established 15% energy consumption reduction target: *"demand response could target consumption of electricity by industries, residential, office and commercial buildings, and transport sectors.* ***To unleash the potential of demand response already for next winter, Member States should open all markets to flexible demand-side resources to enable their participation.*** *Based on industry estimates, if fully exploited and activated across all markets, flexible capacity in the electricity system could reduce EU imports of Russian gas by 5%."*

Moving towards more concrete solutions, the 1st of June of 2022 the EC invited ACER to submit framework guidelines[7] for the development of a Network Code on Demand Response within the following six months. This requirement is based on Art. 59 of the Electricity Market regulation and has been prompted by the recent communication of the EC "*Short-Term Energy Market Interventions and Long-Term Improvements to the Electricity Market Design – a course for action"* published the 18th of May of 2022.

On the invitation the EC highlights the need to address regulatory barriers for DR related to the following products:

- Electricity balancing markets, including frequency containment reserves
- Congestion management by DSOs and TSOs
- Voltage control

[4] REPower EU: Affordable, secure and sustainable energy for Europe. Available on: REPowerEU: affordable, secure and sustainable energy for Europe | European Commission (europa.eu)

[5] Fit for 55: Fit for 55 - The EU's plan for a green transition - Consilium (europa.eu)

[6] Save Gas for a Safe Winter. Available on: Save Gas for a Safe Winter (europa.eu)

[7] European Commission: Invitation to submit framework guidelines for the development of a network code based on Art. 59(1)(e) of the Electricity Market Regulation. Available on: 2022 06 01 FG Request to ACER_final.pdf (europa.eu)

Furthermore, the EC also mentions underlying challenges to DR market participation such as cooperation between TSOs and DSOs, and data exchange not only between system operators, but also between system operators and flexibility providers. On this last topic Expert Group 1 of the Commission's Smart Grids Task Force (SGTF) has recently started working on recommendations advice for the EC development of the act on data required for demand response. Finally, the EC also requires ACER to develop the codes considering potential challenges and interlinkages with prequalification processes, multiple market participation, baseline methodologies, aggregation, and the ownership of storage by DSOs and TSOs.

### 1.3.2 Germany – Policy and regulatory developments

The regulatory framework regarding the electricity market in Germany has changed since the 1st of October 2021. On that day the regulatory package known as "Redispatch 2.0" entered into force. In the following paragraphs some of the regulatory mega trends arising from this new regulatory framework are described.

#### Redispatch 2.0

With the national Network Expansion Acceleration Act ("NABEG"), numerous new regulations had entered into force from 1st of October 2021. These are collectively referred to as "Redispatch 2.0". The most transformative change from "Redispatch 2.0" is that within this new regulatory framework German DSOs become responsible for performing active redispatch of generation devices and controllable loads, extending the scope of the redispatch regulation in Germany from 50 MW assets down to assets with installed capacities of 100 kW or higher. In this new framework created by the regulatory authorities the role of DSOs becomes critical for the operation of the system.

"Redispatch 2.0" is the second step in Germany to resolve grid constraints caused by fluctuating feed-in of renewable energies (for example PV combined heat and power plants (CHP) or small hydropower plants). Whereas in the first step only plants with an electrical output of 10 MW or more were affected, the new limit is now 100 kW. This affects around 100.000 renewable energy generation assets alone. In the first stage, responsibility for redispatch lay exclusively with the TSOs. Now, with the second stage, the responsibility has been extended to all DSOs. DSOs can now switch off applicable generation assets if necessary to ensure grid stability. The operator receives compensation for the curtailed energy output, depending on the balancing model. Most rooftop PV systems in commercial and industrial applications are larger than 100 kW. Every self-generation plant above 100 kW installed capacity that can theoretically feed into the grid, i.e. is at least indirectly connected to it, is obliged to participate in redispatch.

On top of the active management of distribution grids, "Redispatch 2.0" means new tasks for DSOs and new obligations for plants above 100 kW, for instance the technical master data of all affected plants must be available. For this purpose, a central registry has been created, which the grid operators can access. Furthermore, during grid operation the DSOs must also prepare forecasts for each affected plant and report them to the upstream grid operator. This is the only way to simulate with sufficient advance notice whether grid congestion is to be expected as a result and whether interventions in the operation of individual plants are necessary.

Redispatch is not a market-based mechanism. The participation of generation assets above 100 kW is mandatory like it was before for plants above 50 MW. Likewise, the compensation mechanism is precisely defined. The new processes were introduced in Germany in October 2021 and are already operational.

The aim of the new regulation is to find a cost-optimal 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 the costs effectiveness of possible measures in advance, i.e. based on forecasts and load flow analyses. Grid operators then define appropriate redispatch measures at the various voltage levels in a close coordination process to avoid identifiable grid constraints.

**Termination of national feed in system for renewables**

On 1st of January 2021, the first PV systems were no longer eligible for the national feed-in tariff in Germany. After 20 years the subsidy ended for them. Owners who built a photovoltaic system in the early 2000s used to feed all their electricity into the public grid. At that time, solar PV plants were quite expensive, but the high remuneration of around 50 cents per kilowatt-hour enabled profitable operation despite the high initial costs. In 2021, approximately 10.000 PV systems have already dropped out of the compensation. By 2026, the number will increase by a factor of 20. Between 2029 and 2032, a particularly large number of systems will have dropped out of the subsidy scheme. By 2033, the compensation for a total of more than one million solar installations will expire.

For operators of PV systems older than 20 years, the question therefore arises as to whether and how they can continue to operate the systems after the end of the subsidy. Technically, the systems are always capable of doing so - solar power modules usually have a service life of 30 years or even more. There are two options for continuing to operate the system:

1. Grid feed-in
2. Self-consumption

Grid feed-in

The legislator has decided on a temporary connection regulation at the end of 2020. According to this, operators may continue to feed their electricity into the grid and receive the "annual market value of solar" as remuneration. In the past years, this amounted to between 2.5 and 4.5 cents per kilowatt-hour. A flat rate is deducted from the solar market value to cover the costs of marketing solar power for the responsible DSOs. In 2021, the flat rate amounted to 0.4 cents per kilowatt hour and will be determined by the grid operators from the actual costs incurred from 2022 onwards.

However, the regulation is initially limited until the end of 2027. Many plants still function well after 20 years and may simply continue to feed into the grid under the new legal situation. The threat of having to actively look for a buyer for PV electricity via "other direct marketing" is off the table. In practice, the so-called direct marketer is a service provider. However, the situation is made more difficult by the fact that only a few of these specialized direct marketers are interested in small units because, from their point of view, the quantities of electricity are too small, and the administrative costs are too high. In the case of small units, the costs exceed the achievable feed-in revenues in direct marketing.

Self-consumption

In the case of smaller rooftop solar systems whose electricity generation is of a similar magnitude to the electricity consumption of the residents, the option of no longer feeding the self-generated electricity into the grid but consuming it yourself is also worthwhile. This usually requires only minor modifications to the electrical installation in the meter cabinet. In residential buildings, electricity is needed permanently, for example for refrigerators and other electrical appliances. The PV system can often cover this consumption during the day. Depending on the size of the system and the electricity consumption, typically around 20 to 30 % of the solar electricity can be used quite easily. If you want to increase the share even more, you can also shift the power consumption of the dishwasher or washing machine to midday. In this way, you can consume 30 to 40 % of the solar power yourself with very little effort.

Why is this worthwhile? Rooftop PV units only costs around two to four cents per kWh net for depreciated small systems - the only expenses are for meters and, if necessary, maintenance, repairs, and insurance. Who now uses this favorable self-produced electricity for the own consumption saves up to date more than 20 cent per kWh – tendency rising. The lucrative self-consumption can be further increased with battery storage. Shares of up to 70 % are then possible.

### 1.3.3 Croatia – Policy and regulatory developments

The Croatian government adopted a new Electricity Market Law - ZOTEE (Zakon o tržištu električne energije, NN 111/2021)[8], effective from 22 October 2021, which incorporates all provisions related to balancing defined by Regulation (EU) 2019/943 and Directive (EU) 2019/944. ZOTEE defines terms important for system flexibility such as aggregators, active customers, distributed generation, energy communities, charging points, energy storage and others. Furthermore, it establishes common rules for the production, transmission, distribution and storage of energy and the supply of electricity; ZOTEE defines that end customers can independently or through aggregation participate equally in all electricity markets. It also introduces smart meters that empowers end customers in a way that such systems provide them with accurate feedback on energy consumption or production in almost real time, and there are many other novelties important for the electricity market.

According to provisions of ZOTEE, new adaptations of Rules on Balancing the Electric System - POUEES (Pravila o uravnoteženju elektroenergetskog sustava, Official Gazette, no. 133/06, 135/11) and new adaptations of Rules on electricity market organization (Pravila o organiziranju tržišta električne energije, Official Gazette no. 107/19, 07/11/2019) are expected by the end of 2022. POUEES defines national balancing services market rules and ensures legal possibility for HOPS to participate in common European balancing energy exchange platforms in accordance with Articles 19 to 22 of EB Regulation. Pursuant to Article 62 of the Electricity Balancing Guideline (EB GL), Croatian Energy Regulatory Agency (HERA) at its 15th session of the Management Board, held on 23 July 2021 adopted a decision on granting approval to the HOPS for derogation from the obligations laid down in Article 21 of EB Regulation for the period from 24 July 2022 to 24 July 2024, or earlier if HOPS becomes technically capable to connect earlier to aFRR/mFRR platforms.

There are some other laws, regulations and methodologies adopted in 2021 and 2022 (and some that should be adopted by the end of 2022) which can be found on the Croatian Energy Regulatory Agency (HERA) web page[9]:

- Law on renewable energy sources and high-efficiency cogeneration (Zakon o obnovljivim izvorima energije i visokoučinkovitoj kogeneraciji, NN 138/2021),
- Rulebook on the system for monitoring, measuring, and verifying energy savings (Pravilnik o sustavu za praćenje, mjerenje i verifikaciju ušteda energije, NN 98/2021),
- Tariff Methodologies (Methodology for determining the tariffs for guaranteed electricity supply - Metodologija za određivanje iznosa tarifnih stavki za zajamčenu opskrbu električnom energijom, NN 20/2022; Methodology for determining the tariffs for distribution of electricity - Metodologija za određivanje iznosa tarifnih stavki za distribuciju električne energije, NN 84/2022; Methodology for determining the tariffs for transmission of electricity - Metodologija za određivanje iznosa tarifnih stavki za prijenos električne energije, NN 84/2022; Methodology for determining the the electrical network connection charge - Metodologija za utvrđivanje naknade za priključenje na elektroenergetsku mrežu, NN 84/22),
- Rulebook on quality conditions of electricity supply (Pravilnik o uvjetima kvalitete opskrbe električnom energijom, NN 84/22),
- Rules on permits for performing energy activities and keeping the register of issued and withdrawn permits for performing energy activities (Pravilnik o dozvolama za obavljanje

[8] Electricity Market Law, NN 111/2021 www.zakon.hr

[9] Croatian Energy Regulatory Agency (HERA), www.hera.hr

energetskih djelatnosti i vođenju registra izdanih i oduzetih dozvola za obavljanje energetskih djelatnosti, NN 44/2022).

**Transposition of the Clean Energy Act into Croatian national law**

The Electricity Market Law transposes European Directive (EU) 2019/944 into Croatian legislation. Once accomplished, the Croatian Electricity Market Law implements at a national level the following acts of the European Union:

- Regulation (EU) No 1227/2011 of the European Parliament and of the Council of 25 October 2011 on wholesale energy market integrity and transparency
- Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management
- Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action
- Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity
- Regulation (EU) 2016/1952 of the European Parliament and of the Council of 26 October 2016 on European statistics on natural gas and electricity prices.

Another important law in the implementation of the green transition is the Law on Renewable Energy Sources and High-Efficiency Cogeneration (ZOIEVUK), which is adopted in accordance with Directive (EU) 2018/2001[10] on the promotion of the use of energy from renewable sources. This law ensures the implementation of the following acts of the European Union:

- Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action
- Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics.

The main features of this law are the application of support programs for RES in a form that does not lead to distortions in terms of the functioning of the electricity market and the tender procedures for grants are open to all producers of electricity from renewable sources on a non-discriminatory basis. Additionally, to avoid market distortions caused by the excessive import of resources from third countries the life cycle approach is promoted in the new legislation, together with the principle of equal consideration of electricity produced and imported from third countries.

### 1.3.4 Norway – Policy and regulatory developments

The Nordic Balancing Model (NBM) program is a joint effort by the Nordic TSOs Svenska Kraftnät (Sweden), Energinet (Denmark), Fingrid (Finland) and Statnett (Norway). Svenska Kraftnät and Statnett are Common Service Providers (CSP) with the responsibility to deliver common services for balancing the Nordic grid. The NBM program has presented a roadmap for the implementation[11] of each building block, see **Error! Reference source not found.**.

At the end of 2021 Norway was the first Nordic country where balancing service providers (BSPs) can offer bids to a new platform for aFRR (automatic frequency restoration reserve) capacity to the transmission system owner (TSO). TSOs must ensure that they have sufficient aFRR resources to handle imbalances in system operation. As aFRR resources are unevenly distributed across the Nordic countries, reserving cross-zonal capacity for aFRR makes it possible to procure aFRR across bidding

[10] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

[11] The Nordic Balancing Model roadmap [Online]. Available: https://nordicbalancingmodel.net/roadmap-and-projects/

zones. aFRR balancing capacity is procured by the TSOs prior to the day-ahead market, considering geographical distribution and network constraints.

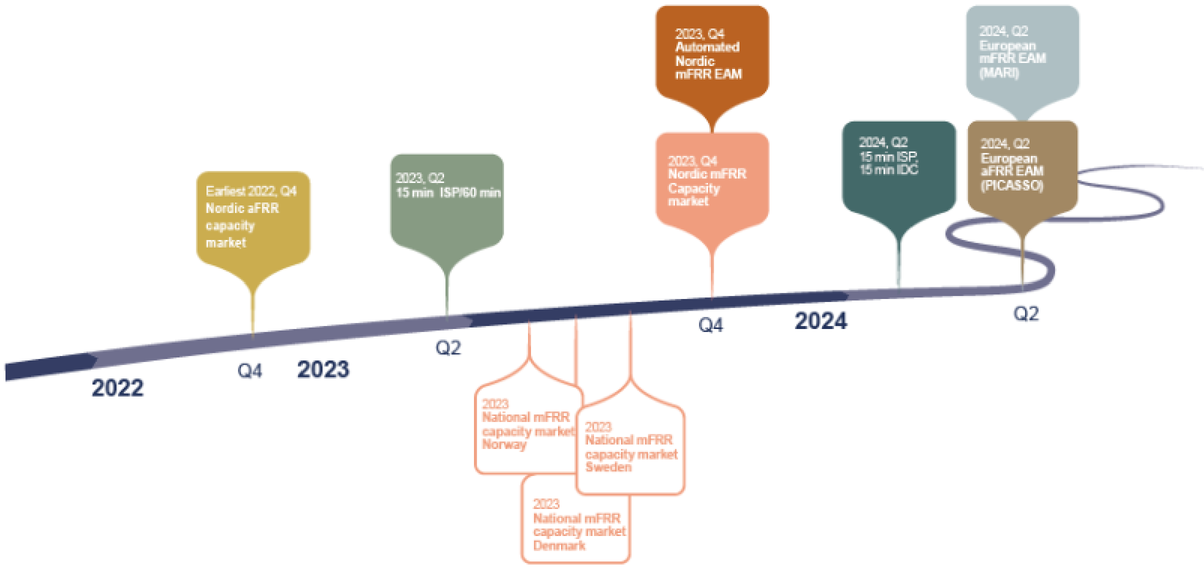



**Figure 3: the Nordic Balancing Model roadmap for implementing each building block.**

All metering production and consumption values are stored in a datahub called Elhub[12]. 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[13]. "Reguleringsmyndigheten for energi" (RME), the politically independent Norwegian regulator for energy has no separate regulations concerning flexibility.

**FLEXGRID H2020 Contributions:** In this section an overview of the recent **updates in the EU policy** framework and the relevant events shaping the EU energy transition have been presented, together with the latest regulatory updates from **Germany, Croatia, and Norway.** At EU level, the invasion of Ukraine has accelerated the energy transition, and has led to the creation of the new **REpowerEU** funding scheme. Furthermore, new energy policy guidelines highlighting the role of flexibility have been defined in the "**Save Gas for a Safe Winter**" package. Finally, ACER (asked by the EC) started the process to create framework guidelines for the creation of **Demand Response network codes.** At national level, from October 2021 in **Germany** "Redispatch 2.0" entered into force. The DSOs have an additional responsibility for grid stability and security of supply. Additionally, in January 2021 the German national feed in system ended. In **Croatia**, the new Electricity Market Law (ZOTEE, transposition of the CEP) entered into force in October 2021, and by the end of 2022 new rules on balancing, and electricity market organization are expected. Finally, in Norway, the Norwegian TSO has started together with the other Nordic TSOs, the Nordic Balancing Model, a joint venture to improve the balancing process in the Nordics and with the final goal to join the EU balancing platforms MARI and PICASSO by 2024.

[12] https://elhub.no/en/

[13] Elhub, "Personvern i Elhub,"

# 2 FLEXGRID final business models

The business case analysis performed in WP8 investigates the business motivations (objectives) and business cases for each of the stakeholders in FLEXGRID's ecosystem. Based on the KERs of the FLEXGRID project (presented in section 1.2) this chapter analyses the business/exploitation potential of the most relevant services according to the industrial partners. The services studied have been selected considering the urgency and importance of the problems they can solve, but also – when possible - the readiness of today's energy system framework (regulations, digitalization, etc.). In the following pages the business model of each service/KER is presented along with a quantitative analysis of their value proposition using business cases. This chapter sets the foundation for chapter 3 where FLEXGRID's business exploitation plan is described.

For a deeper understanding of the FLEXGRID potential we suggest the reader to go through D8.2[14]. In that document all FLEXGRID business models and business cases are analyzed, showing the value propositions of the services, the business model canvas for the different business actors and the mapping of business cases for each High-Level Use Case.

## 2.1 Business Model Analysis Methodology

The business model analysis methodology hereby presented extends the work in D8.2 by refining the described business models and their associated value propositions and narrowing down their scope to show closer-to-market applications of the developed solutions. Furthermore, the economic value of the developed solutions, and the viability of the business models are evaluated through the quantitative analysis of business cases. The business cases studied have been selected by the consortium partners as the ones with the highest potential from an exploitation perspective. In D8.2 three business modelling scenarios have been described. The final version of the exploitation work focusses its scope on business models that are as close to the market as possible. However, FLEXGRID is a low TRL project (most developments ending at TRL 6) and thus most of its developed solutions do not have the proper commercialization aspects yet implemented but the prospect of business models for the tools is needed in order to develop additional interfaces for commercial offering. Therefore, the final business modelling analysis has been done with a combination of Scenario 1 – today's EU distribution networks (DN) infrastructure and regulatory framework - and Scenario 2 – 2025-2030 EU DN- business cases – business models and services, in mind.

The methodology applied splits the analysis into three sections. First, the final business models are presented through a deeper look at their business model canvas and the different stakeholders involved. This shows the perspective of the commercial actor selling/providing the service (business bubble in Figure 4). The second part of the methodology presents one or more business cases associated with the customer segment and services developed, aiming to show the explicit value for the specific case. To do so, context for each business case is given, followed by a description of it, and the business goals (and objectives) of the stakeholders involved. Then the counterfactual business-as-usual (BaU) scenario is introduced. Finally, the qualitative analysis is presented. The last part of each business model evaluation aims to summarize the results obtained from the business cases and transfer them into correspondent value propositions.

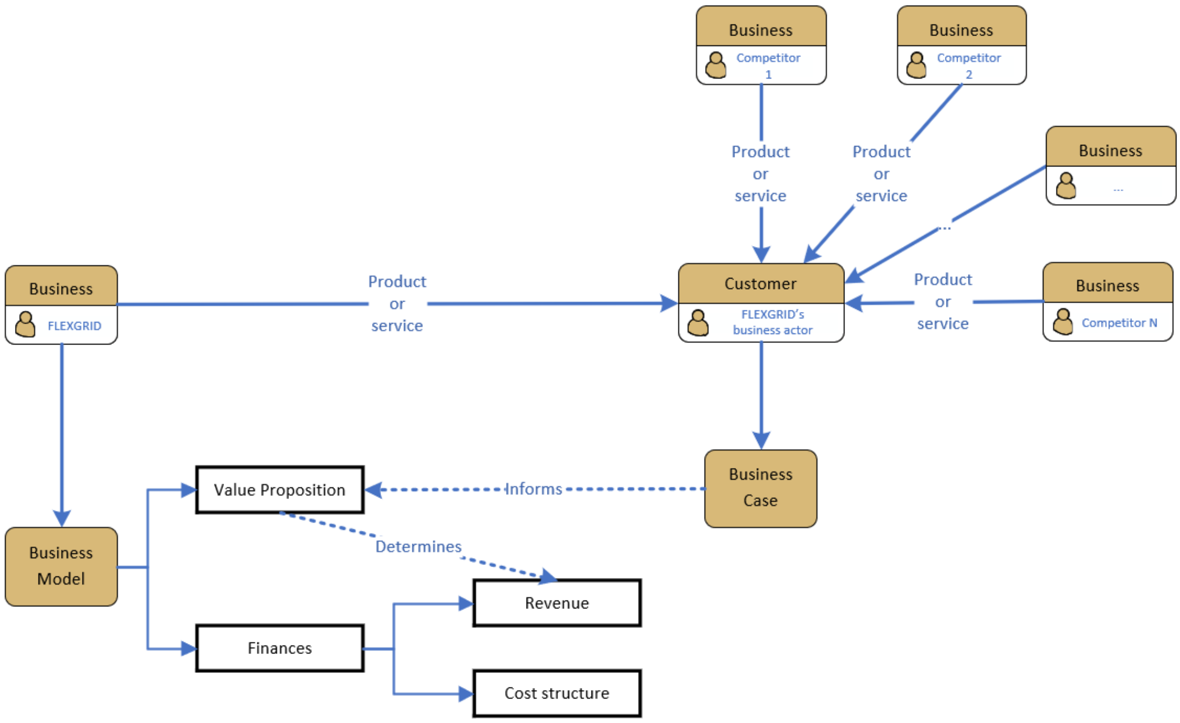



**Figure 4: Business model quantification framework**

In previous deliverables the Lean-Start-up methodology framework was used to develop the business/product development plan of FLEXGRID. This deliverable is about the exploitation plan and market readiness of the FLEXGRID solutions. For this reason, we have decided to use the market development strategy knowledge from the book *Crossing the Chasm*[15]. The strategy described in the book aims to show how to access mainstream markets with disruptive innovations. The current FLEXGRID ecosystem faces similar situations for most of its services and therefore it has been considered a relevant literature reference for this deliverable.

The strategy described allows disruptive innovations to reach the mainstream markets and encourages product developers and companies to focus their marketing efforts in one or two niche markets. Once these markets have been conquered start expanding to others. The logic behind this is that when it comes to innovations, more than selling a product you must create a market for it. Most of the solutions developed in FLEXGRID fit within this category and therefore it has been considered that the niche market approach would be best suited in this context. Consequently, out of all the business models and business cases presented in D8.2, only those with the highest potential have been selected to study their potential marketability. This reduction of business cases also implies a reduction of the relevant value propositions offered by FLEXGRID ATP. The extensive list of business models, business cases, and value propositions can be found in D8.2. The following table presents the final business models and their respective business cases that are analyzed in D8.3.

**Table 2: Deliverable 8.3 business models and business cases.**

| Business Model | Business Case |
|---|---|
| FLEXGRID platform for flexibility market operation | • FMO using advanced algorithms to increase the efficiency of market clearing [C03; C04] |

[15] G. A. Moore, *Crossing the Chasm: Marketing and Selling Disruptive Products to Mainstream Customers*, 3rd ed. Harper Business, 1991.

| | |
|---|---|
| FLEXGRID platform for DSOs (and TSOs) | • DSO using FLEXGRID ATP to predict peak power demand and request flexibility [C11]<br>• DSO avoids grid enhancement by requesting flexibility from a local market [C09]<br>• Long-term economic analysis of TSO using DN-level flexibility through a DLFM [C19] |
| FLEXGIRD platform for FlexSuppliers | • ESP optimizes its performance in day-ahead and intraday energy markets [C24] |
| Aggregator – using the FLEXGRID functionalities to provide increased value to prosumers | • Prosumer optimizes aggregated FlexAsset portfolio to sell flexibility [C22] |

## 2.2 Business Model Quantification: FLEXGRID platform for flexibility market operation

### 2.2.1 Business Model

The following section introduces the business model by expanding on the business model canvas presented in D8.2. This information serves as a preface to the coming sections where the business model is evaluated through the analysis of different business cases.

The first business model presented is that of a software provider that sells the FLEXGRID software platform (i.e., the ATP and its functionalities) to flexibility market operators to improve the operation of their DLFMs. Additionally, the same model can be used to sell the platform to market operators to expand their portfolio of products. One example of this approach is the acquisition of Centrica's DLFM by EPEX SPOT[16]. Therefore, the target customer are FMOs and MOs who could buy the FLEXGRID developed solutions either using a Software-as-a-Service, or licensing parts of it to support/expand the operation of their flexibility market.

In D8.2 two intermediate business models linked to DLFM operation were presented. The main difference between the two was that, whereas in one FLEXGRID acted solely as a software provider, in the other the offering included the operation of the market. This is, for instance, the business model of NODES and Piclo Flex. The final exploitation plan of FLEXGRID points towards a software developer more than an active FMO. Becoming a MO implies multiple responsibilities and additional tasks that for FLEXGRID as a company would mean higher complexity of management, a completely different business model and a different marketing strategy. Furthermore, establishing FLEXGRID as a MO has direct consequences over the rest of the business models developed in the project, because the offering of the developed services in a SaaS manner can be counterproductive for the business goal of FLEXGRID as a MO. For this reason, and to align all the presented business models, it has been discarded from the list of BMs. So, the current business model presented for the FMO is that of FLEXGRID as an algorithm developer and software provider.

Two are the value propositions of this business model. The first, *Improved market clearing process,* has been identified as the **core value proposition** which could sustain a business model on its own. It is the most disruptive technical innovation within the FLEXGRID FMCT toolkit. The implementation of network aware algorithms for continuous and auction-based markets is far from being an industry standard; however, interest for this type of solutions is growing in the industry. With that said, the DLFM ecosystem is still on its initial stages, the technology needed (advanced metering and control devices), even if available, has not been adopted yet by the majority of the potential market

[16] EPEX SPOT Localflex press release – Link: Press Release (eex-group.com)

participants, and the regulatory framework for DLFMs – in general, not only network-aware - is under development. FLEXGRID offers a future proof solution for local MOs, with which their DLFM can gain network aware capabilities while not increasing heavily the computational power needed. The other value proposition of this business model is strongly linked to the concept of **Whole Product** as described in multiple marketing books. One of the envisioned disruptive aspects for the long-run success of FLEXGRID' solutions is the possibility to implement the ATP as an integrated marketplace for flexibility trading. Through the ATP all the actors can access services that ease flexibility trading, but also the calculation of flexibility needs and potential, and the optimization of flexible assets. This means that the DLFM business actors would have access to all the necessary tools that would support their participation in the DLFM. This challenge, where a product needs "external services" to reach its full implementation is not new for innovations, and it has been described in books such as *The Marketing Imagination* and *Marketing High Technology*, under the concept of **Whole Product Model** (see Figure 5).

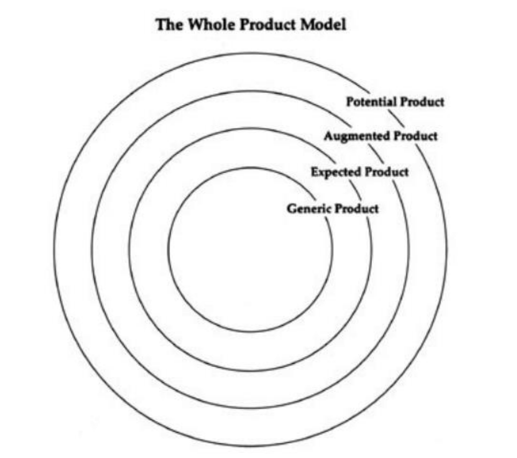


**Figure 5: Whole product model**

The idea behind the concept is that in disruptive innovations there is a gap between the marketing promise (the whole product) and the shipped product. When compared to other solutions FLEXGRID ATP ultimately aims to be the Whole Product by offering a different set of services that supports all the tasks that lead to flexibility procurement or offering. For the FMO business case, the core products are the market clearing algorithms; however, without additional services (external or internal) that help market participants to identify their flexibility needs and potential, DLFMs couldn't exist. Other DLFM platforms are partnering with multiple actors to reach the same goal[17]. It is within this framework that the second value proposition of this business model fits. The *Increase the service offering to FlexBuyers and FlexSuppliers* value proposition consists of the additional services that are offered with the FLEXGRID ATP, and how to make DLFMs more attractive to FlexBuyers and FlexSuppliers. This value proposition aims to help FMOs and MOs to provide their clients the whole product.

Regarding the revenue streams, two are identified: exclusive licensing or a subscription model. The exclusive licensing approach could be done with all the FLEXGRID ATP services; however, it makes particular sense for the network-aware algorithms. The reason for that being, that the market clearing algorithm is at the core of the DLFM product offering. From the FMO perspective having access to it through a subscription model means a) that they do not own the technology that creates their minimum viable product, and b) that their core technology can be also used by their competitors, therefore not giving them any competitive advantage. Since the number of potential competitors is low, the ownership and therefore exclusive licensing of the technology is relevant for FMOs. On the other hand, the SaaS (or subscription) model makes sense for the rest of the offered services. In this case exclusive licensing could also be an option; however, the pool of potential clients for the rest of the FLEXGRID services is significantly higher, and contrary to the FMO case the services will be used to participate in markets with a high degree of competition. Therefore, it has been considered that the best for the business model was to offer the services of the ATP either as a subscription fee or as

[17] NODESconnect partnership program to encourage collaboration in creating local sustainable flexibility markets in the energy sector. Link: NODESconnect - NODES (nodesmarket.com)

non-exclusive licensing agreement, allowing to maximize the pool of ATP users and therefore the revenue of the platform.

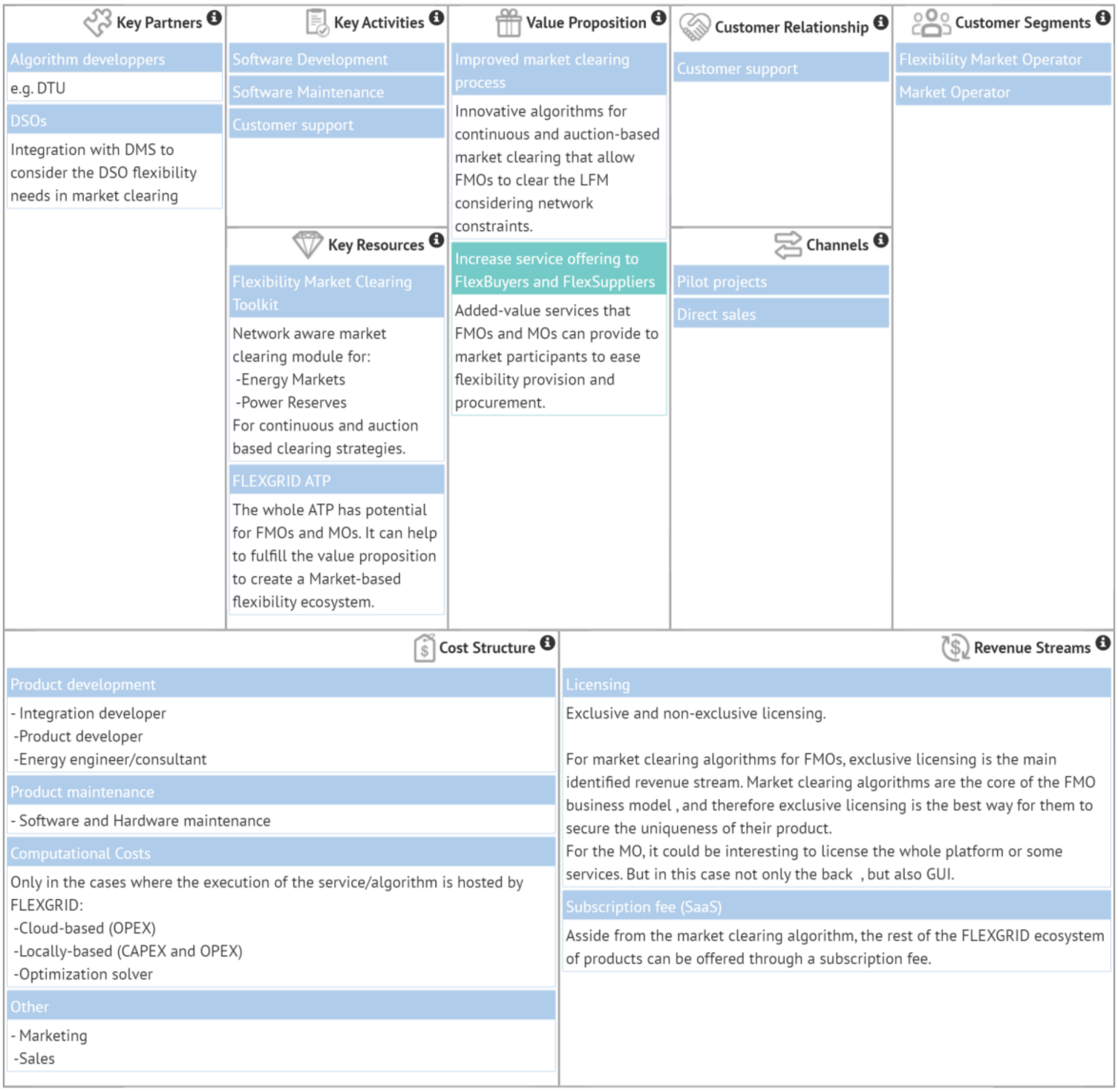



**Figure 6: Business model canvas for the provider of the FLEXGRID platform for flexibility market operation**

All the information about the cost structure can be found in the Annex where the costs of development and operation of FLEXGRID's ATP are presented.

### 2.2.2 Business Cases

*FMO using advanced algorithms to increase the efficiency of market clearing*

*Context*

Flexibility Markets at (DN) level can reduce costs for grid upgrades and increase the integration of distributed energy resources to solve grid constraints. According to Eurelectric and E-DSO [18], investments in distribution grids in the EU will rise from € 26 bn in 2019 to an average of € 34 to 39 bn/year during this decade. Furthermore, almost 90% of the investments needed will be used to

[18] Eurelectric & E-DSO: Connecting the dots: Distribution grid investment to power the energy transition. Available on: https://www.eurelectric.org/connecting-the-dots/

purchase new equipment. In this scenario of grid transformation, flexibility markets can be a valid solution to defer investments in a cost-effective manner and to help DSOs ensure quality and security of supply while upgrading the constrained grids.

This business case is part of FLEXGRID's High Level Use Case 01, which focuses on the efficient operation of flexibility markets by FMOs. Currently, the implementation of local flexibility markets is at initial stages. Projects such as Enera, GoPacs, NODES and Piclo Flex are being tested in multiple EU countries with different success rates, and there is a growing interest from energy system actors to have access to flexibility connected at distribution level[19][20][21].

As of today, most FMOs' core business offering is focused on providing a SaaS platform where DSOs can procure flexibility products to solve grid issues. Additionally, and with the intention of increasing liquidity in the markets, in some pilot projects where NODES participates, local FlexSuppliers are offered the opportunity to also interact with TSOs. Based on the current DLFM offering, not considering network constraints for the purpose of market clearing is not a significant burden for DLFM participation; however, in an envisioned future with higher number of flexible DERs connected to the distribution grid, not considering these constraints in the market clearing algorithms could lead to unfeasible transactions.

*Business case description*

The business case evaluated consists of a FMO using innovative algorithms that improve market clearing efficiency of. Nowadays FMOs offer DLFMs as a service to DSOs to actively manage their grids. This analysis evaluates the added value for the FMO of utilizing market clearing algorithms able to consider the physical state of the grid and optimize market clearing. To do so, the impact of the created algorithms on the market participants business goals will be evaluated.

The business ecosystem for this business case is represented through roles in Figure 7**.** The frame there presented is focused on a short-term horizon, for this reason the TSO is shown as an independent role that is not directly buying flexibility at a local level. Ideally, the role of a FlexBuyer in LEMs can be expanded to more market parties such as BRPs and TSOs.

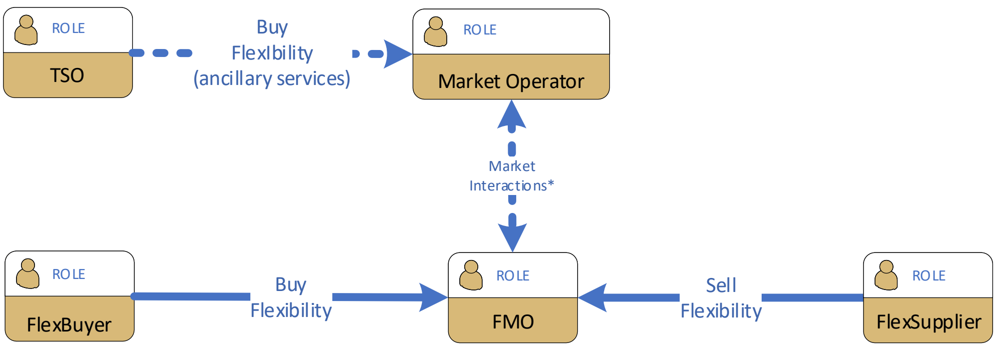



**Figure 7: Simplified FLEXGRID business ecosystem for this business case**

Based on D8.2 the business goals of each of the stakeholders have been identified. First, the FMO and MO business goals are to increase their service offering to DSOs and TSOs and to improve market clearing efficiency. In case of the DSO (FlexBuyer), its business goal is to ensure quality of supply and

[19]ELIA Group, Distributed Flexibility. Available on: https://innovation.eliagroup.eu/projects/distributed-flexibility/

[20]smarten, Open Letter: A Network Code for Distributed Flexibility. Available on: http://www.smarten.eu/wp-content/uploads/2020/04/Open-Letter-on-a-Network-Code-for-Distributed-Flexibility.pdf

[21]Arthur Little, Distributed Flexibility: The next pool of value. Avalable on : https://www.adlittle.com/en/insights/report/distributed-flexibility-next-pool-value

security of supply in the most cost-effective way possible. Finally, the flexibility supplier (FlexSupplier) business goal is to maximize the revenue of flexibility provision.

To summarize, in the "with FLEXGRID" scenario the clearing of the market uses network-aware algorithms developed by DTU, allowing a more secure, and in the auction-based case efficient, market clearing. Thanks to this the FMO can position their DLFMs as a better solution for DSOs to procure flexibility for their grids. Additionally, the optimization algorithms can create a more attractive market for flexibility suppliers by maximizing social welfare, which should translate into more flexibility available in the market.

*Counterfactual scenario*

The counterfactual scenario considered for this business case is an FMO operating a local flexibility market using non-network aware market clearing engines. Although this scenario is supposedly considered less effective in terms of market clearing, it surely holds various advantages and overcomes certain complications that are still not solved. An FMO running a DLFM complies with general market rules regarding independence, anonymity, and transparency. Furthermore, the separation of the flexibility market and the DSO allows for a concentration on the core responsibilities. So, according to the current approach, local flexibility markets are a complementary tool for DSOs that facilitate access to DRES and manages the validation and settlement. The purpose, time and dimension of use still depends on the DSOs' available measures to ensure security of supply and to solve grid constraints.

Quantitatively, it is not possible to provide values of the counterfactual scenario since market clearings are a very specific events which cannot be compared other than if the exact same conditions are given to both algorithms. For this reason, the Case Study section submits both network aware and non-network aware algorithms to the same market clearing conditions, and then evaluates the difference in performance.

*Case study*

In the following paragraphs the setup created for the case study will be explained, together with the justification of the assumptions made.

The distribution grid used as a base for the case study has been provided by bnNETZE and is in the Freiburg area. The grid has 81 nodes connected in a radial topology. bnNETZE has provided information regarding line maximum power capacity and node voltage ranges. All this information is part of the inputs for the network aware algorithms but cannot be disclosed since it was shared under an NDA agreement.

In the business case *2. DSO avoids grid enhancement by requesting flexibility from a local* market, another grid from the same region is described. That specific grid currently is operating during peak time at 14% utilization. In under-utilized lines such as that one, the risk of internal congestion due to flexibility activation is low (see the commercial DLFMs in operation). For this reason, in this case study the type of assets connected to the distribution grid have been modified to depict a future grid with higher electrification of mobility and an increase of RES power plants. Table 3 presents the peak power of the assets connected to the grid.

**Table 3: Asset characterization for business case 2.2.2**

| **Generation: Wind and PV farms** | |
|---|---|
| **Node** | **Maximum Power [MW]** |
| 117 | 0,3 |
| 130 | 0,2 |
| 138 | 0,3 |
| 154 | 0,3 |

| | |
|---|---|
| 172 | 0,12 |
| 181 | 0,12 |
| **Industrial loads: EV charging station** | |
| **Node** | **Maximum Power [MW]** |
| 116 | 0,2 |
| 121 | 0,2 |
| 132 | 0,15 |
| 137 | 0,2 |
| 168 | 0,1 |
| 177 | 0,1 |
| 182 | 0,1 |
| 183 | 0,2 |
| **Prosumers** | |
| The maximum power rating of the household is 5,2 kW. Some households also have PV panels. | Some households have additionally an active EV charger. |

Based on the connected assets, the scheduled set points of the grid have been created. These setpoints represent the day-ahead scheduled load and generation, and in most of the cases studied represent the trigger for the use of the DLFM. Three are the initial setpoints created to evaluate the performance of the market clearing algorithms:

- High generation: This setpoint considers a market time unit where the setpoint of the assets creates a congestion at the root node of the grid due to reverse power flows. The line capacity connecting to the root node is at 214%. Additionally, from the rest of the lines, three of them are at utilization rates over 60%. One operating at 97%, another at 75% and the third at 65%.

- High demand: This setpoint considers a market time unit where the set point of the assets creates a congestion at the root node due to high load. The line capacity connecting to the root node is at 212%. Additionally, from the rest of the lines, two of them are at utilization rates over 60%. One operating at 99%, and the other at 71%.

- Normal operation: This initial setpoint considers a market time unit where the grid is operating under normal conditions. The line connecting the root node with higher voltage is operating at 48% of its capacity, and the maximum usage of a line is at 71%.

With the initial states of the grid explained, the last necessary input for the case study is the flexibility market orderbook. Before explaining that, it is relevant to properly define the kind of flexibility product traded in this analysis. After a thorough literature review of the operative local flexibility markets in Europe and talks with the consortium partner NODES, it was decided to evaluate the market through active-power-related products. The reason behind it is that nowadays DLFM products are used in most of the cases for congestion management, and additionally in some cases are also participating in balancing activities, both of which are based on active power products.

To improve the clarity of the analysis it has been decided to define in further detail the product exchanged in the DLFMs simulated. Table 4 shows part of the product characteristics, mostly oriented towards FlexSuppliers. It has been assumed that all market participants fulfil the technical requirements for participation.

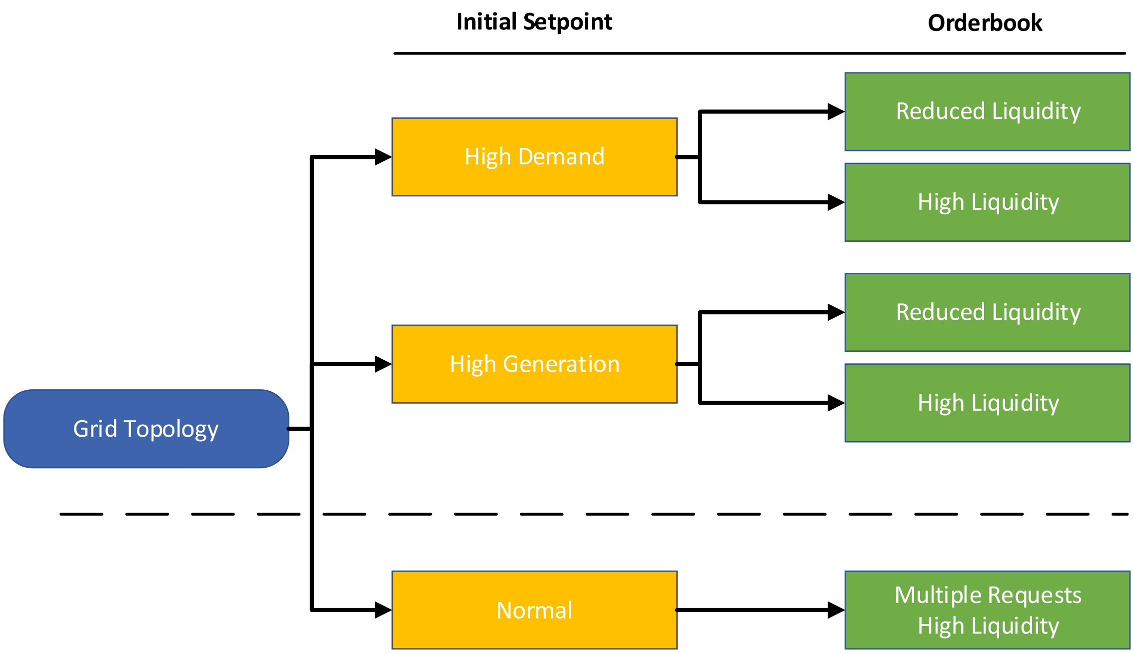
**Table 4: Market product definition.**

| Minimum Bid Size | Product Resolution | Duration of Delivery | Max. Number of Activations | Symmetry | Tender Period |
|---|---|---|---|---|---|
| None | 60’ | 60’ | 1 | No | Continuous/ Day Ahead (MTU 1h) |
| **Energy/Power** | | **Utilization Payment [€/MWh]** | | **Availability Payment [€/MW/h]** | |
| Energy | | Yes | | No | |

Two market orderbooks have been created for the FlexOffers. The first orderbook considers a short-term scenario where flexibility offers solely come from generation and industrial loads. The second includes participation from prosumers in addition to the bids from the first orderbook, to depict a future scenario where assets of any size and type can participate in the market. In the case of the FlexRequest, in the *high generation* and *high demand* cases there is a single FlexRequest and it aims to solve the existing congestion in the grid. Additionally, the *normal operation* case considers multiple FlexRequests to test a long-term DLFM where DSOs, TSOs and BRPs compete for flexibility.

In this business case the performance of network-aware versus non-network aware algorithms is evaluated under the same market conditions. For this reason, one of the main challenges of flexibility pricing is not that relevant. The results can be presented through the relative (%) difference in social welfare or procurement costs between clearings of the same orderbook. This information is already able to show the different performance between the algorithms.

However, a price has been used to create the bids. It has been extracted from Piclo Flex open access market data[22].




[22] Piclo Flex market data – Historic Competition. Link: Historic Competitions (google.com)

**Figure 8: Tree diagram of the simulated market clearing scenarios**

Regarding the simulation methodology the market clearing events are simulated using both, network, and non-network aware versions of the FLEXGRID algorithms[23]. To reduce the influence of the assumptions made, 200 events have been simulated, half using the “reduced liquidity” orderbook and the other half using the “high liquidity” orderbook. Each new event is characterized by a randomized orderbook composition, while the rest of the inputs remain constant.
To evaluate the performance of the algorithms from the business case perspective two types of KPIs have been defined. First, there are the KPIs that provide valuable information to market participants:

- Feasibility of the market clearing – Binary KPI (Yes/No). The main interested business actor is the DSO.
- Procurement costs – Numeric KPI. The main interested business actor is the DSO.
- Social welfare – Numeric KPI. The interested business actors are DSOs and flexibility providers.

Then, a specific KPI related to the computational capacities of the algorithms and their technical performance has been defined. The main business actor interested in this KPIs is the FMO:

- Execution time – Numeric KPI.

Additionally, linked to the auction-based algorithm, NODES has provided some additional indicators that would be relevant for an FMO. These are the following: Execution time to reach the first solution, execution time to reach the optimal solution (included in the execution time KPI). Difference between first and optimal solution - in terms of objective function -, and how the complexity of the grid and/or market clearing scenario affects the performance of the algorithm. These KPIs will be discussed in the auction-based algorithm results section.

*Case study results*

Market clearing events are very specific to the grid analyzed, the type of assets connected, the initial setpoint of the assets, and the available flexibility in the market. These considerations are even more relevant in the case of network-aware market clearing algorithms due to the added consideration of network constraints and the location of the assets. The following results have to be interpreted as a proof-of-concept of the use of network-aware algorithms. For real-life implementation a long consultation process would be needed to assess the viability and impact of the local flexibility market (same process as today’s DLFMs).

**Continuous Clearing Algorithm**

Table 5 and Table 6 present the results for the *Feasibility of market clearing* KPI. The results in the tables show how even in the reduced liquidity scenarios, in a constrained grid, the network aware algorithm can avoid creating new congestions.

**Table 5: Market clearing results - High generation**

| | Algorithm | Feasible Market Clearing | Unfeasible Market Clearing |
|---|---|---|---|
| **Reduced Liquidity** | Network Aware | 97 | 3 |
| | Non-network Aware | 36 | 64 |
| **High Liquidity** | Network Aware | 100 | 0 |
| | Non-network Aware | 66 | 34 |

[23] The non-network aware algorithms are downgraded versions of the network aware algorithms developed by DTU and presented in D5.3. Therefore, the OPF algorithm is the same optimization problem but with a lower number of constraints (removal of the LinDistFlow simplification).

**Table 6: Market clearing results - High load**

| | Algorithm | Feasible Market Clearing | Unfeasible Market Clearing |
|---|---|---|---|
| **Reduced Liquidity** | Network Aware | 95 | 5 |
| | Non-network Aware | 26 | 74 |
| **High Liquidity** | Network Aware | 100 | 0 |
| | Non-network Aware | 54 | 46 |

However, as shown in the tables there are some cases where the algorithm fails to avoid a congested clearing. If the market clearing results are analyzed in more detail it can be seen how the main issue in most of the cases is a lack of liquidity in the market. See for instance Table 7 where two of these events are presented. In the high generation scenario event, the network aware algorithm reduces the initial problem (230 kW of excess generation), down to only 44 kW, whereas the non-network aware behaves similarly but creates additional problems by causing new congestions due to excessive demand on a line. A similar behavior can be observed in the high load example where the network-aware algorithm reduces the initial problem from (226 kW of excess load) to 3kW.

**Table 7: Detailed behavior of the algorithms in two events with unfeasible market clearing.**

| | Event | Power Not Served [kW] | Power Curtailed [kW] |
|---|---|---|---|
| **High Generation** | **Network Aware** | 0 | 44 |
| | **Non-network Aware** | 28 | 44 |
| **High Load** | **Network Aware** | 3 | 0 |
| | **Non-network Aware** | 54 | 56 |

With that said, there has been one market clearing out of the 400 where the network aware market clearing has performed worse than the non-network aware. Detailed information on the event can be seen in Table 8. On it, it can be seen how none of the offers processed by the network aware algorithm resulted in a positive market clearing result. Furthermore, see the execution time, the highest of all the 400 events simulated, and the power not served which is the same as in the initial setpoint.

**Table 8: Detailed market clearing information. Event: network aware unfeasible, non-network aware feasible clearing.**

| Algorithm | Social Welfare | Procurement Cost | Congested | Power Not Served [kW] | Power Curtailed [kW] | Liquidity [MW] | Execution Time |
|---|---|---|---|---|---|---|---|
| **Network Aware** | 0 | 0 | Yes | 226 | 0 | 0,9 | 45,74s |
| **Non-network Aware** | 15,8301 | 134,1054 | No | 0 | 0 | 0,9 | 0,17s |

The average difference in procurement costs and social welfare can be seen in Table 9, presenting the percentual increase of the KPIs when comparing the network-aware performance versus the non-network aware performance.

**Table 9: Average differences between algorithms in Procurement Cost and Social Welfare**

| | Event | Procurement Cost increase | Social Welfare increase |
|---|---|---|---|
| High Generation | Reduced Liquidity | -1% | +2% |
| | High Liquidity | -0,5% | +1% |
| High Load | Reduced Liquidity | -5% | +4% |
| | High Liquidity | 0% | +1% |

Overall, the results in Table 9, show that - on average - the use of network aware market clearing should not have a significant impact in the behavior of the market for its participants.

The following Figure 9 and Figure 10[24], present a visual representation of the events simulated in terms of procurement costs and social welfare, for the high generation initial setpoint. On them it can be seen the specificity of each event for the high generation scenario.

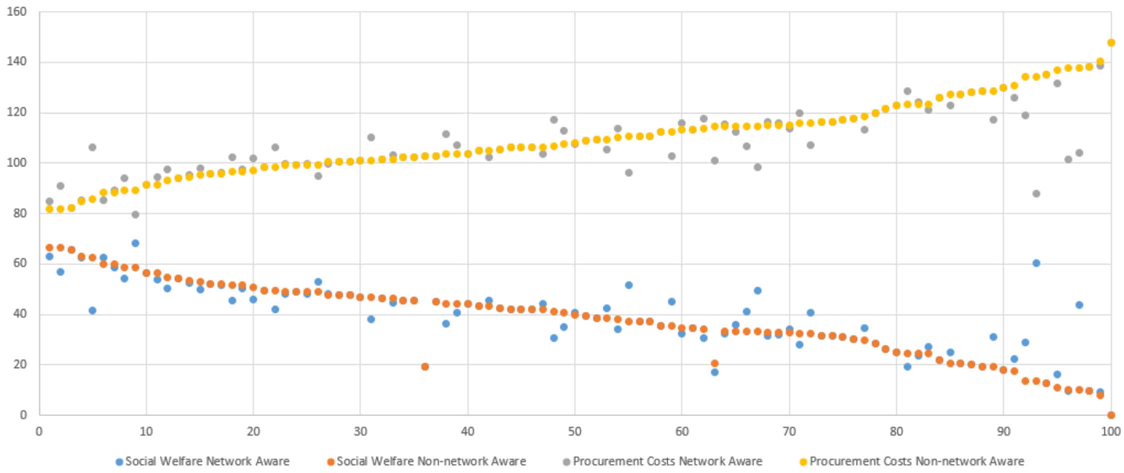



**Figure 9: Visual representation of market clearing events - Reduced Liquidity**

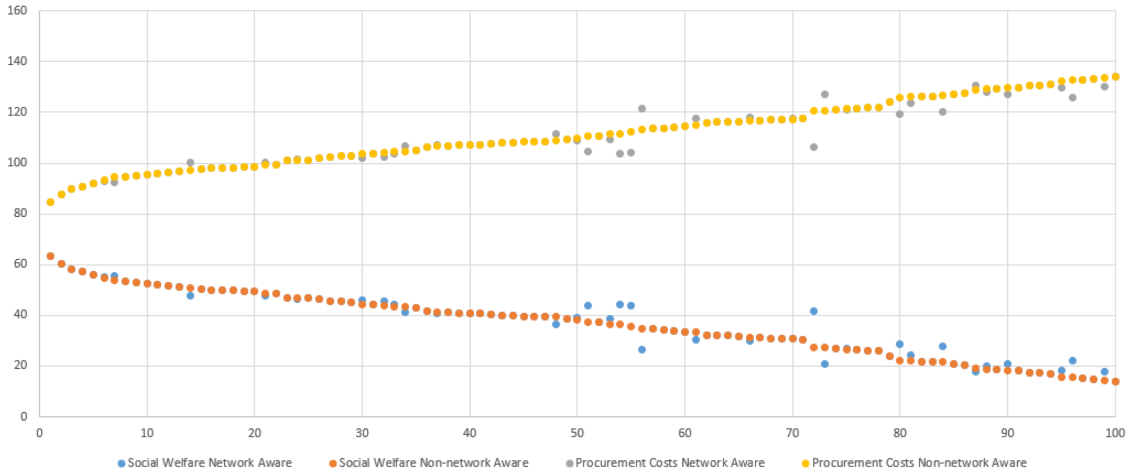



**Figure 10: Visual representation of market clearing events – High Liquidity**

The figures are representative to depict the reality of market clearing where individual events are analyzed, instead of average results. They show how there can be a significant discrepancy between

[24] The market clearing events are sorted based on the non-network aware procurement costs (yellow dots) results.

network and non-network aware market clearing results. Furthermore, if the reduced liquidity scenario results (Figure 9) are compared to the high liquidity case (Figure 10), it can be seen that in market clearings with higher liquidity coming from smaller assets the variability of the clearing results is significantly lower. This follows the logic of the algorithm, since the potential risk for the grid of accepting a 5 kW offer is lower than accepting a 100 kW offer. The results observed for the high-load scenarios depict very similar trends.

Switching the analysis towards the FMO, the following paragraphs present the results of the execution time for each market clearing. This KPI is able to show the increased computational power needed to clear the market using network-aware algorithms. Additionally, it also should serve as an indicator of how the complexity of the market clearing can affect the computational power needed. To present the results, we have decided to focus on the high generation initial setpoint.

In Table 10 the average execution time for high generation scenario is presented, considering both reduced and high liquidity orderbooks. The first observation is that the impact of network checks has a significant influence on time performance. Focusing the scope on the reduced liquidity orderbooks, even in the market clearings where the non-network aware algorithm clears the market in a feasible manner the execution time is 1.682% higher for the network-aware algorithm.

**Table 10: Average execution times for network aware and non-network aware algorithms**

| | Algorithm | Both Feasible | Network Aware Feasible | Not Feasible |
|---|---|---|---|---|
| Reduced Liquidity | Network Aware | 5,89s | 11,42s | 8,11s |
| | Non-network Aware | 0,35s | 0,35s | 0,34s |
| High Liquidity | Network Aware | 8,58s | 22,25s | -- |
| | Non-network Aware | 1,55s | 1,46s | -- |

Furthermore, if the market-clearing complexity increases, so does the difference between network and non-network aware market clearing time. This can be seen through both, rows, and columns. For instance, in the both feasible result, there is a significant difference between Reduced liquidity (14 offers) and the High liquidity (80 offers) in terms of execution time. It is also true that the impact is significantly higher for the non-network aware algorithm. On the other hand, the impact of the complexity of market clearing can also be observed through the different rows, on them the network aware algorithm increases its average execution time if there is risk of congestions, whereas the non-network aware does not. With that said, this extra computational power needed comes at the benefit of not creating new issues in the grid. Additionally, when operating in real-life conditions, continuous clearing algorithms do not clear all the market at the same time (which is what has been calculated as KPI), instead they clear the market every time an offer or request enters the orderbook. Therefore, the impact of this increase of computational power would be divided across multiple market clearing events.

Finally, the following paragraphs show the results for the Normal Operation initial setpoint. This set of results have been relegated to the end of the section because they depict a futuristic scenario where the market clearing conditions are very different from the other scenarios analyzed.

First and foremost, the impact of more complex market clearing scenarios for the feasibility of market clearing is quite noticeable. In Table 11 it can be observed how different actors competing for their own interests – the contrary to the case of the other scenarios analyzed – makes it much harder to "accidentally" clear the market in a feasible manner (non-network aware).

Table 11: Market clearing results - Normal Operation

| Algorithm | Feasible Market Clearing | Unfeasible Market Clearing |
|---|---|---|
| Network Aware | 100 | 0 |
| Non-network Aware | 14 | 86 |

The procurement cost and social welfare results can be seen in Figure 11. As expected with a higher volume of requests, a higher number of transactions were made. Therefore, the procurement costs, when compared to the previous analysis are significantly higher.

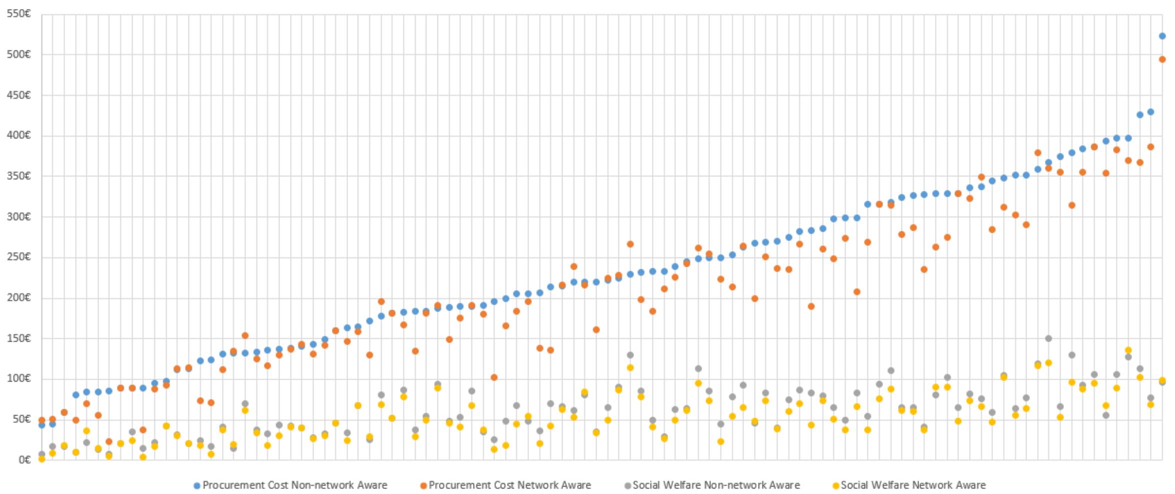



**Figure 11: Visual representation of market clearing events – Normal Operation**

On the other hand, there is the behavior of social welfare. Since it is not dependent on the total number of transactions it stays relatively flat and in the same value range as the previous scenarios (this can be attributed to the use of the same price creation strategy). Due to the variability of the requests (and their price) per orderbook there is a much higher variability in the observed social welfare results.

Finally, in Table 12 the average execution time can be observed. The results follow the trend seen in the previous cases. The higher number of offers/requests, 80 in this scenario, causes longer execution times. Then the higher complexity of the overall market clearing event, with multiple offers but also multiple requests have a significant impact on execution time for the network-aware algorithm.

**Table 12: Average execution times for network aware and non-network aware algorithms**

| Algorithm | Both Feasible | Network Aware Feasible | Not Feasible |
|---|---|---|---|
| **Network Aware** | 25,19s | 43,49s | -- |
| **Non-network Aware** | 1,37s | 1,42s | -- |

**Auction-based Algorithm:**

The results of the auction-based algorithm have been affected by issues with the solver, during the business case evaluation period. The issues were related to inconsistency when applying the network aware constraints, therefore the solver was considering them sometimes, but not others. From Work Package 8's perspective we acknowledge the challenges and risks of not being able to test the fully operational version of the algorithm. However, it has been considered that the information extracted from the working simulations is valuable to evaluate the future business model of auction-based network-aware DLFMs.

Focusing on the obtained results, the following tables show the *Feasibility of market clearing* KPI results. On it, the solver failures are included to be transparent about the limitations of the analysis.

**Table 13: Market clearing results - High generation**

| | Algorithm | Feasible Market Clearing | Unfeasible Market Clearing |
|---|---|---|---|
| **Reduced Liquidity** | Network Aware | 55 | 45 |
| | Non-network Aware | 54 | 46 |
| **High Liquidity** | Network Aware | 55 | 45 |
| | Non-network Aware | 55 | 45 |

**Table 14: Market clearing results - High load**

| | Algorithm | Feasible Market Clearing | Unfeasible Market Clearing |
|---|---|---|---|
| **Reduced Liquidity** | Network Aware | 24 | 76 |
| | Non-network Aware | 23 | 77 |
| **High Liquidity** | Network Aware | 24 | 76 |
| | Non-network Aware | 24 | 76 |

As can be seen in Table 13 and Table 14, the failure rate of the network aware algorithm has increased significantly, when compared to the continuous clearing algorithm. The following part of the analysis will be restricted to the feasible market clearing events, this restricts the reach of the results, but at the same time is quite significant behavior of the network aware optimization algorithm.

Moving towards the average difference in procurement costs and social welfare, they can be seen in Figure 12 and Figure 13 which present the obtained results - for the High Generation initial setpoint - when comparing feasible market clearings for both algorithms. This information shows an overall trend (also in the failed market clearings) where when using an auction-based algorithm (with enough liquidity) the differences between network and non-network aware outputs in terms of these KPIs are very similar, if not the same. The fact that only the non-network aware results can be seen is because the values are overlapping in most cases.

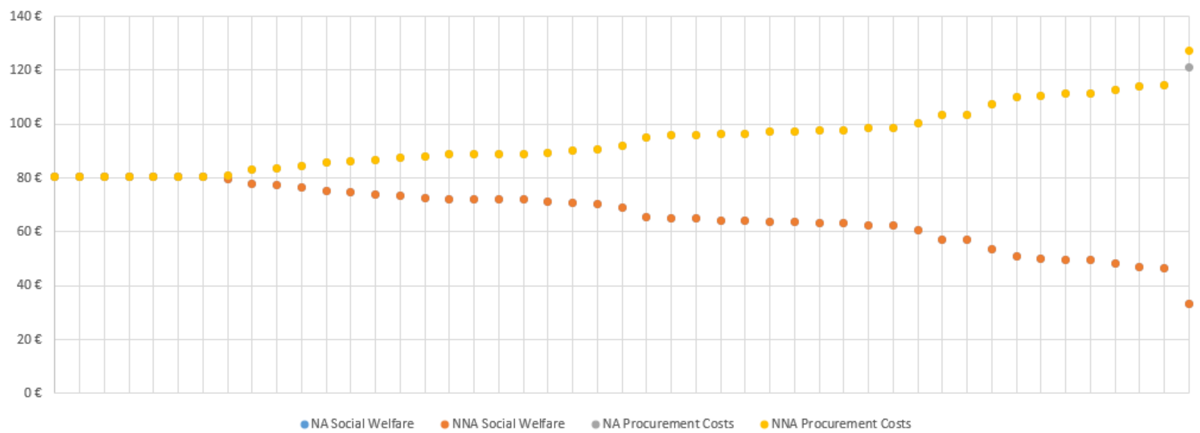



**Figure 12: Visual representation of market clearing events - Reduced Liquidity**

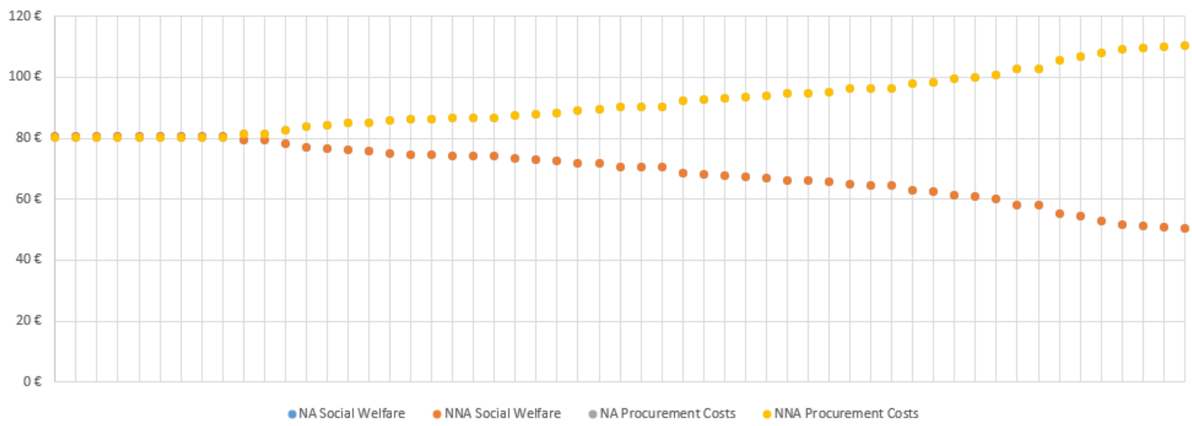



**Figure 13: Visual representation of market clearing events - High Liquidity**

An interesting point to consider is how the auction-based algorithm, in the same circumstances as the continuous clearing algorithm, can maximize the social welfare (objective of the optimization) and keep the procurement costs low. Furthermore, the auction-based results show less variability, in terms of Social Welfare and Procurement Costs, across the whole market clearing simulation. With that said, this is something to expect thanks to the optimization nature of the algorithm.

Switching the analysis towards the FMO, initially for the auction-based algorithm NODES has provided inputs of the valuable KPIs for an FMO. In the following paragraphs these KPIs are addressed considering the limitations of the setup. The first KPI to analyze is the average Execution Time, in this case the analysis is focused on the feasible market clearing results, and it is presented in the table below.

**Table 15: Average execution times for network aware and non-network aware feasible clearing**

| | High Generation | | High Load | |
|---|---|---|---|---|
| **Algorithm** | **Reduced Liquidity** | **High Liquidity** | **High Liquidity** | **Reduced Liquidity** |
| **Network Aware** | 0,30s | 0,74s | 0,30s | 0,96s |
| **Non-network Aware** | 0,25s | 0,69s | 0,26s | 0,89s |

Under the analyzed circumstances the difference in performance between network aware and non-network aware algorithms is significantly smaller. The non-network aware algorithm clears the market – on average- from 20% to 7% faster, which is a significant difference compared to the continuous clearing case. Furthermore, in absolute terms the optimization algorithm can clear the market faster than the continuous clearing (relatively expected by the nature of both algorithms). In Table 15 the impact of more complex orderbooks can also be seen. In the high liquidity scenarios, with higher offers to optimize from, the algorithm requires more computational power.

One topic that was discussed with DTU regarding their analysis of the algorithm (performed in 5.3) is the difference between the first solution and the optimal in terms of time, and difference between objective function results (delta). Since the optimization algorithms are solving a linear problem, DTU mentioned that the difference between first and optimal solutions are small from both execution time and delta.

### 2.2.3 Value proposition quantification

In this section the main findings from the results section will be shown, together with the most relevant findings from the business modelling process.

First, the performance evaluation of the algorithms has shown that the implementation of network aware market clearing algorithms in the analyzed cases did not significantly increase the procurement costs for the DSO and did not decrease social welfare in the market. Therefore, if there is enough liquidity available network aware market clearing algorithms do not harm the overall market performance. In the case of continuous clearing algorithms, the results showed that for most market participants there would not be a substantial difference if a network aware algorithm were to be implemented. However, the impact of the algorithm at an individual asset level can be much bigger, depending on their location in the grid. This is not caused by the algorithm itself, instead it is due to the grid configuration. Nowadays DSOs are also coping with similar issues, but they use tools such as interruptible tariffs and non-firm connection agreements[25] to allow new assets to connect to the grid in those points in risk of congestion. Therefore, from a pure cost perspective, DSOs and FlexSuppliers should not see any repercussion of the implementation of network aware algorithms. Furthermore, from the DSO perspective network aware algorithms can offers significant advantages, since during the market clearing process the QoS and SoS of the system are one of the considered variables.

In the case of the auction-based algorithm the results show also that network-aware algorithms can increase value for market participants. Since auction-based clearing mechanisms are optimization solvers, the implementation of these algorithms does not only ensure the feasibility of the market clearing, but also select the bids that maximize social welfare, benefitting both FlexSuppliers and FlexBuyers. With that said the use of an optimization algorithm also creates some challenges for the business model of FMOs such as new cost streams in the business model or challenges regarding the liability over failed market clearings.

From a FMO perspective, the main analyzed KPI, execution time, has shown a lower performance when compared to the non-network aware algorithms, particularly in the continuous clearing case. This was expected, and in the analyzed grid, it has not been something to worry about. Furthermore, the results presented are the ones of the whole market clearing process, whereas in the continuous clearing case the algorithm will be executed once per each received bid. With that said, further research needs to be done to evaluate the impact of the size and complexity of the grid on execution time and the overall performance of the algorithms. In case of the auction-based algorithm the observed differences have been smaller, and due to the nature of the optimization problem the expected impact of complexity on execution time should also be lower.

So, up until now the performance and potential applications of the algorithms have been shown. However, a business model goes further than the value propositions and performance of the algorithms. During the consultation process to develop this business case and subsequent business models we have identified some major barriers for the development of the business that should be properly discussed and understood before taking the decision to move forward with the business model:

- Liability over market clearing
- Data access and availability
- Regulatory framework

The first challenge for the implementation of network aware DLFMs is the definition of responsibilities. Once the service offered by the FMO “guarantees” network awareness, and therefore not causing new internal congestions, the FMO interferes with the role of the DSO. This challenge needs to be properly discussed and defined between FMOs and DSOs before implementing any new market. Furthermore, if the FMO becomes accountable for infeasible market clearings and consequent issues in the grid, this supposes a major change in the business model of traditional FMOs.

[25] **Interruptible tariff**: Reduced tariff to allow the DSO to reduce or interrupt the power supply of a customer in the case of need; **Conditional connections**: new assets are allowed to connect to the grid, but their maximum power can be temporarily limited.

This additional responsibility issue is something that FLEXGRID needs to be aware of when marketing its services, since it will probably be a major stopper for FMOs to adopt the new technology. The second challenge, and it is also very relevant for the business case, is the accessibility of market data and the willingness of DSOs to share potentially sensitive information. In order to operate a network aware DLFM it is fundamental for the FMO to have access to grid topology data, and to the future setpoints of the nodes in the grid. On the one hand, DSOs might be reluctant to share sensitive data regarding their grid's topology (for instance, an NDA was signed by SIN to have access to bnNETZE's grid data). On the other hand, depending on the voltage level where the DLFM is going to be implemented there is the possibility to not have any day-ahead setpoints or forecasted loads or generation. This is likely to be solved in the coming years with the roll out of smart grid technologies and the creation of new business actors that heavily rely on data analysis and forecasting (such as aggregators). In any case, nowadays most distribution grids are not there yet, and therefore the implementation of network aware DLFMs can face issues. On top of that, and looking back to the FMO, the collection and storage of sensitive grid data is a new responsibility that it would need to take to implement network aware DLFMs. This consequently means another change in their business model, and probably cost structure. Overall, what is clear from the two elements discussed above is that if network aware DLFMs are to be implemented by an FMO, this would suppose a significant impact on their business model. Even though DLFMs are still at an early stage, some of the players have properly defined their business model and where they want to head towards (at least in the overall DLFM framework). For this reason, it seems that network aware market clearing algorithms can be more compelling for new actors, or even actors that want to enter this early market.

Moving to the last part of the discussion, as with most innovation projects regulation tends to be a challenge. However, as presented in the policies section the EC has started the consultation process to create the Network Codes on Demand Response, which among others will address the standardization of flexibility products, congestion management for DSOs, and data exchange between system operators and service providers.

**FLEXGRID H2020 Contributions:** The analysis of the business model *FLEXGRID platform for flexibility market operation* has provided relevant insights of the performance of network aware DLFMs for FlexSuppliers, FlexBuyers, and FMOs. The **main relevant findings from the market operation perspective** are **a)** with enough liquidity in the market network aware DLFMs ensure SoS and QoS in distribution grids, **b)** network aware DLFMs have none-to-positive impacts on Social Welfare and Procurement Costs for market participants, and **c)** the implementation of network aware algorithms requires higher computational power, particularly in continuous clearing markets. From the business model perspective FLEXGRID has also reached relevant conclusions, showing how the transition from non-network to network aware LFM has a significant impact on the business model of the FMO. The **main relevant findings from the business modelling** perspective are: **a)** Grid observability can be a challenge for the implementation of network aware DLFMs (today), **b)** DSOs might be reluctant to share the confidential information that the FMO needs to operate the market, and **c)** The definition of liabilities over "failed" market clearing needs to be properly defined, the implementation of network aware DLFMs blurs the role of the FMO and brings it closer to the DSO. Overall, network aware DLFMs are a very innovative business model that will face significant challenges to stablish itself, the establishment of network codes for Demand Response, including DLFMs, should help foster the adoption of DLFMs by creating a regulatory framework.

## 2.3 Business Model Quantification: FLEXGRID platform for DSOs (and TSOs)

### 2.3.1 Business Model

The second business model is that of a software provider selling the FLEXGRID software services to DSOs. This company provides a software solution which exploits the intelligent services provided by the FMCT, and eventually the opportunity to integrate it with a DLFM and other market actors through the ATP.

There are two types of value propositions in the final business model: the ones directly linked with the services that FLEXGRID as a platform can offer to DSOs (see in blue), and the ones in green which are part of the **whole product** concept of FLEXGRID. The value propositions that FLEXGRID can directly offer to DSOs as services (blue ones in the Business Model Canvas (BMC)) are the reduction of capacity payments to upstream network operators and the identification of potential voltage and congestion issues. The first value proposition combines the forecasting engine from the FST to forecast load and generation, with a market-based procurement of flexibility to allow DSOs reduce peak consumption from the upstream network. As will be presented in the business case analysis this bundle of FLEXGRID services can be very valuable for DSOs but is also highly dependent on national regulations. The second value proposition allows DSOs to run “what-if” scenarios using the market clearing algorithms, but without an objective function. This allows DSOs to forecast potential congestions and voltage issues based on the scheduled/forecasted load and generation profiles. The rest of the value propositions (in green) can be highly relevant for DSOs and TSOs but can only be achieved by implementing the whole FLEXGRID ecosystem. This means that the value propositions do not come from a direct service sold to the DSO or TSO, instead it comes from FLEXGRID services offered to other flexibility market participants which can help DSOs and TSOs to reach their business goals. The implementation of a DLFM that allows DSOs and TSOs to easily access a pool of flexible assets is not an innovative approach; however, the framework provided by FLEXGRID as a complete flexibility ecosystem adds value to DSOs and TSOs seeking to tap into the potential of flexible assets in the distribution grid.

The revenue streams defined for this business model are also split in two. The ones referred to the services that this business model can directly provide to DSOs (in blue), which are presented more thoroughly in the BMC, and the ones in green that represent the indirect revenues derived form integrally implementing the FLEXGRID ecosystem. Focusing the scope on the direct revenue streams, they have been refined considering DSOs needs and concerns. One concern that cannot be addressed in the business model canvas though, is the liability of failed forecasts and how this needs to be addressed in the contracts. That’s why the performance-based subscription model is considered. This liability issue is solved instead in the non-exclusive licensing revenue model since the DSO would be taking full ownership of the code. Additionally, non-exclusive licensing also avoids hosting the service in a cloud server which reduces cost structure for FLEXGRID and is able to clear any potential concern from DSOs about data privacy. The indirect revenue streams are harder to quantify considering only this specific business model, but they can be seen in more detail in the other presented business models. As mentioned before, the implementation of FLEXGRID as an integral solution allows to maximize its potential and give more value to all the provided services.

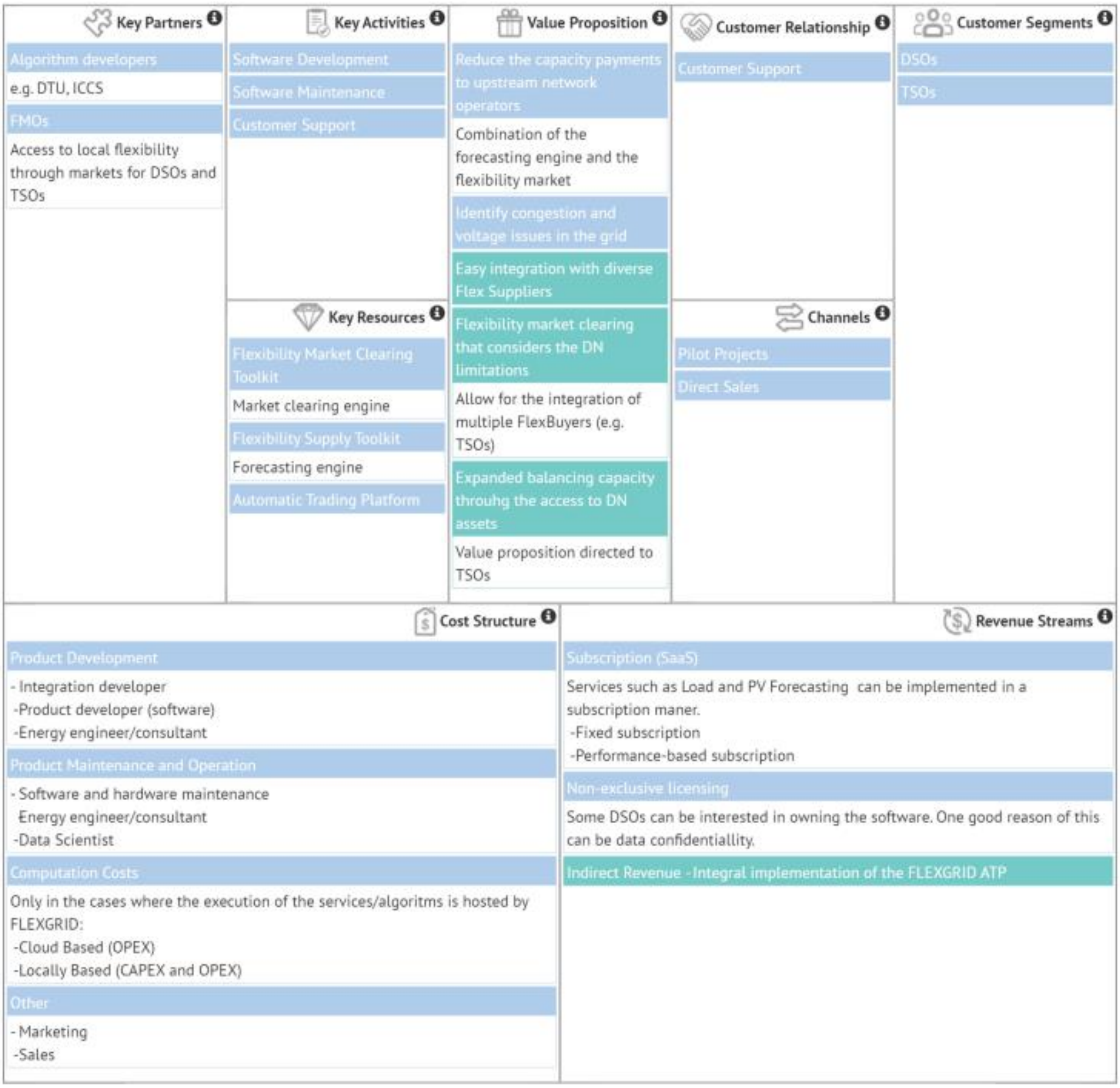



**Figure 14: Business Model Quantification: FLEXGRID platform for DSOs (and TSOs)**

### 2.3.2 Business Cases

*1. DSO using FLEXGRID ATP to predict peak power demand and request flexibility (Peak Shaving)*

*Context*

One business case, which was analyzed within FLEXGRID, was preventing peak loads in the entire grid from the perspective of the DSO. Figure 15 illustrates the peak shaving approach on the example of bnNETZE's main electrical grid. It is common in countries like Germany and Norway, that a DSO must pay a grid tariff for the highest physical peak load in its grid over a one-year period. The highest quarter hour value is relevant for settlement. The metered power values at all coupling points are aggregated to determine the total peak. Typically, peak loads in the grid occur in the morning, around noon or in the evening. There is a strong dependency on daytime, day type, seasons, temperature, solar radiation and even wind speeds.

If it is possible to forecast the expected peak time precisely, it is possible to activate flexibility in the grid accordingly, and reduce the expected peak load. DERs could offer their flexibility potential directly or via an aggregator to the DSO. This would result in substantial cost savings over the span of the year. However, all peak loads occurring after this event must be kept under this new limit too. So, one single attempt will not be sufficient to salvage the cost savings until the end of the year.

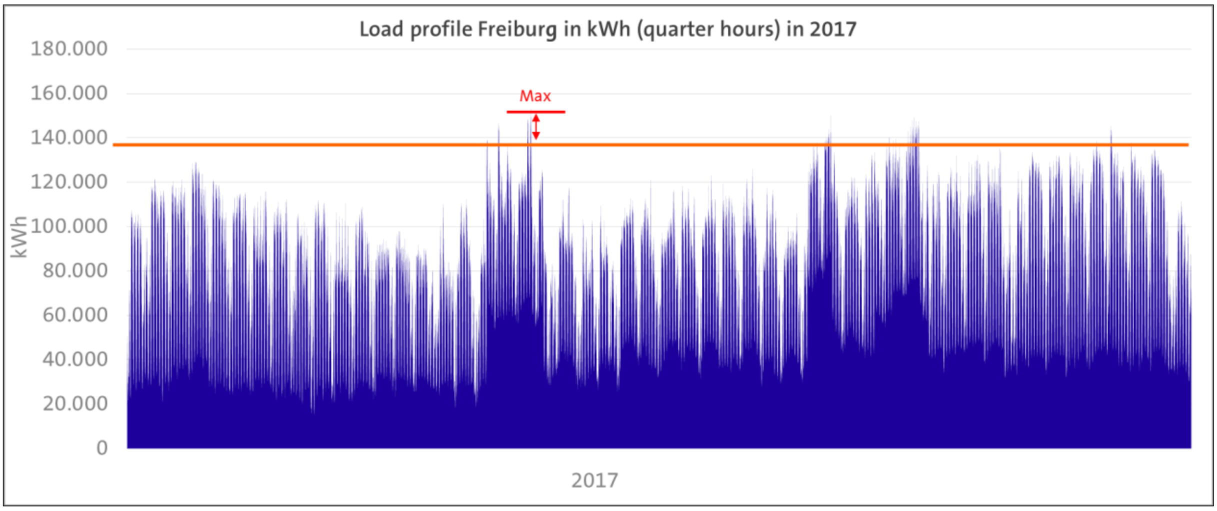



**Figure 15: Peak shaving example for the main electrical grid of bnNETZE**

Other business cases for a DSO are theoretically possible, but due to different reasons not practicable in Germany. The following Figure 16 shows some ideas and the result of their evaluation.

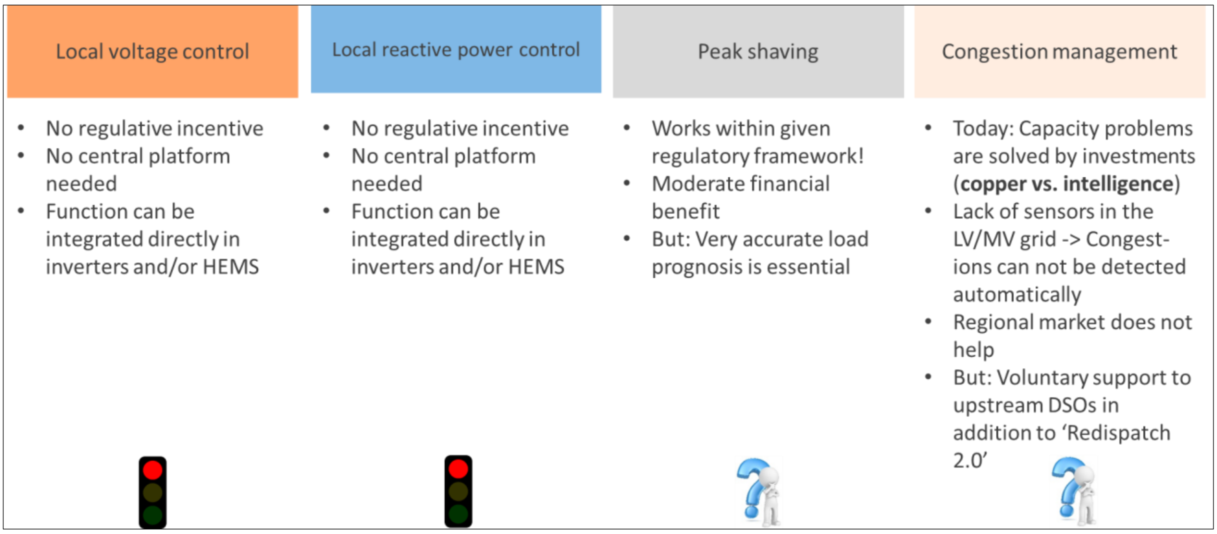



**Figure 16: Possible business cases for DSOs**

This business case is related to the business case C09 from D8.2, and it is part of the High-Level Use Case 1 and 3. Especially in HLUC_03, the DSOs' main goals are twofold: To ensure QoS and SoS to end-users and to delay or avoid investment in network reinforcement infrastructure.

*Business case description*

The peak shaving business case contributes to the second point, as electrical grids are always designed to cover the highest expected peak loads. If it is possible to reduce peak loads with high certainty, weaker grid structures can be built. This means significant cost savings. The other positive effects are the direct cost savings of the DSO as the grid tariffs to be paid to the upstream grid operator are reduced.

*Counterfactual scenario*

The counterfactual scenario considered for this business case is a DSO operating a local distribution grid without the possibility to reduce peak load. In this case the DSO can only act in the role of an observer. What is needed from the grid is physically served by the upstream grid and paid at the end of each year in the settlement process. The case study tries to identify the possible cost saving potential by activating distributed flexibilities to decrease the peak load.

*Case study*

The upstream grid operator to bnNETZE is the EnBW subsidiary Netze BW GmbH. This company announced the grid tariffs for its electricity grid for 2022 on January 1, 2022. The state-regulated grid tariffs are included in the calculation of the grid tariffs for all downstream electricity network operators and must be paid by them. The payment of the grid tariffs covers the use of the grid in front of the coupling points as well as all upstream grid and transformer levels.

**Error! Reference source not found.** shows all grid tariffs on grid and transformer levels published by the upstream system operator. This table is valid for all kinds of grid connection. From Low Voltage ('Niederspannung') to Medium Voltage ('Mittelspannungsnetz') up to High Voltage ('Hochspannungsnetz') which means in the context of Netze BW the 130kV level. The tariffs consist of two parts: a price for peak power ('Leistungspreis') and a price for energy ('Arbeitspreis'). Relevant for 'Peak Shaving' is only the tariff for peak power. The relevant tariff for the electricity grid of bnNETZE is highlighted in orange.

| | Jahresleistungspreissystem | | | |
|---|---|---|---|---|
| | Jahresbenutzungsdauer $T_m$ < 2.500 h/a | | Jahresbenutzungsdauer $T_m$ >= 2.500 h/a | |
| Leistungspreissystem für Entnahmestellen mit registrierender Lastgangmessung | Leistungspreis €/kWa | Arbeitspreis Cent/kWh | Leistungspreis €/kWa | Arbeitspreis Cent/kWh |
| Hochspannungsnetz | 13,92 | 4,29 | 113,90 | 0,29 |
| Umspannung Hoch-/Mittelspannung | 14,07 | 4,34 | 115,40 | 0,29 |
| Mittelspannungsnetz | 19,02 | 5,64 | 139,46 | 0,82 |
| Umspannung Mittel-/Niederspannung | 19,07 | 5,66 | 140,03 | 0,82 |
| Niederspannungsnetz | 19,32 | 5,66 | 122,08 | 1,55 |

**Figure 17 Grid usage fees for bnNETZE**

The relevant peak power price is therefore € 113.90 /kWa. This means that if it is possible to reduce the peak power by 1 kW, this reduction has a value of € 113.90 per year. Or in other words 1 MW power reduction is worth € 113.900

If bnNETZE were to issue a FlexRequest, this would be bnNETZE's maximum willingness to pay for flexibility in the market. However, this simplified approach is only a theoretical consideration. It must be considered that a FlexRequest must be set on a market platform with a certain lead time. This means that a very precise forecast of the peak power by value and, above all, by the exact activation time is essential. The quarter-hourly interval must be hit precisely. Otherwise, flexibility will be requested at the wrong time, increasing the operational costs for the DSO. They even add to the grid usage costs for the peak load since this was not corrected. It must always be considered that an uncertainty will remain. For this reason, a DSO would never spend the whole amount of possible savings on one FlexRequest.

Figure 18 provides details about the electricity grid of bnNETZE relevant for the case study 'Peak Shaving'. It is noteworthy to state that badenova supplies much more natural gas than electrical energy. The districts that are plotted in grey refer to the regions where natural gas is distributed. The districts where electricity is also supplied are colored brown.

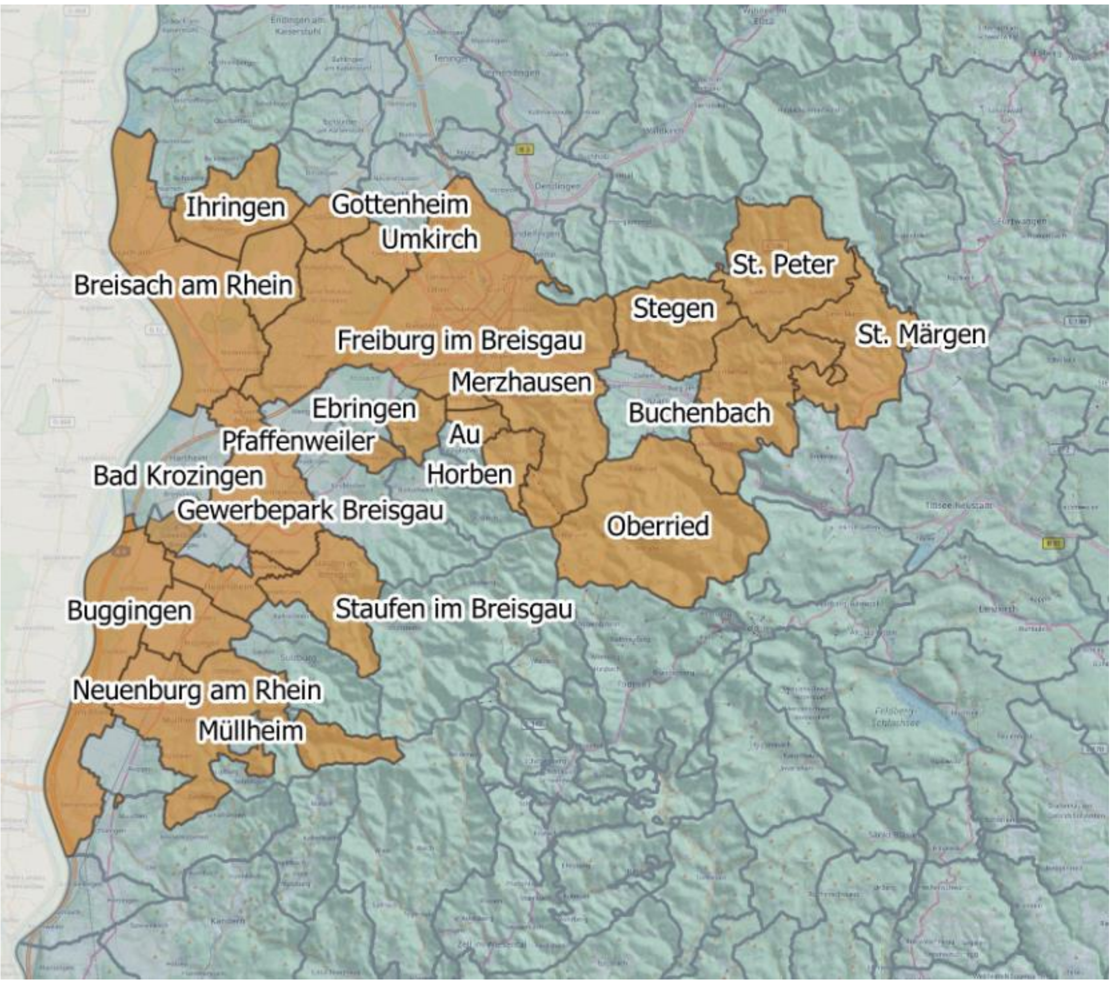



**Figure 18: Map of all bnNETZE electrical grids**

The main electricity grid of badenova lies within the city limits of Freiburg. It consists of five 110/20 kV substations with a total of 12 transformers functioning as coupling points to the upstream grid. These substations are interconnected through a 110 kV ring. The energy is transported locally on a medium voltage grid operated at 20 kV. The low voltage grid is responsible for transporting the energy to the customers. Several smaller cities and villages in the neighboring districts are also supplied by bnNETZE. Some of them are directly connected to the core grid in the city via medium voltage links. The analysis of the business case was focused on the city of Freiburg as well as the following directly linked communities:

- Stegen
- St. Peter
- St. Märgen
- Buchenbach
- Oberried
- Horben
- Au
- Merzhausen
- Ebringen
- Pfaffenweiler

Further, two smaller utilities are directly connected to the grid which are responsible for the communities of Gundelfingen and Kirchzarten. Even if their areas are not highlighted in the attached map, their demand was covered as well.

Other villages and cities which are too far away from badenova's main grid have their own coupling points to the upstream grid. Therefore, they are not relevant for this case study. Regarding grid tariffs they are treated separately. In total, the electrical grid covers an area of about 690 km$^2$ and has a length of almost 5.960 km.

One of the most important influencing factors within the main grid is the industrial Combined Heat and Power (CHP) plant operated by the private company CERDIA with two gas turbines with a total of 40 MW nominal power. Sometimes planned and unplanned outages can occur, which have a direct impact on the physical load flow at the grid coupling points. As well as the thousands of PV systems installed from 3 kW up to 2,5 MW. Further, several CHPs in the range between 100 kW up to several MWs contribute to power generation. What is relevant for the peak shaving business case is not only the electrical consumption in the grid but also local generation which in total leads to the residual load flow measured at the coupling points. This mix is relevant for settlement at the end.

The business case 'Peak Shaving' is a perfect example for validating the use cases already described in D7.1 and D8.2. The flexibility of DERs (or else FlexAssets) on distribution grid level is normally represented in electricity markets and managed by the independent aggregator. All information regarding user preferences and constraints and costs of FlexAssets within the portfolio of the aggregator are described in FlexContracts.

The aggregator interacts with the energy market by accepting FlexRequests from the market and by creating FlexOffers towards the market as seen in Figure 19. A FlexRequest from the market e.g. by a DSO requests an energy amount for activation of FlexAssets for a specific price, while a FlexOffer contains price/quantity pairs of flexible energy that the aggregator offers to potential flexibility buyers in the market that better suit its portfolio.

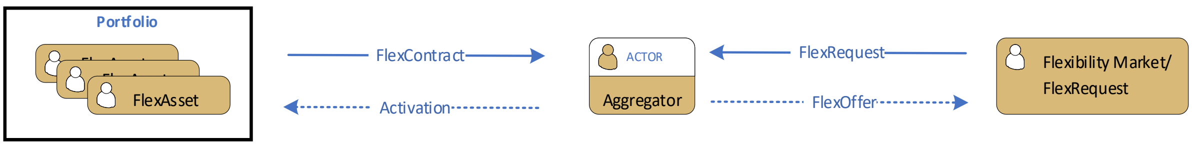



**Figure 19: FlexRequest and FlexOffer**

An aggregator efficiently responds to FlexRequests made by TSO/DSO/BRPs by optimally orchestrating its aggregated flexibility portfolio of end energy prosumers. The independent aggregator needs to efficiently respond to a FlexRequest made by a FlexBuyer by optimally selecting (in a centralized manner) the dispatch per flexibility asset/end user. A FlexRequest contains a given price for a required amount of energy for specific Market Time Units (MTUs).

When an aggregator positively responds to a FlexRequest, the objective is to maximize its profits from providing the requested flexibility. This translates to maximization of the revenues and minimization of the associated costs. For a given FlexRequest, the revenue of the aggregator is given by the price of the FlexRequest minus the associated costs. The associated costs can be divided into two categories. The first are end-user compensations for provision of flexibility, defined in FlexContracts. The second involves potential imbalance costs, meaning the financial effect of activating flexibility and deviating from the baseline (scheduled energy profile of the flexibility assets).

The aggregator can react to a FlexRequest from a DSO with a positive or negative response. In case of a positive response, the aggregator is called to manage a FlexRequest. As the FlexRequest contains a specific price for a given amount of energy, the aggregator needs to reach the desired amount of energy through its portfolio, while respecting the cost and utility functions of its end-users. In the following case study results the value of a flex request for 1 kW flexible electrical power is calculated regarding the special circumstances of the bnNETZE electrical grid.

*Case Study results*

It was described above, that one successful FlexRequest for one year would not be sufficient. If the peak load was reduced once successfully to a certain level, in the following all other peaks above this limit have to be forecasted and successfully reduced as well. The challenge is to find an optimal balance between possible peak power reduction actions and the number of events for keeping this level constant throughout the whole year. If the number of events becomes too large, the value per event becomes too low to motivate market partners to participate on a voluntary basis.

To find a resilient approximation the residual load of bnNETZE was analyzed over several years. The results of the analysis can be found in Table 16.

**Table 16: Residual load of bnNETZE's grid in 2020, 2021, and 2022.**

| 2020 | | 2021 | | 2022 | |
|---|---|---|---|---|---|
| **Day** | **Peak Power** | **Day** | **Peak Power** | **Day** | **Peak Power** |
| 13/10/2020 | 130.82 MW | 30/11/2021 | 142.84 MW | 27/01/2022 | 149.34 MW |
| 09/12/2020 | 130.12 MW | 25/11/2021 | 139.55 MW | 26/01/2022 | 147.98 MW |
| 21/01/2020 | 126.26 MW | 02/12/2021 | 139.18 MW | 11/01/2022 | 147.49 MW |
| 03/02/2020 | 125.92 MW | 08/12/2021 | 139.12 MW | 16/05/2022 | 145.60 MW |
| 26/06/2020 | 125.09 MW | 15/12/2021 | 138.37 MW | 12/01/2022 | 143.45 MW |

As a result of the analysis summarized in Table 16, the following can be stated:

- During 2020 the highest peak occurred the 13/10 in the 15 min interval 18:00-18:15 with 130,82 MW.
- During 2021 the highest peak occurred 30/11 in the 15 min interval 11:45-12:00 with 142,84 MW.
- In 2022 until 30.05.2022 the highest peak occurred 27/01 in the 15 min interval 12:30-12:45 with 149,34 MW. Additionally, in total 10 days with a higher load than 140,00 MW occurred

The comparison of these three years shows significant differences. In 2020 the peak load was remarkably lower than in the following years. This due to partial lockdowns because of the Covid pandemic. Therefore, these values are not representative for the normal residual load in the bnNETZE grid. In this case study this year was not considered.

In 2021 we observed already higher values. The first half of the year was still characterized by actions against Covid which led to changes in the consumption patterns. Especially the high peak loads normally arising at the beginning of year were reduced. Therefore, this year is not representative either.

In the following we focused on the year 2022, which can be titled as a completely normal year so far. Here only days with at least 140 MW peak load are relevant for settlement. These events occurred ten times until 30.05.2022. The highest peak load was 149,34 MW. This results in a maximum achievable saving of 9,34 MW or 1,063 Mio. €. Thus, the DSO bnNETZE would spend per FlexRequest at maximum 1.063 Mio. € / 10 days = 106.382 €. Over all ten events in 2022 a power of 33,86 MW for the five days listed above plus further 9,32 MW for the subsequent five days would have had to be reduced. In total 43,18 MW. This means a maximum price per request of 1,063 Mio. € / 43,18 MW = 24.618 € / MW or 24,62 € / kW, all under the assumption that the load forecast is 100% accurate and no savings are kept. This is to be considered a best-case calculation. It must be stated that a 100%

precise forecast is not possible. In case one peak load event had been missed all would have been for nothing. To avoid this situation, the DSO would place more and/or even longer FlexRequests to be on the safe side. A factor of four seems appropriate, which would result in a value of 24,62 € kW/4 = 6,15 €/kW/request. This is a value, which could keep private prosumers interested in participating in a regional flex market. From the experience of bnNETZE a value of less than 5€/kW/request leads to a disregard of prosumers. In consequence a local flex market would fail due to less participants.

*Conclusion*

Regarding the business case 'Peak Shaving' 1 kW flexibility is worth 6,15 €/kW/request with an estimated activation rate of 40 events per year. This under the assumption that the residual load forecast is never 100% accurate and no savings are kept by the DSO.

*2. DSO avoids grid enhancement by requesting flexibility from a local market*

*Context*

On the consumer side, a strong trend towards increasing electrification of almost all everyday activities can be observed. Electromobility plays a decisive and probably the most important role in this regard. The increased use of EVs in public and private local transport requires the construction and expansion of charging infrastructure. Its implementation is a major challenge for local DSOs and is the subject of many research projects. The fact that the pace of this change is increasing is also due to government support measures at various levels. Investment programs which make it possible to finance EV chargers at favorable rates, are worth mentioning here. Other incentives are provided through tax benefits for EVs and through direct government subsidies. Public charging points, often characterized by fast charging capacities are required due to the increase of EVs which leads to significantly higher peak loads. Furthermore, other energy-intensive installations such as heat pumps will come into focus soon and will also contribute to an increase in power demand.

*Business case description*

The municipality of St. Peter is located 20 kilometers from Freiburg and has a population of 2651 (as of 2020). Over the last 20 years, the municipality has experienced a population growth of 10%. In the past, clock workshops and agriculture played an important role for the local economy. Tourism is also an important industry today. There is no direct public transport connection to Freiburg. Several bus lines are limited to connections to other tourist destinations. As a result, the residents are dependent on individual passenger transport to satisfy their needs. Calculated based on the number of inhabitants, approx. 1350 cars are registered in St. Peter. If these are converted to full/part EVs due to the change described above, the accompanying expansion of the charging infrastructure will result in a considerable increase in power in the electric grid. In addition, it is conceivable that in the coming years an open-space solar PV park in the order of several megawatts will be connected to the grid in St. Peter. In addition, it can be assumed that additional installations of photovoltaic systems < 10 kW peak will also increase in the private household sector in the future. These will require additional capacities in the local grid but can also be used as available flexibilities if the installations are equipped with an energy storage system.

The municipality of St. Peter serves as a test case for other parts of the bnNETZE electricity grid area, where developments are expected to be similar. The current utilization rates of the transmission lines were determined as well as the costs for a possible grid reinforcement. The costs for grid expansion could be avoided through a local flexibility market. At the same time, the costs for grid expansion sets the benchmark for a flexibility market. Under no circumstances may the costs for this be higher than the investment case, as otherwise the grid operator will opt for the business-as-usual strategy.

This business case is closely related to the business case C09 from D8.2 and it is part of the High-Level Use Case 1 and 3 FLEXGRID ATP offers advanced flexibility services to FMOs and system operators, respectively. The main business actor involved is the DSO whose goal is to delay or avoid network reinforcement investments.

*Counterfactual scenario*

The municipality of St. Peter is supplied via the medium-voltage grid (20 kV level) There are three overhead lines, each with a cross-section of 70 mm supplying the grid and a capacity of 10 MW. An upgrade of the grid without FLEXGRID solutions would require a reinforcement of the existing lines or constructing new lines connecting to St. Peter. The potential lines for an upgrade are line 1 via Stegen and line 2 via Iben valley.

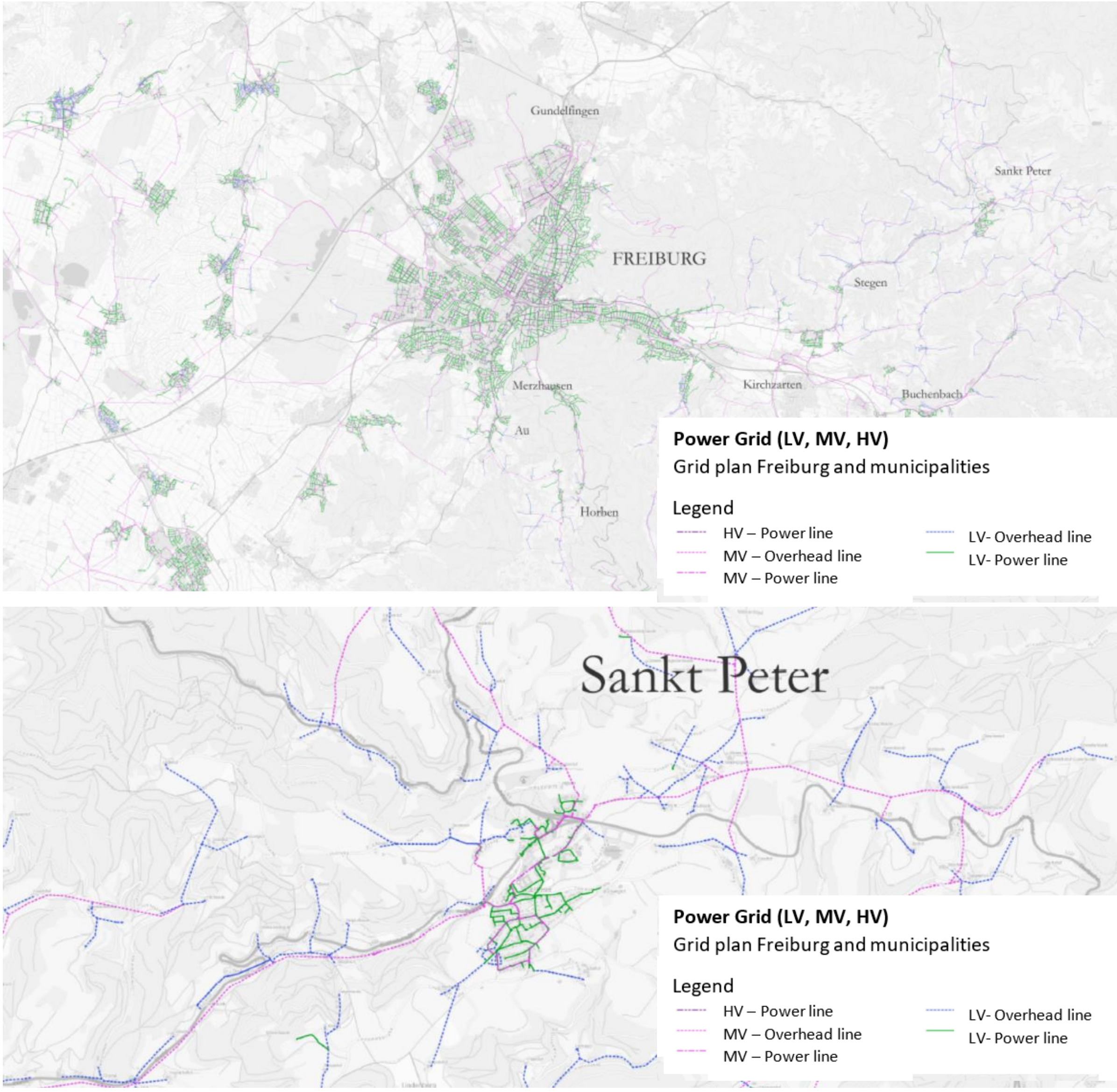



**Figure 20: Counterfactual scenario**

*Case study*

All three lines have a protective setting according to the requirements. In this case, currents are limited to a maximum of 162 A. Due to these restrictions, a power of approx. 5 MW can be transported on each of them. Safety-related redundancy requirements further limit the maximum power to be calculated. As a result, only 2 x 5 MW can be assumed in the analysis. The third line serves as a backup in the event of a failure of one of the others. All three lines converge in the grid station in St. Peter and supply the 400 V low-voltage grid from there. This results in an available transport capacity for the municipality of St. Peter of approximately 10 MW.

Since further steps will consider scenarios assuming a strong load increase, the first action is to determine the current load situation on the overhead interconnectors to St. Peter. Thus, the actual load situation is analyzed in this section. It should be noted that the maximum peak loads to and from St. Peter are the decisive factor. To determine the current load situation, internal network data from the bnNETZE database of the last few years was used. It was possible to determine the maxima for supply and recovery for all three lines. The maximum value for the regenerated power was 1,1 MW on 22.03.2022. The maximum drawn power value was 1,4 MW on 18.11.2021. Together with the maximum power of 10 MW from the grid analysis and this calculation, it results that the grid was utilized only to a maximum of 14%. 86% of the transport capacity – even under max. peak load conditions – are so far unutilized.

Taken on its own, this value may not seem particularly high, but a closer look shows that in an expansion scenario of charging infrastructure, the limits could quickly be reached. For example, an additional installation of 300 private EV chargers with 11 kW alone would result in an additional load of 3.3 MW, which would not have to be carried at all times but must be met at special times. In addition, as above described, there would also be other load factors like heat pumps now being introduced into the German heating market at high speed. Taking this into account, the following consideration of the grid expansion and its calculation is correct. The result should be an economic value that serves as a comparative value and upper price limit for the creation of a flexibility market in the sense of FLEXGRID.

*Case Study results*

The case study presents a possible expansion scenario and its associated costs. First, we worked out the possible expansion options for the lines to St. Peter. We examined the possibility of increasing the cross-section of the aluminum-steel line (AL/ST) from 70 to 95mm² on existing masts as well as laying a second system with a cross-section of 70 mm² AL/ST on the existing masts. Underground cabling was not considered as an alternative due to the associated high costs of €/ 300m. However, cabling is to be used for parts of the line. The analysis showed that only an upgrade of two 70 mm² to a diameter of 95 mm² AL/ST line could be considered for the extension. The third line would stay in its current state and would be operated in a way to stabilize the voltage in the area. A further increase of power towards St. Peter with this third line is not possible. Each of these upgraded systems could, when considering the limitations mentioned above provide an additional power of 7 MW. Together, this would result in a maximum carrying capacity of approx. 24 MW, which is an increase of 240%.

**Table 17: Cost Calculation Line 1**

| Cost category | Cost | |
|---|---|---|
| Material | 30 000 m x 2.90 €/m | 87000 € |
| Pole adaption | 56 Poles at 597 € | 33 432 € |
| Pole exchange | 10 Poles at 20 000 € | 200 000 € |
| Labor | 6 workers with 720 hours at 71 €/h | 51 120 € |
| **Total** | | **371 552 €** |

**Table 18: Cost Calculation Line 2**

| Cost category | Cost |
|---|---|

| | | |
|---|---|---|
| Material | 43 000 m x 2.90 €/m | 124 700 € |
| Material cable | 1000m x 300 €/m | 300 000 € |
| Pole adaption | 78 Poles at 597 € | 46 566 € |
| Pole exchange | 14 Poles at 20 000 € | 280 000 € |
| Labor | 9 workers with 1000 hours at 71 €/h | 71 000 € |
| **Total** | | **822 266 €** |

Table 17 (line 1 via Stegen) and Table 18 (line 2 via Iben valley) show the costs for a planned extension of the lines in the above description. If both extensions are implemented, the costs amount to a total of € 1.193.818. It should be noted that this analysis only looks at the extension of the medium-voltage overhead lines to St. Peter and does not consider potentially necessary reinforcements at the 400 V level.

*Conclusion*

The economic value serves as a comparative value and upper price limit for the creation of a DLFM in the sense of FLEXGRID. The upper limit found, when enforcing the two existing lines, is € 1.193.818. Due to the described developments in St. Peter the revenues for the provision of electricity would also increase along with a higher electricity demand. It is also possible that in the future the pricing methodology for grid tariffs will be adapted towards a bidirectional model where feeders also pay for required capacities. This becomes especially important when a solar PV park is considered in the expansion plans of St. Peter. These developments in the revenue streams are difficult to predict and make it therefore more applicable to consider pure investment costs when comparing projects. To add on this, we can compare annual costs for the financing of the grid expansion scenario with the operational costs of a DLFM. Considering the € 1.193.818 investment sum and an interest rate of 5% the annual costs of the grid investment would amount to € 94.544 over a time horizon of 20 years which is suitable for infrastructure investments of this kind. The presented annual investment costs also serve as a reference for the operational costs of a flexibility market in the fashion of FLEXGRID.

*3. Long-term economic analysis of TSO using DN-level flexibility through a DLFM*

*Context*

The Croatian (HOPS) is the only TSO in the Republic of Croatia and the owner of the entire Croatian transmission network. The Croatian power system in comparison to the other power systems in Europe belongs to the group of small and well-connected systems. Due to the geographical location and layout of production units, for most of the year electricity is transmitted from the south to the north and vice versa, and from north to east. The southern part of Croatia has a specific power consumption profile because it is an area with a high tourism industry. Therefore, during summer season (June-September) the electricity demand in this area is very different from the winter season, as presented in Figure 21. Electricity demand during summer increases because of the high number of tourist facilities such as hotels and apartments. This area is an area with high potential for the TSO-DSO coordination from the viewpoint of provision of flexibility for the TSO from the large number of hotels with installed flexible loads such as air conditioners, and EV chargers along with generation assets like solar PV. This characterization is especially relevant during the summer months. During the recent years, the flexibility contribution curve of this assets has increased exponentially.

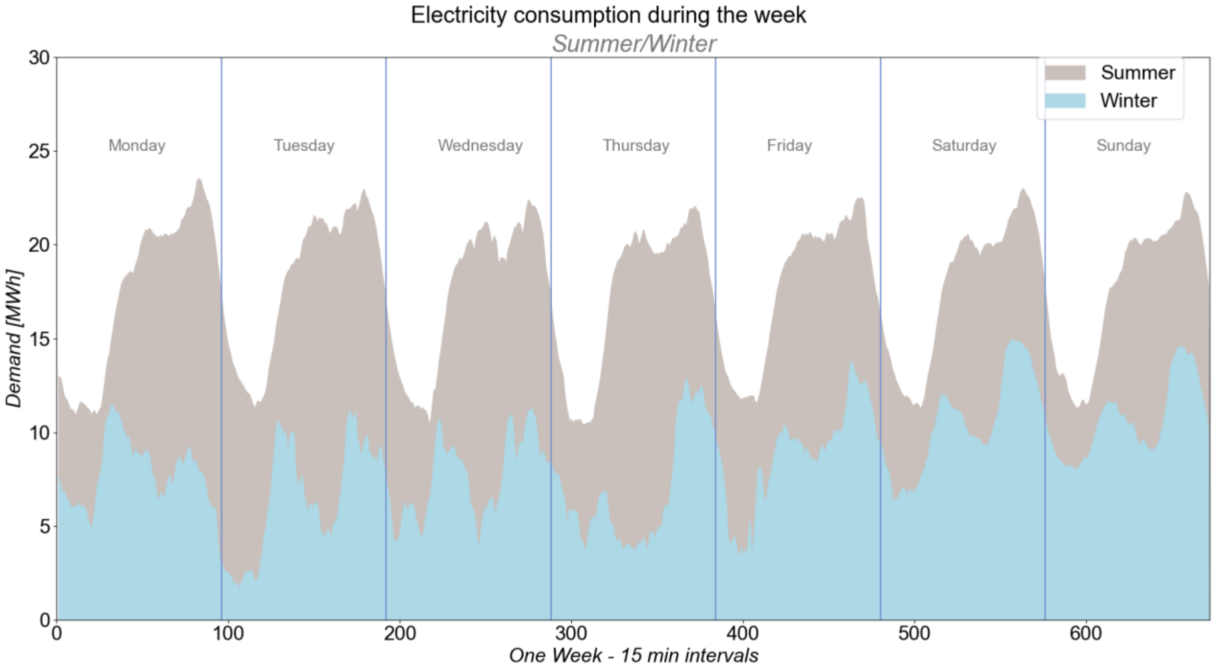



**Figure 21: Comparison of demand during the summer week and the winter week in Šibenik area**

The scope of this business case is to analyze the potential impact for the TSO's operation, of hotels offering flexibility through aggregator platforms to the balancing markets.

For the purpose of balancing the power system, HOPS currently uses different balancing services: frequency restoration reserve with automatic activation (aFRR) and/or respective balancing energy, and frequency restoration reserve with manual activation (mFRR) and/or respective balancing energy. Balancing services are procured in a transparent and non-discriminatory manner by conducting a procurement procedure through public tenders that are conducted on a periodic basis. Balancing service providers (BSP) can be all individual network users and aggregators who have signed the Balancing Service Agreement (BSA) with HOPS. BSA can be signed by all individual network users and aggregators who successfully completed the prequalification process and demonstrated technical ability to provide balancing services. By 2022, HOPS has prequalified and concluded 10 Balancing Service Agreements with BSPs for mFRR. Four of them are on the distribution level. In addition to that, from 2022 the first independent aggregator has been successfully registered and actively participates in balancing market in Croatia. Aggregation opens the space for central management of new distributed sources and consumers of electricity.

Due to the specifics of the Croatian power system and the increased electricity consumption during summer in the Šibenik region, it is interesting for HOPS to analyze the business case of flexibility provision through aggregation. This business case is closely related to the business case C19 from D8.2 and it is part of the High-Level Use Case 3 FLEXGRID ATP offers advanced flexibility demand management to services to system operators described in Deliverable 8.2. The main business actor involved is the TSO whose goal is to minimize the procurement cost of reserve capacity and balancing services.

*Business case description*

The Šibenik region is a very popular region during summer with numerous hotel parks and great potential for further increase of accommodation capacities. In this case study an example of providing flexibility services from the distribution level to theTSO, HOPS, through the DLFM will be analyzed. Providing flexibility at the distribution level has the potential for TSOs to decrease reserve capacity procurement cost and balancing energy costs by creating a more competitive market with a higher number of participants. For the development of the study, historical data has been used with modified names of measuring points.

*Counterfactual scenario*

If the TSO is not using flexibility from the DN, only resources from the transmission network can be used for the balancing of the system. This is a more traditional scheme which has been the business-as-usual scenario for years. In that case the TSO makes an agreement with production units on the transmission network for their reserves (yearly, monthly, daily contracts) and balancing energy. The price of such flexibility is usually determined by using specific methodologies and depends on activated amounts of balancing energy, corresponding prices in previous years, and some other specific factors related to the technology of the power plant providing balancing services.

In Croatia, there is only one big BSP on the transmission network, and due to its dominance in market share/balancing capacity, the balancing market is not functioning optimally. HOPS is now having only four BSPs from DN and with each of them has signed an agreement according to their successful prequalification process. It is also essential to have specific rules on data exchange between TSOs, DSOs and generation units connected to the distribution system. The TSO has around € 85 million in investments per year and this number would not be significantly reduced by using flexibility from the DN, but investments in the distribution network will certainly increase significantly due to the connection of many distributed resources to the network. The average monthly costs only for reserves in Croatian transmission system are between € 2,5 to 3,0 million and in addition more than € 6 million for balancing energy. HOPS's opinion is that using flexibility from the distribution network through some specific platform could reduce costs and improve the whole system of procurement of balancing capacity and/or balancing energy (agreements, prequalification, auctions (product specification, bid structure), activation, settlement, congestion management).

*Case study*

To analyze the business case a model has been created to simulate the real-time operation of the balancing market. The model includes a simplified network with its physical constraints together with a mix of modelled and real generation and consumption data of connected to the network. The objective function of the case study is to minimize operational costs while incorporating clean solutions, such as residential PV capacity, battery storage systems, and wind power plants. As well as assessing the flexibility from the distribution network. The model is tested on a simplified network a schematic figure of which is presented on Figure 22.

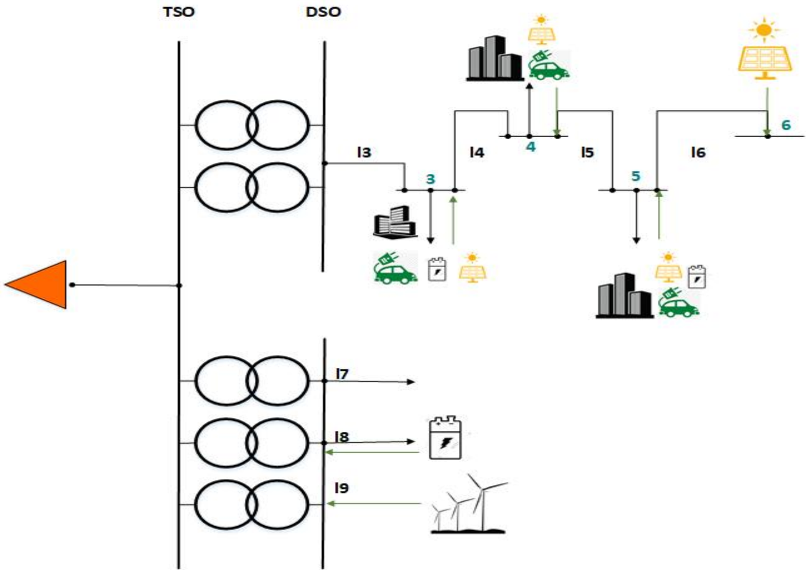



**Figure 22: Network Model**

As can be seen from Figure 22, except for Bus 6 and Bus 9, the rest of the buses have connected loads. The most relevant and representative load for this analysis is the hotel complex connected at Bus 3. This load can be subdivided in two, the hotel complex load and the EV charger's load. In the case of the data for the hotel complex the model uses the real consumption (see Figure 23) of the complex during the summer season (June-August). In the case of the EV charging the consumption patterns have been extracted from data analysis. Two charging patterns have been identified: i) sunny weather, and ii) cloudy weather. During a sunny day, the chargers work in the period of 0-6 AM (night consumption) and 12-4 PM (day consumption). However, during a cloudy day, they do it in the period 0-6 AM and 6-11 PM. In the hotel complex two are the type of charging stations installed 11 kW and 22 kW.

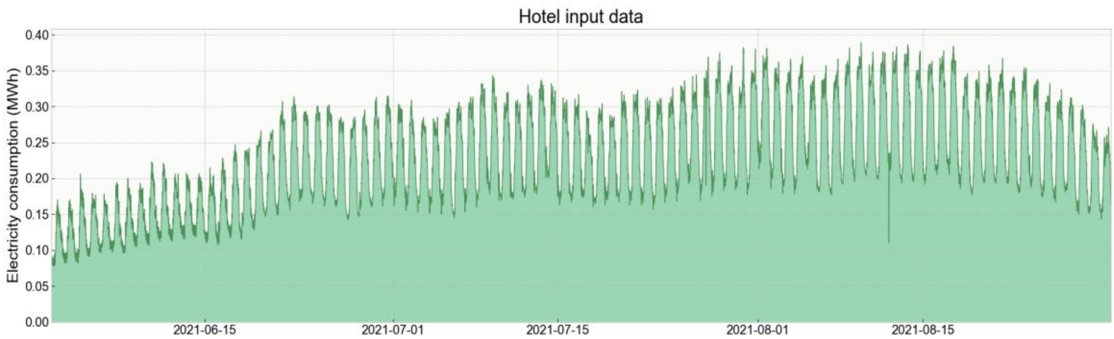



**Figure 23: Hotel Input Data**

Buses 4 and 5 represent the city of Šibenik with its corresponding electricity consumption. In terms of generation, all buses have generation assets included. However, the most significant ones are in Bus 6 representing a 10 MW solar PV park, and Bus 9 representing a wind farm with an installed capacity of 43 MW. The remaining buses have the following installed capacity (from PV panels): Bus 4 – 5 MW, Bus 5 – 4 MW, and Bus 3 – 0.9 MW. Figure 24 represents the total PV power production throughout the simulated period, and Figure 25 the total wind power production.

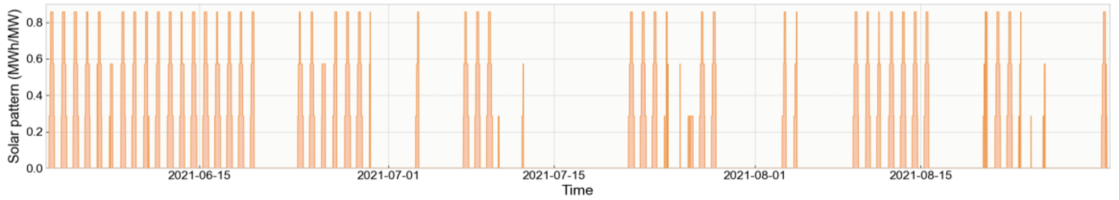



**Figure 24: PV power production**


**Figure 25: Wind power production**

There are also BSS installed in the grid. In Bus 3 the installed battery power is 0.3 MW, in Bus 5 it is 4 MW, and in Bus 8 a 10 MW power peak BESS is connected to the grid.

During the simulations, the model was run for the summer period with a 15-minute time resolution. The main aim of the model, and therefore for the business case is to show how much flexibility TSO can procure from the DSO side and the added value that this can provide for the TSO operation and the aggregated flexibility providers. For this business case it is assumed that the TSO is sending an activation signal-request to the DSO. At the DSO side can be an aggregator or a similar structure which can accept the signal and respond to the TSO with an activation of the associated resources (Figure 26). The TSO's goal is to activate as many reserves capacity at the DSO side as possible, assuming that distribution level flexibility has a lower price than large power plants connected to the transmission level. The prices used in the model represent prices extracted from the Croatian Power Exchange (CROPEX) day-ahead market, here presented as $\pi$. Currently, Croatia has regulated prices for the balancing energy calculated considering the factor *k,* which is different depending on the type of reserve. A detailed methodology approach for balancing prices can be found in Electricity Balancing Rules (*"Pravila o uravnoteženju EES-a, HOPS 5/2016"*). The price for flexibility activation is calculated for both UP and DOWN direction. UP direction bids for both BES and DSM providers are priced at $1.1*\pi$. Furthermore, DOWN direction bids for BES providers are priced at $0.9*\pi$, while for DSM providers is just $\pi$.

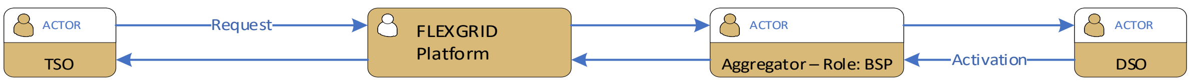



**Figure 26: Model Concept**

*Case study results*

The model results are presented by the following scenarios considering different shares of renewable distributed sources, and loads at DN level in the upcoming years:

**Base Case** – Represent today's summer season.

**Long Term** – Represents the summer season but assuming an increase to represent a long-term projection: demand (+10%), solar production (+30%), wind production (+0%), BES installation (+30%), EV charger installation (+30%), DSM flexibility (+20%)

*Base Case*

In the base case, the first part of the analysis is focused on showing the state of the distribution grid before aggregators are engaged in balancing market participation.

The results of flexibility activation starting from the same initial state of the grid are presented. Analyzing the results of a period simulation of three-month, the flex activation from the distribution side covers 14% (2.5 MWh) of the total TSO requests in the UP direction, and 34% (5 MWh) of the total TSO requests in the DOWN direction as shown in Figure 27. The highest amount of flexibility from the distribution side was provided to the TSO in August. The results obtained are already indicating a high potential to contribute to balancing services. Furthermore, it has to be considered that these are only the results for one location in the distribution network. Considering the total distribution network even a higher share could be achieved.

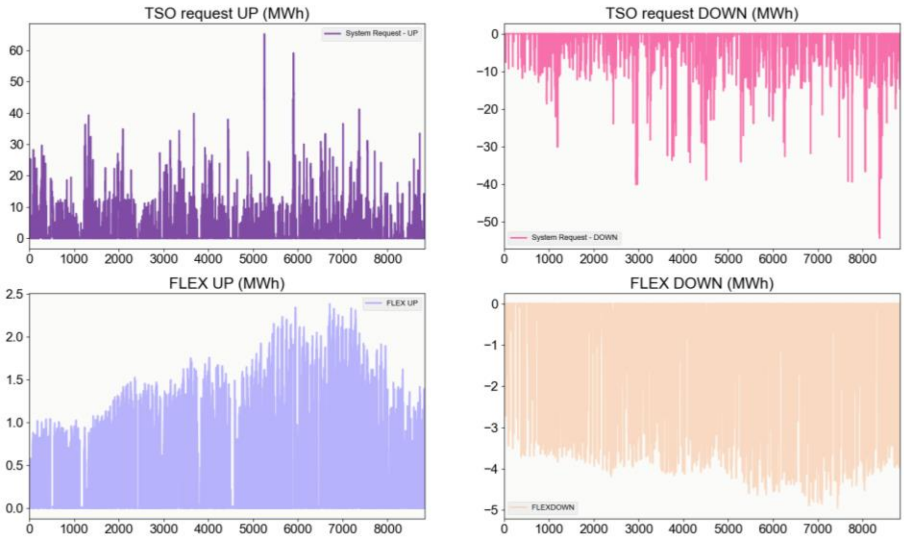



**Figure 27: TSO request and flex activation – Base case**

The congestion level is as follows: Line 3 is at full capacity 97% of the time, Line 4 is 75%, Line 5 is 43%, and Line 6 is 56%, respectively. This gives an input to the DSO that the rising share of distributed sources will have a direct and important impact on the power flows in the network. It is assumed that they will give a flexibility to the TSO in the near future. Although this flexibility could be used in different ways, not only for providing flexibility for the TSO, but also for other services, such as redispatch and congestion management in affected parts of distribution network. Therefore, a good coordination between DSO and TSO to achieve an optimal solution in both cases will be extremely important. The use of network aware clearing algorithms at distribution level would also help DSOs to keep their grids operating within the limits.

Due to favorable weather conditions at the beginning of June, solar production units were producing more solar power than during the July. As the demand is increasing to reach the peak of the season, the higher level of loss of load is measured. The main reason is the lack of power line capacity which could distribute the energy to the end users.

The following subsections dive deeper on the analysis of specific days (96 15-minute intervals) in the base case scenario.

*Beginning of the season*

TSO requests and corresponding flexibility activations are presented in Figure 28 separated by direction for the date 1$^{st}$ June which represents the beginning of the tourist season. It can be seen that activation of distribution sources from distribution level could cover small part of the flexibility request in the UP and DOWN direction.

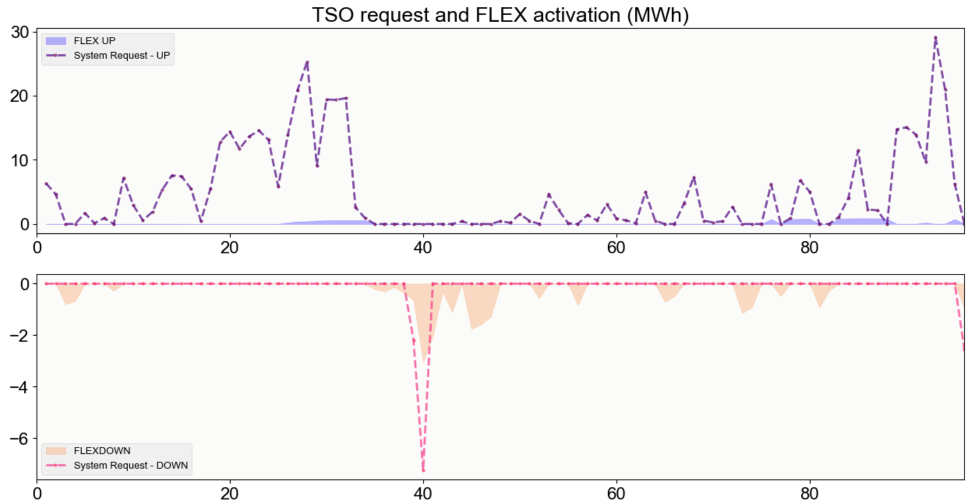



**Figure 28: TSO request and FLEX activation – UP and DOWN direction (MW), date 1/6**

Which part of the flex activation is covered with BES and which with DSM is shown in Figure 29. In this case, activation from the DN could cover 56% of TSO request in the DOWN direction (request 33,78MW, flex activation 21,77 MW), and 8% of request in up direction (request 474,89 MW, flex activation 13,82 MW). DSM has a higher share in flex activation.

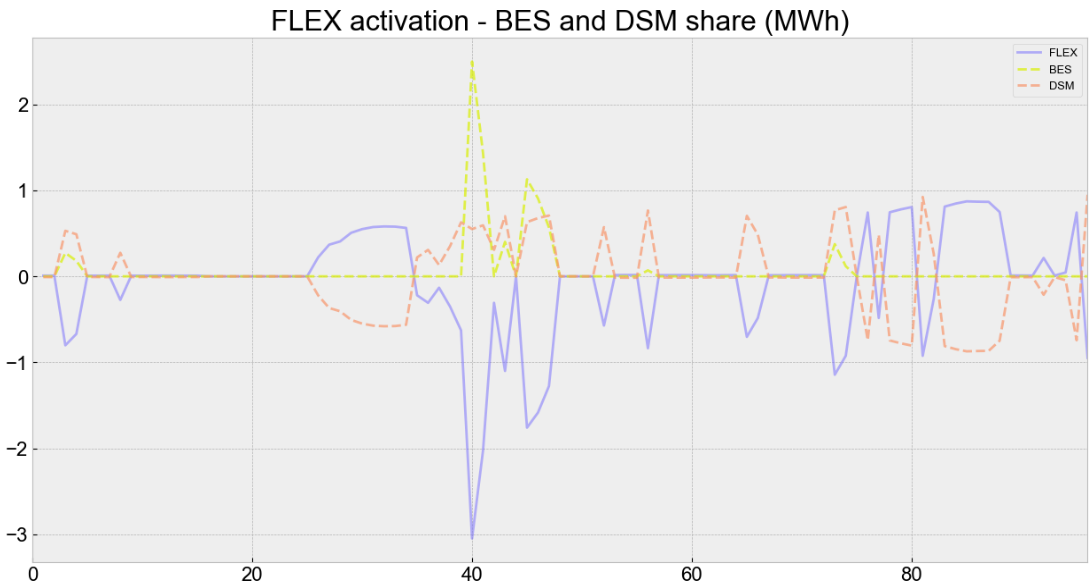



**Figure 29: Share of the BES and DSM in flex activation, date 1/6**

In Figure 30 it can be seen that some lines (l3-l6) are overloaded for some period of time, and it could be input or/and recommendation for DSO in view of new enhancements of the network.

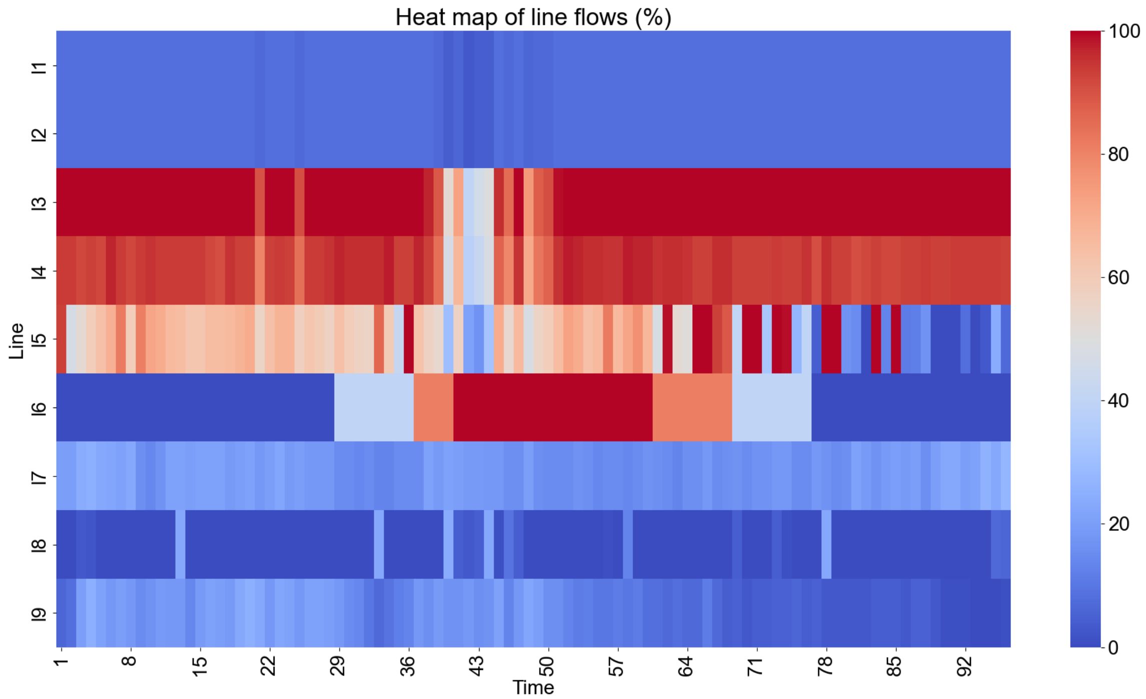



**Figure 30: Heat map of line flows (%), date 1/6**

*Middle of the season*

In Croatia, the middle of the season is usually around 10th of August. Even though the load is higher in this part of the summer, the share of flex activation has not changed significantly: 56% of flexibility activation cover the request in down direction and 8% in up direction, as you can see in Figure 31.

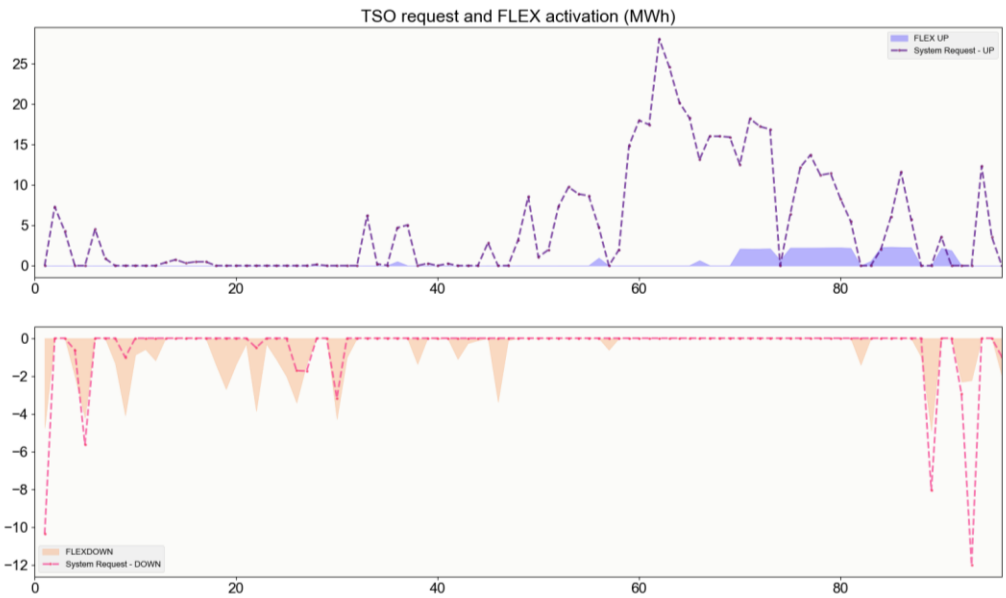



**Figure 31: TSO request and FLEX activation – UP and DOWN direction (MW), date 10/8**

The share of DSM and batteries in flexibility activation is similar in share as for the beginning of the season (see **Error! Reference source not found.**).

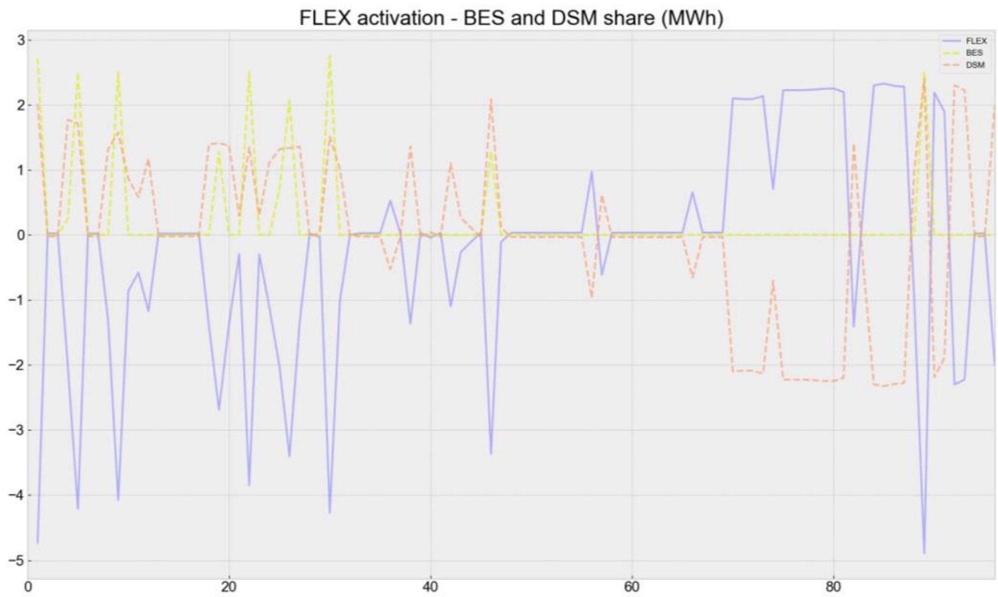



**Figure 32: Share of the BES and DSM in flex activation, date 10/8**

Overload occurred on the same lines as in the beginning of the season day too, as can be seen in Figure 33To be more specific, Line 3 is all day operating at full capacity, line 4 is most of the day operating at around 80% capacity, and lines 5 and 6 are more constrained during the middle of the day when the load is the highest.

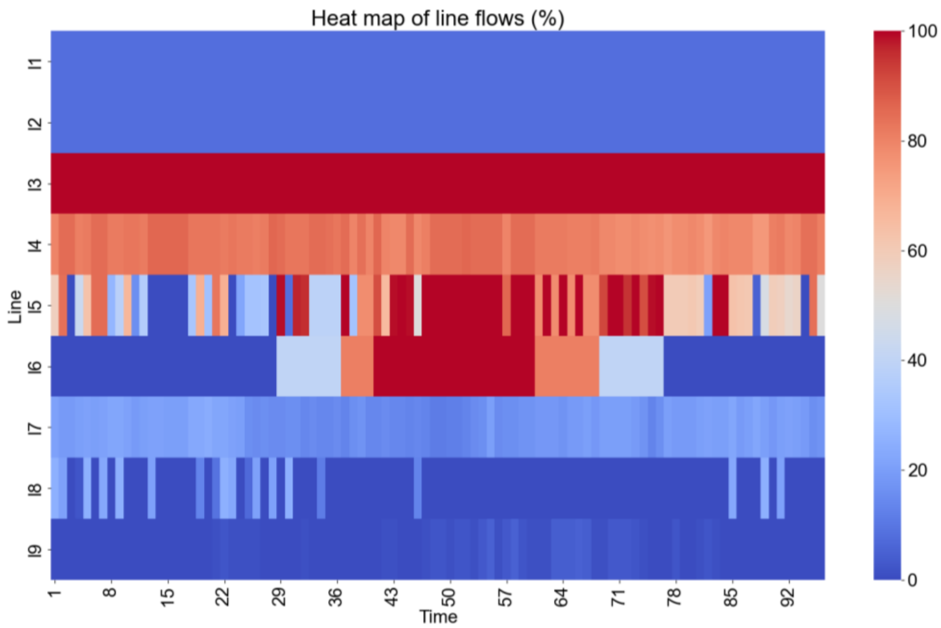



**Figure 33: Heat map of line flows (%), date 1/8**

*Long Term*

In **Error! Reference source not found.**Figure 34 the long-term scenario results are presented: the results of share of flex activation from the DN is higher: 22% in the UP direction, ad 46% in the DOWN direction. This long-term scenario also has 23% higher production of solar power, but the renewable energy curtailment is almost three times bigger. This shows how without improvements in network and the management of redispatch issues this part of the DN will not be able to cope with the expected large increase of renewable sources, which would also play a relevant role in flexibility services provision.

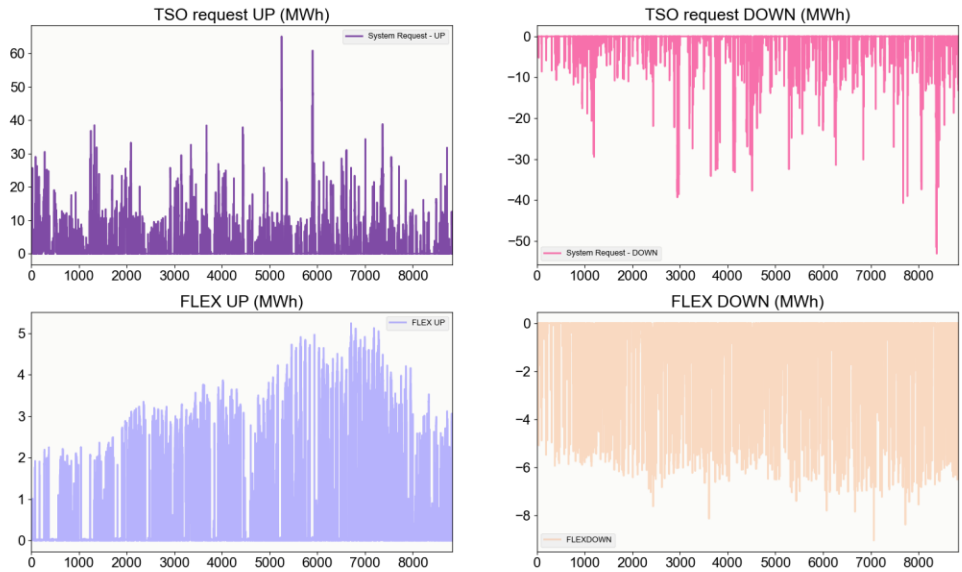



**Figure 34 TSO request and flex activation – Long-term case**

*Line capacity increase*

A high utilization factor of power lines is a problem that can reduce the lifespan of the lines and make power distribution inefficient. To study the capacity factor of the power lines and the impact of a capacity increase June 1st has been used as the representative date for this case.

Figure 35 presents the capacity factor of the distribution grid lines as of today. All the analyzed lines present high capacity rates at least at some point during the day. Lines 3, 4 and 6 are under heavy congestions for extended periods of time.

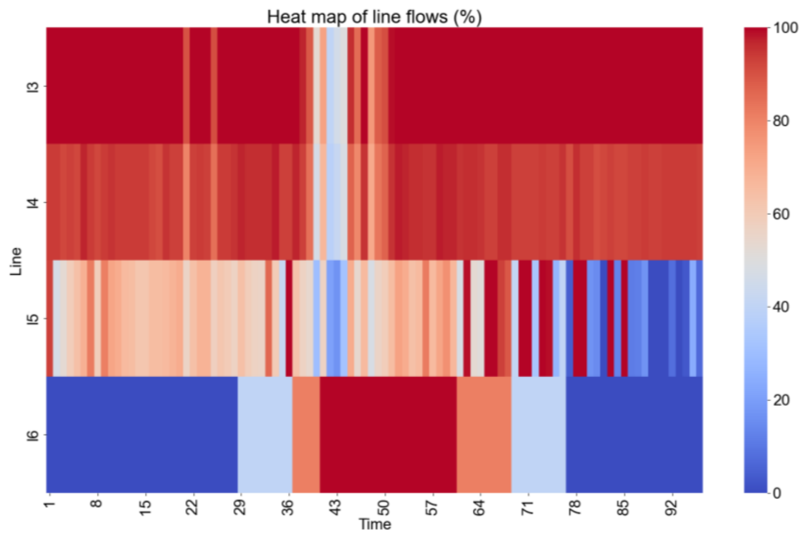



**Figure *35*: Line flows – Base case, date 1/6**

In Figure 36, the exact same scenario but now with a 1.5x and 2x (left and right respectively) extended grid capacities is presented. As expected, the congestion of the grid is reduced; however, during the day there are still some congested areas. It means that DSO should consider some other steps to release the pressure in that part of the network that part of the network – network reinforcements, redispatch and others.

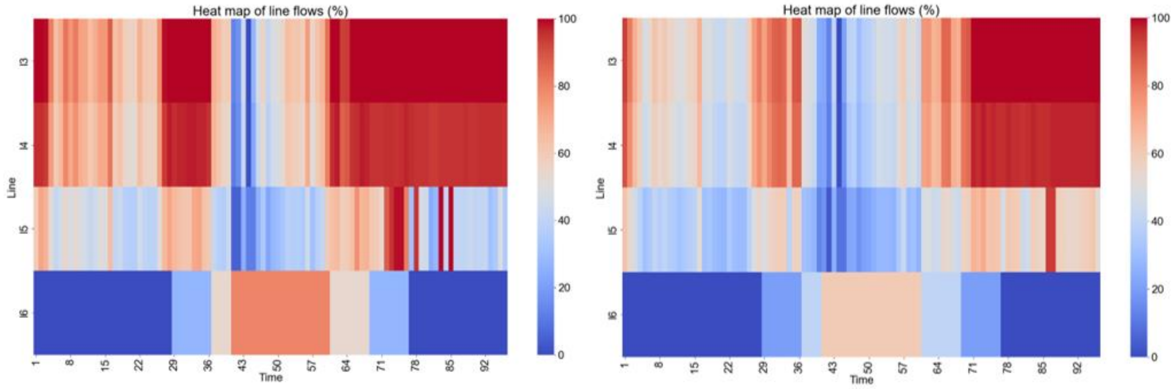



**Figure *36*: Line flows – Line capacity increase 1,5X (left) and 2X (right), date 1/6**

*Scenarios comparison*

During the summer season, the use of flexibility from the distribution network could be crucial for balancing the system, because the summer season is mostly a dry period and hydropower plants that in the BaU case are used to balance the system are not able to provide the contracted reserve and balancing energy. Table 19 and Table 20 show the simulated potential impact of expanding the BSP pool to include energy actors from the distribution grid. The blue colored area in the tables shows the TSO balancing costs without the introduction of flexibility from distribution network. The lowest impact at the TSO decrease of costs is measured in the scenario B-season (Table 19). This scenario represents a single day, and the reduction of costs is 6.92%. Further analysis considering the expansion of the capacity of the lines up to a 150% of their current capacity do not show an improvement of savings (6.82%), similarly if line capacity is increased up to 200% the cost reduction stays on similar values (6.77%). There reason for this behavior is the specific activation on that day. However, for other cases the impact in TSO savings is significant. It is also important to emphasize that during M-season consumption is significantly higher and in this case TSO has even greater benefits from the use of flexibility from the distribution network.

**Table 19: TSO balancing cost (€), Solar and wind production (MWh) and total curtailment, VOLL per each scenario (comparison between beginning of the season and middle of the season – one specific day results, 96 MTU).**

| | TSO balancing cost (€) | Percentage (%) | Renewables (MWh) | Total curtailment (MWh) | LL (MWh ) |
|---|---|---|---|---|---|
| **B-season noFLEX** | **48,742.25** | - | - | - | - |
| **B-season** | 45,368.37 | -6.92 | 448.50 | 7.36 | 146.66 |
| **M-season noFLEX** | **111,584.97** | - | - | - | - |
| **M-season** | 88,223.59 | -20.94 | 158.30 | 7.36 | 1,353.41 |
| **B-season 1.5X** | 45,416.79 | -6.82 | 455.86 | 0 | 79.79 |
| **B-season 2X** | 45,440.69 | -6.77 | 455.86 | 0 | 40.05 |
| **M-season 1.5X** | 88,156.14 | -21 | 165.66 | 0 | 1,223.56 |
| **M-season 2X** | 90,932.39 | -18.51 | 165,66 | 0 | 1,101.16 |

The highest business potential achieved is in long-term scenario 2x and it amounts to 52.94% of reduction in costs, as can be seen in Table 20. Total production of renewable energy is presented in forth column in Table 19, and the highest amounts for long term scenarios due to increasing of renewable capacity in the power system network. Similarly, the same behavior in the total curtailment, as well as in VOLL, which affects to long term scenarios.

**Table 20: TSO balancing cost (€), Solar and wind production (MWh) and total curtailment, VOLL per each scenario (3 months results).**

| | TSO balancing cost (€) | Percentage (%) | Renewables (MWh) | Total curtailment (MWh) | LL (MWh ) |
|---|---|---|---|---|---|
| **noFlex BASE CASE** | **5,363,069.75** | - | - | - | - |
| **BASE CASE** | 2,954,994.03 | -44.90 | 19,342.71 | 253.55 | 76,579.6 |
| **LT BASE CASE** | 2,555,307.46 | -52.35 | 20,688.70 | 758.10 | 83,076.34 |
| **BASE CASE 1.5X** | 2,955,864.36 | -44.88 | 19,592.23 | 4.03 | 65,250.39 |
| **BASE CASE 2X** | 2,955,036.01 | -44.90 | 19,581.07 | 15.19 | 54,370.27 |
| **LT BASE CASE 1.5X** | 2,534,707.18 | -52.73 | 21,357.3 | 89.49 | 70,740.13 |
| **LT BASE CASE 2X** | 2,523,621.12 | -52.94 | 21,429.00 | 17.79 | 59,668.87 |

Finally, Figure 37 presents a summary of the results obtained from the simulated scenarios considering the whole season simulation. As can be seen in the figures, the potential for reducing costs for the TSO through local flexibility procurement is high in Croatia, showing the potential business opportunity for DLFMs and integrated flexibility ecosystems such as FLEXGRID.

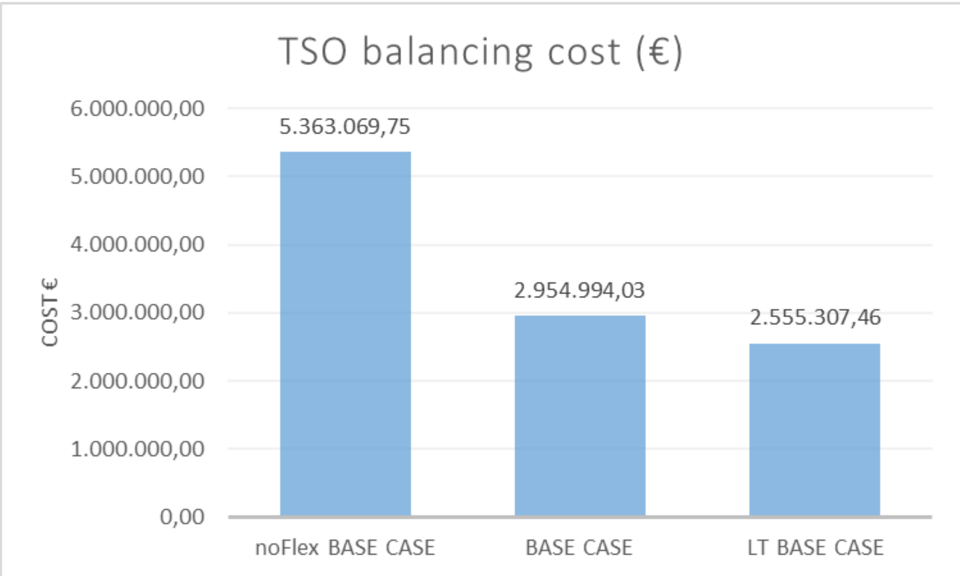



**Figure 37: TSO balancing cost comparison**

*Conclusion*

After analyzing the results, there is a great opportunity for the TSO from the viewpoint of flexibility provision from distribution network. Increasing share of renewable sources in DN, especially solar PV plants in combination with batteries, increases the flexibility possibilities, but also have a big impact on the DN and power flows. Demand side flexibility is enabling customers to become active participants in the market, and to provide flexibility services to DSOs and TSOs, with the aim to ensure efficient system operation. Using the flexibility from the distribution level, TSOs could cover most of the balancing requests, without activation of more expensive power plants from the transmission network. This means that final balancing energy costs, which are at the end covered by imbalanced parties, could be lowered. Using the flexibility from distribution network could be a possibility, not only for the system operators, but also for the balancing service providers (BSP). Providing flexibility opens a wide range of options to participate in European balancing energy platforms, as MARI and PICASSO, which could be a great financial opportunity for BSPs.

There are still many issues and gaps which should be solved to enable final customers to become active in the market and towards system operators to make the best use of flexibility with insurance of efficient system operation. Some of them are: framework agreements between BSP's and other parties, grid tariffs, easier pre-qualification processes (per product, at aggregator level), data collection (smart meters), transparency for all service providers (what and how information should be made transparent), TSO-DSO coordination and coordination of the market processes, improving of forecasting at DL (wind, solar, load in the day-ahead and intraday timeframes), dynamic tariffs, shorter gate closure times and product resolutions on different markets etc. A common interface or a common platform, as FLEXGRID, should support easy access and level playing field for market parties (including end customers). A single place or single platform for collecting and selling flexibility from balancing and flexibility service providers could be a good answer to many challenges and issues emphasized above. On this way, TSO-DSO cooperation could be coordinated in real time and interacting with flexibility providers could be established.

### 2.3.3 Value proposition quantification

The final part of this business modelling exercise builds on top of the results from the business cases. It does so to quantify the capacity of the FLEXGRID's tools of fulfilling the value propositions defined in D8.2. A value proposition is a promise of value that summarizes how a service or product will benefit the client. In this sense, the results obtained from the business cases show how FLEXGRID's developed tools and services can benefit the DSO and TSO in their day-to-day operation.

The methodology followed to quantify the value propositions is inspired by NobelGrid's business model evaluation tool [26]. However, the scope of this section is limited to value proposition quantification and therefore not all the capabilities of the tool have been used.

**Business case - Peak Shaving**

The conclusions from this business case show that, at least for German DSOs, the reduction of peak load can be a very beneficial model. The total cost per extra MW of yearly peak power is 113.900 €; however, after considering all the uncertainties and risks of this business case bnNETZE sets a maximum of 6.150 €/MW per 15 minutes request considering a total traded volume of 43,18 MWh/year to shave a peak of 10 MW during a year. bnNETZE's internal reports state that flexibility is not attractive for prosumers below 5 €/kW per request. The obtained results are promising for FLEXGRID services particularly in the mid/long-term horizon (Scenario 2 and 3), since based on public data from NODES[27], the price of local flexibility in today's LEMs ranges between 100 €/MWh and 1500 €/MWh (on average) a value lower than the estimations from bnNETZE, even though bnNETZE refers to residential prosumers and in today's DLFMs the participants are from aggregators to CHP plants. Furthermore, if DLFMs become mainstream it is expected to see a decrease of local flexibility prices due to an increase in competition.

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[26] NOBEL GRID: NOBEL GRID | Innovation and Networks Executive Agency (europa.eu)

[27] Market Data - NODES (nodesmarket.com)

In terms of replicability, a similar business case can be extracted from the sthlmflex project, where NODES is the flexibility market operator. In sthlmflex, regional DSOs use load forecasting services combined with local flexibility to avoid violation of the capacity agreement signed with the Swedish TSO. Furthermore, in sthlmflex local flexibility providers are occasionally competing with TSO-DSO temporary agreements for extended capacity. In sthlmflex the maximum price of flexibility is limited either by temporary agreement price (average of 22,4 €/MW/h[28] during winter 2021) or the regulated capacity violation penalty of 280 €/MW/h.

Therefore, FLEXGRID load forecasting services combined with access for the DSOs to local flexibility is fulfilling the defined value proposition, and the potential of its replicability has been proven through the sthlmflex example.

Until now only the benefits and maximum price for flexibility provision have been analyzed. However, FLEXGRID business model is based on licensing the tools that make this business case possible. In the following Table 21, different scenarios are presented to identify the potential value of the FLEXGRID services. In this scenario the objective of the DSO is to reduce the peak power by 10 MW (from 150 MW to 140 MW), the considered price of flexibility is assumed to be closer to the values observed in current DLFMs. Additionally, the yearly flexibility volume traded has been increased to 100 MWh and 300 MWh, which respectively represent 10 days of 1h activations and 10 days of 3h activations.

**Table 21: Sensitivity analysis performed of the value proposition for the business case 2.3.2**

| DSO - Cost Items [/year] | | | | | |
|---|---|---|---|---|---|
| **Cases** | | **750€/MW/h; 100 MWh traded** | **750€/MW/h; 300 MWh traded** | **1500€/MW/h; 100 MWh traded** | **1500€/MW/h; 300 MWh traded** |
| **Business as usual** | **Peak Power (+10 MW)** | 17.055.000 € | 17.055.000 € | 17.055.000 € | 17.055.000 € |
| **FLEXGRID** | **Peak Power** | 15.918.000 € | 15.918.000 € | 15.918.000 € | 15.918.000 € |
| | **Load Forecasting service** | -- | -- | -- | -- |
| | **Local Flexibility market license** | -- | -- | -- | -- |
| | **Flexibility Procurement** | 75.000 € | 225.000 € | 150.000 € | 750.000 € |
| | **Difference** | 1.062.000 € | 912.000 € | 987.000 € | 387.000 € |

When considering local flexibility prices closer to the observed in pilot DLFMs, the potential of FLEXGRID's value proposition is truly shown. In the analyzed business case, the assumed volume traded was around 50 MWh/year. In Table 21 it is shown that even in a "worst case scenario" with 300 MWh/year the DSO's opportunity costs would still be as high as 387.000 €.

According to bnNETZE the opportunity for a flexibility market in their grids will only be feasible considering a range of prices from 5.000 €/MW to 6.150€/MW per request. In this value

[28] Data extracted from NODES (Market Data - NODES (nodesmarket.com)), and converted from SEK to € using the following conversion rate 0,1 €/SEK.

quantification section, we have removed the floor for flexibility by considering a not-so-distant scenario where prosumers are willing to provide flexibility at lower prices. It is in this scenario where the FLEXGRID ecosystem, can show its potential value for DSOs.

With that said it is also important to acknowledge that the presented value proposition is unique in its integrated approach. If the different services are considered separately there are already some actors competing in the market. In the case of energy forecasting services, utilities have been using such services for an extended period. Companies such as SaS®[29], Itron[30], and AleaSoft[31] are already offering similar services. From the DLFM the existing DLFM alternatives are less, and only one of them, Localflex from EPEX SPOT can provide a similar value proposition to FLEXGRID's. Finally, it is interesting to see how NODES could try to implement a similar value proposition through its NODESConnect program with the company Baseline Energy[32].

**Business case - DSO avoids grid enhancement**

This business case fits in the Scenario 2 category, because today the grid studied in the business case is operating at 14% capacity. However, in the business case bnNETZE is able to show how fast things can change with electrification of transport, and how soon the network could be operating at a much higher capacity. One of the main challenges when it comes to the quantification of this value proposition is related to the expected lifetime of network upgrades, added value of new lines, and how flexibility might be a temporary solution to grid enhancement[33].

The business case presented, shows an opportunity cost; however, realistically speaking the grid analyzed is not under the risk of congestion. On the other hand, across Europe the number of distribution grids close to its limits is increasing. For instance, Liander (DSO from the Netherlands) as a map (see **Error! Reference source not found.**) showing the availability of new connections of large-scale business consumers and there is significant capacity issues particularly in the industrialized areas of the Netherlands. On a similar note, SP Energy Networks (a DSO from UK) is already securing flexibility for the years to come in these areas where their forecasted load growth indicates that during the period 2023 to 2028 the lines will be congested. SP Energy Networks[34] has tendered a total of 1.4GW in spring 2021, which represent a total of 1554 locations.

At this point, it has been shown that DLFMs are a good value proposition for DSOs to actively manage their grids. The case of Liander is particularly insightful to evaluate the value proposition of FLEXGRID because on their report *Congestion area North Papaverweg*[35] hey provide insights on how to evaluate the feasibility of using local flexibility to mitigate congestion before they can upgrade the grid. The following bullet points present a summary of the cases analyzed:

Distribution station Noord Papaverweg cable NDP 10-1V112L 23
Maximum capacity: 68 MVA
Peak load (2021): 49 MVA
Expected date of upgrade: Q2 2025

[29] Energy Forecasting | SAS

[30] Energy Forecasting Services (itron.com)

[31] Energy demand forecasting - AleaSoft Energy Forecasting

[32] Baseline Energy – Calculating the future

[33] Eurelectric: Connecting the dots - Connecting the dots: Distribution grid investment to power the energy transition - Eurelectric – Powering People

[34] ESP Networks - April 22 - Procurement Report.pdf (spenergynetworks.co.uk)

[35] Liander's Report - 20211209 Vooraankondiging verwachte congestie Noord Papaverweg v1.2.pdf (liander.nl)

According to Liander they expect to be forced to curtail 334 MWh in 2023, 1485 MWh in 2024 and 1388 MWh 2025. Furthermore, they analyze the potential flexibility from end-users by assessing the number of assets over 1 MW that would be interested in participating in the local flexibility scheme.

High consumption for Noord Papaverweg cable NDP10-1V112L
Maximum capacity: 2,91 MVA
Peak load (2021): 2,63 MVA
Expected date of upgrade: Q1 2023

In this case the congestion will be created by the conversion of the area form an industrial zone to a residential neighborhood. Due to this, Liander couldn't find any potential flexibility supplier, since the majority of the loads in the area are residential (not big enough). For this reason, they concluded that the project is not viable.

In the report from Liander there are cases the use of DLFM has been discarded due to the lack of "large-enough" loads. This is the case where the FLEXGRID ecosystem is able to give an added value to DSOs, and all market participants since it is able to facilitate market participation to FlexBuyers and FlexSuppliers.

After showing the replicability potential of the FLEXGRID ecosystem, and moving back to bnNETZE's business case, a small economic analysis could be done. As of today, and based on the literature review performed [36], local flexibility is used to defer investments and not to avoid them forever. Considering this use case, and using the values given by bnNETZE in the business case a high-level assessment of FLEXGRID tools value can be done. The annualized opportunity costs amount to a total of 94.544 € for the specific studied upgrade, the use of a DLFM could help to defer the investment but also could be used to actively manage the stressed grid once the grid upgrade is under construction.
Each delayed year of investment has a maximum value for the DSO of 94.544 €, assuming that there is no difference between a grid upgrade and using an DLFM. The OPEX costs involved with the DLFM option are: DLFM as SaaS, and the cost of flexibility. As already mentioned in previous cases it is expected to see a reduction in local flexibility prices overtime that would help to improve the value of FLEXGRID tools. The following table aims to show a prospective evaluation of the use of a flexibility market. However, all the numbers shown are assumptions created for this "sensitivity analysis". First of all, knowing the peak power of 1,4 MW of the line, it has been assumed that the average load of the grid is 0.5 MW, leading to a annual electricity consumption of 4.380 MWh. To assign flexibility needs, a % of the total "simulated" load has been assumed:

Case 1 - 1,5%
Case 2 - 2,5%
Case 3 - 5%

For the flexibility price, to maintain a close approach in all the value propositions evaluation the 750€/MWh value has been used.

[36] Sthlmflex (SvK) - sthlmflex | Swedish power grids (svk.se); AFRY & Nordic Energy Research - Market design options for procurement of flexibility

**Table 22: Sensitivity analysis on the use of local flexibility to defer investments.**

| DSO - Cost Items [/year] | | | | |
|---|---|---|---|---|
| **Cases** | | **Case 1** Flexibility need: 54,75 MWh | **Case 2** Flexibility need: 109,5 MWh | **Case 3** Flexibility need: 219 MWh |
| **Business as usual** | **Grid Upgrade** | 94.544 €/year | 94.544 €/year | 94.544 €/year |
| **FELEXGRID** | **Local Flexibility Market license** | -- | -- | -- |
| | **Flexibility Procurement** | 41.062,5 € | 82.125 € | 164.250 € |
| | **Difference** | 53.481,5 € | 12.419 €/year | - 69.706 €/year |

Based on the threshold set by the annualized cost of the grid investment over a 20-year time horizon, Table 22 shows the potential margin for FLEXGRID services to share the value created with the DSO. From this prospective analysis it is relevant to see the impact of the flexibility needs over the viability of the market. In other words, if the need for flexibility is very high (for whatever reason), there is a high chance for the flexibility procurement costs to jeopardize the DLFM business model. This, however, can be different in the scenario where the DLFM is used while the grid is in the process of being upgraded.

As mentioned in the previous paragraph, the delay of investment scenario is quite relevant for the business case; however, as of today the main pain point that FLEXGRID's ecosystem could help to solve is the management of distribution grids during upgrade periods. This approach is the one used in sthlmflex, and Liander's report. As bnNETZE has shown even with a grid at 14% capacity in the worst-case scenario, the load profile of a network can change drastically in a short period of time due to the electrification of transportation and installation of heat pumps. Furthermore, and considering the current invasion in Ukraine and the role of energy as a war weapon, it can only be expected a more rapid uptake of electricity-based heating technologies, particularly in countries with a high dependency on Russian gas, such as Germany. In the use case where DLFMs are used during a grid upgrade, the available alternatives, such as bilateral flexibility agreements and conditional connections, are disincentivized by the EU in favor of DLFMs market-based approach. Therefore, if feasible from the liquidity perspective DLFMs will be the preferred option (see Liander's report).

**Business case – TSO using DN-level flexibility through a DLFM**

This business case has a long-term scope, it fits in Scenario 3 (beyond 2030) and its value quantification is subject to higher levels of uncertainty. On this scenario local flexibility markets are well stablished markets and therefore different market players have access to them in a coordinated manner.

As of today, NODES is running some pilot projects where local flexibility has access to TSO balancing markets[37] . However, the business case analyzed in this document goes a step further and aims to calculate the potential benefit of TSOs being able to access flexibility in local flexibility markets.

[37] NorFlex: NorFlex project demonstrates integration with Statnett's regulating power market | | Innovation | Our business | AE.no; sthlmflex: sthlmflex | Swedish power grids (svk.se)

ENTSO-E's working paper *Distributed Flexibility and the value of TSO/DSO cooperation* [38] gives insightful data of the economic impact of DERs participating in balancing markets. First, it is worth mentioning that, as of today, there is already significant amounts of DER are participating in balancing markets all over Europe. Figure 38 , from ENTSOE's report[39] shows the capacity participating in balancing markets that is connected at DSO grids considering the following countries: AT, BE, DK, F, D, GB, HU, NL and ES.

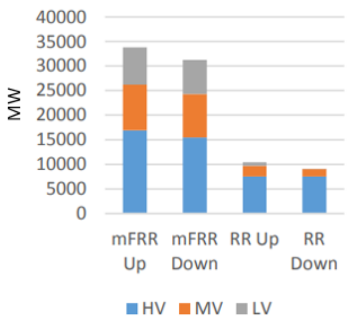


**Figure 38: DN balancing capacity**

The report also provides insightful data about the impact of allowing DER participation in balancing markets. For instance, in France DER (generation, demand, and storage) are allowed to participate in the markets since 2012. In 2016 they represented the 32% of the total mFRR contracted capacity, and the procurement costs of flexibility have reduced around 20%. In the case study developed within this deliverable the reduction of costs is expected to be up to a 45%. This is a significant discrepancy with the available numbers from the French mFRR market; however, in the case of the present document HOPS has analyzed the potential of a specific grid node, and the obtained results can be highly affected by the type of assets connected to the distribution grid. Furthermore, as mentioned by HOPS during the analysis, today's Croatian BSP ecosystem is almost monopolized by a single big BSP able to actively influence the market.

The report from ENTSO-E simplifies the potential of local flexibility to three core services: balancing services (TSO), congestion services (TSO), and congestion services (DSO). The results of the analysis performed are focused on balancing for TSOs but can show how relevant the communication between TSO and DSO will be. In the scenarios evaluated in this business case, TSO's flexibility procurement at the local flexibility market puts under a lot of stress some of the DSO's owned lines. These results are strong - qualitative - arguments in favor of network aware local electricity markets which can clear the market for multiple market players, while respecting grid constraints, potentially simplifying the communication flows between DSOs and TSOs.

Focusing on the value added by the FLEXGRID ecosystem this is one of the cases where it is not easy to quantify. On the one hand the results show a potential 45% reduction in procurement costs for TSOs. On top of that, HOPS has shown the value of network aware DLEM algorithms to mitigate the risk of creating new network issues due to flexibility provision at local level. If we center the scope on the TSO, then some insightful conclusions can be extracted. Table 23 shows the opportunity costs that the TSO is willing to undertake to procure balancing services from distributed assets. The numbers obtained are on a yearly basis but show why TSOs are interested in accessing local flexibility.

**Table 23: Result comparison between FLEXGRID business case and observations from ENTSOE's reports**

| | | 45% Cost reduction<br><br>Business Case analyzed scenario | 20 % Cost Reduction<br><br>ENTSO-E report |
|---|---|---|---|

[38] ENTSOE - *Distributed Flexibility and the value of TSO/DSO cooperation*

[39] ENTSOE: Distributed Flexibility and the value of DSO-TSO cooperation - 170809_Distributed_Flexibility_working-paper_final.pdf (entsoe.eu)

| | | | |
|---|---|---|---|
| Business as usual | **Balancing Costs** | 5.363.069,75 € | 5.363.069,75 € |
| FLEXGRID | **Balancing Costs** | 2.954.994,03 € | 4.290.455,80 € |
| | **Local Flexibility market license** | -- | -- |
| | **Difference** | 2.408.075,75 € | 1.072.613,96 € |

The results obtained, even if from a very simplified analysis (considering the low TRL of the project) show the potential value of FLEXGRID ecosystem for TSOs at a given node of HOPS grid, and according to the analysis performed it can be very beneficial for the TSO. Furthermore, the business model hereby presented should be scalable by implementing the FLEXGRID market solution in all the connection nodes where the TSO is interested. Additionally, if considering the FLEXGRID business ecosystem adding new FlexBuyers is beneficial for the FlexSuppliers since it increases the probability of activation.

**Value quantification final remarks:**

The analyzed business cases showed positive results in terms of value propositions offered by FLEXGRID to DSOs and TSOs. With that said, it is also true that in most cases the individual services analyzed are already available in the market. On the one hand, this is a good sign for FLEXGRID services, because this means that there is interest on the developed services. On the other hand, this means that FLEXGRID services (for DSOs) will face competition in the market.

As has been discussed in chapter 2 the strength of FLEXGRID is its core objective to be a **Whole Product** proposition (i.e. a local flexibility ecosystem). It is in this context where the maximum value can be extracted from the analyzed services. Furthermore, up until here the implementation of DLFMs has been approached as an individual cost on every business case analysis. However, this is not true. The implementation of a DLFM in a DSO network would allow the DSO to actively manage their grids, either for peak shaving or investment deferral, for the same license cost. In the case a TSO wants to access the same DLFM, the costs of the service could be shared between the multiple market players in the role of FlexBuyer. The capacity of FLEXGRID to allow (in the future) for multiple FlexBuyers with diverse interests to co-exist and compete in the same DLFM is a clear benefit for FlexSuppliers, but also for the FMO/FLEXGRID that could increase the revenues thanks to the multiple subscription model, which could also lower the cost per individual FlexBuyer.

**<u>FLEXGRID H2020 Contributions</u>:** The analysis of the business model *FLEXGRID platform for DSOs (and TSOs)* has provided relevant insights of business opportunities for DLFMs and energy service providers. In Germany, the **Peak Shaving business case** has shown an opportunity cost for FLEXGRID services of **113.700 €/MW·year**. In Croatia, the TSO HOPS has shown the value of **distributed flexibility to balance their grid**, showing savings of up to of **2 M€** per year if distributed assets had access to the balancing markets. Finally, from the business case **FLEXGRID services to defer grid investments for DSOs** (Germany), the viability of the business model is less clear. In the case of grid investment deferral, DLFMs must compete with the annualized cost of the investment, in this scenario the procurement costs of flexibility for the DSO can jeopardize the DLFM business model. Scenarios where the DSO has no alternative other than actively manage the grid pose better business opportunities for FLEXGRID.

The business cases analyzed have shown the viability of multiple of applications of the FLEXGRID services for DSOs and TSOs, therefore presenting multiple potential revenue streams for the FLEXGRID ATP. With that said, some challenges have also been identified, the main one being the need for market liquidity (FlexSuppliers), and the concerns of system operators regarding the reliability of delivery of distributed flexibility.

## 2.4 Business Model Quantification: FLEXGRID platform for FlexSuppliers

### 2.4.1 Business Model

The third business model is that of a software provider that sells FLEXGRID services to FlexSuppliers. As with the previous business models, this one has also been modified to focus the exploitation strategy towards closer-to-market services and align it with the work done in D8.3 chapter 3.

The final target customers of the business model are FlexSuppliers, but to be more specific: Aggregators, Independent Aggregators and Retailers which have been identified as the potential users with a bigger "pain" and higher potential benefit from using FLEXGRID's toolkit. Furthermore, Aggregators and Independent aggregators' (innovative) business model is fully aligned with the innovative capabilities of the FLEXGRID ATP.

The value propositions of the final BMC have also been reduced from the original BMC in D8.2, based on the consultation process with industrial partners and the consideration of those offerings that are closer to market readiness. The first value proposition of FLEXGRID in this business model is to maximize the ATP users' profits by optimizing their portfolio participation in different electricity markets. At FLEXGRID we acknowledge that similar value propositions are already fulfilled by existing software in the market; however, FLEXGRID' solution allows to include all available markets in the optimization problem, and consider local flexibility markets (where available). This differentiation is thanks to the ATP integrated Market Price Forecasting Engine. The second value proposition of FLEXGRID was not explicitly mentioned in D8.2 because it was part of a much bigger value proposition. However, in this final BMC that has more specific target customers, it becomes quite relevant. It is the automation of the portfolio management, allowing the aggregators and retailers to optimally assign each of their assets the most profitable task within their technical capabilities. In a near future, when proper regulatory framework for DLFMs will be in place, this automation of portfolio management would also mean maximization of social welfare and reduction of prosumer's discomfort, services that are already being developed within the FLEXGRID project. The last value proposition is the FLEXGRID ecosystem itself. On the BMC this value proposition has a different color, this is because it is not directly a value proposition of the services for ESPs, but, if existent, it benefits the rest of the existing value propositions. The FLEXGRID ecosystem includes tools for FMOs to implement DLFMs and for DSOs to identify their needs, in other words, if the full ecosystem is implemented it can help Aggregators and Retailers to increase the value of their flexibility by increasing the number of potential buyers. This is the reason why DSOs and FMOs have been included in the Key Partners section of the BMC. The FLEXGRID ecosystem on its own as a value proposition makes clear reference to the Whole Product model, presented in Figure 39. In the case of FlexSuppliers and flexibility, the implementation of a whole product is more relevant than for any of the other business actors. Even if they have the tools to manage their flexibility, if FlexSuppliers cannot sell their flexibility - through a LEM (FLEXGRID preferable) or bilateral agreements - their interest for the offered services will disappear.

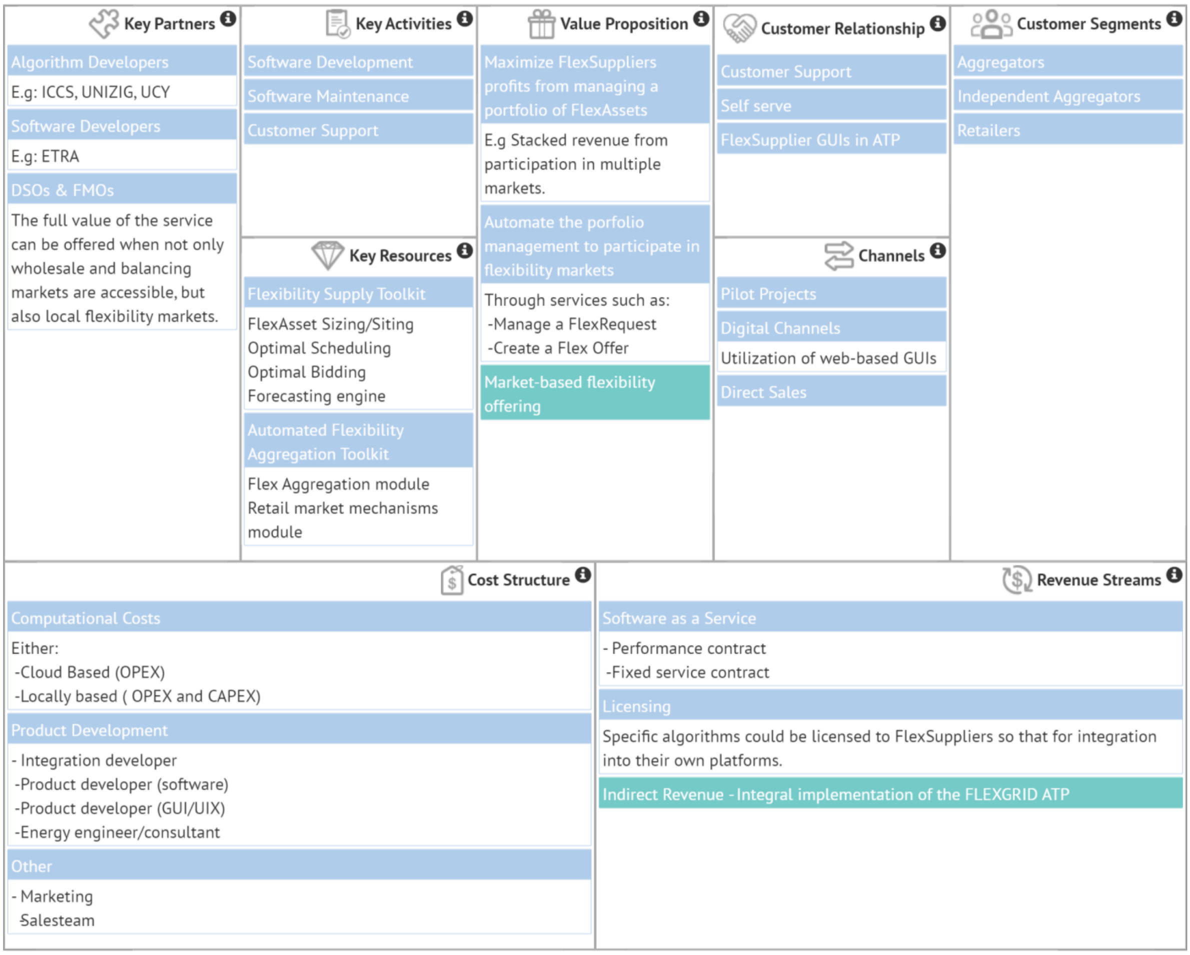


**Figure 39: Business Model Quantification: FLEXGRID platform for FlexSuppliers**

### 2.4.2 Business Cases

1. *ESP optimizes its performance in the day-ahead and intraday markets*

*Context*

In our analysis, we focused on two components that are predestined for flexibility marketing - at least in Germany. On the one hand, a larger CHP unit with an electrical output of 2 MW and, on the other hand, a battery storage system with a storage capacity of 14.5 MWh and 12.5 MW nominal power. Why these components in particular? Because there are thousands of larger CHP units in Germany that are currently only rarely - and mostly not at all - used for flexibility marketing. This means that many MWs of power would be available for flexibility marketing straight away. Currently, however, most of them are operated purely based on heat demand. That is the business as usual. That means they run a lot during wintertime. In summer, they are in standby mode. Thus, the question here was how additional marketing on the spot market can generate additional revenues and thus reduce heat generation costs for the connected heat customers. This is a complex optimization problem, with several variables and constraints. The most important variable is the electricity prices in the different spot markets (day-ahead, intraday auction, intraday continuous trading). Another import variable on the cost side is the gas price. Constraints are e.g., that the heat demand must be always covered. Because heat supply has priority. Another constraint are max. capacity of the heat storage or minimum operation and shutdown times, etc.

For the large-scale battery storage, the current situation is that it is marketed exclusively in the primary control balancing market. This is the business as usual (BAU). Here, it was necessary to investigate whether higher revenues could be achieved by marketing in the spot market. Unfortunately, it is not possible to do both at the same time. A battery can only participate in one or the other market. Thus, the revenues cannot add up.

*Business case description*

To ensure the balance between electricity generation and consumption in the future, despite the weather dependency of the electricity supply, the increased use of plants that allow residual load-oriented operation and whose operating schedules can also be adapted to current market conditions during the day will be necessary. Plants that can be flexibly started and shut down according to the expected residual load are referred to as flexibility options. Numerous biogas and CHP plants, energy storage facilities, and controllable loads located in the distribution grids have the potential to offer their flexibility as a system service on the short-term spot market.

In addition to the technical and operational restrictions, the economic viability of a flexibility option depends largely on the economic incentives of the markets in which the schedule optimization trades are made. These incentives include the future price level development in the various sub-segments of the spot market, demand- or supply-related price fluctuations, and the frequency of extreme prices. Furthermore, the price development on the fuel futures markets and the markets for emission allowances has a significant impact on the realizable contribution margins and cost savings.

This business case is closely related to the business case C24 from D8.2 and it is part of the High-Level Use Case 2 FLEXGRID ATP offers advanced flexibility supply management to services to ESPs. The main business actor involved is the FlexSupplier in the form of aggregator or ESP, and its main business goal is to maximize the profit from selling flexibility.

For this analysis, the reference years 2017 and 2018 were chosen since these years can still be classified as "normal" years with normal price levels. By the end of 2019, the Covid pandemic was already beginning to emerge, which had an impact on price levels. The years 2020 and 2021 were marked by Corona lockdowns, sharply reduced consumption in industry and manufacturing and, as a result, exceptionally low electricity prices in some cases. From mid-2021, these effects were overlaid by a shortage of gas supplies from Russia, coupled with rising gas prices and, depending on this, a renewed sharp rise in electricity prices especially towards the end of the year. This development was also fueled by unscheduled shutdowns of nuclear power plants in France, the permanent shut down of further nuclear power plants in Germany at New Year’s Eve as well as high prices for $CO_2$ allowances. All this led to a severe supply shortage and very high prices, which would not have been representative for analysis.

Figure 40 shows the average German exchange electricity prices for base, peak and off-peak on the day-ahead market of the last 5 years. The ratio of peak to base is approx. 1.2 and of off-peak to base approx. 0.9 and has not changed significantly in recent years.

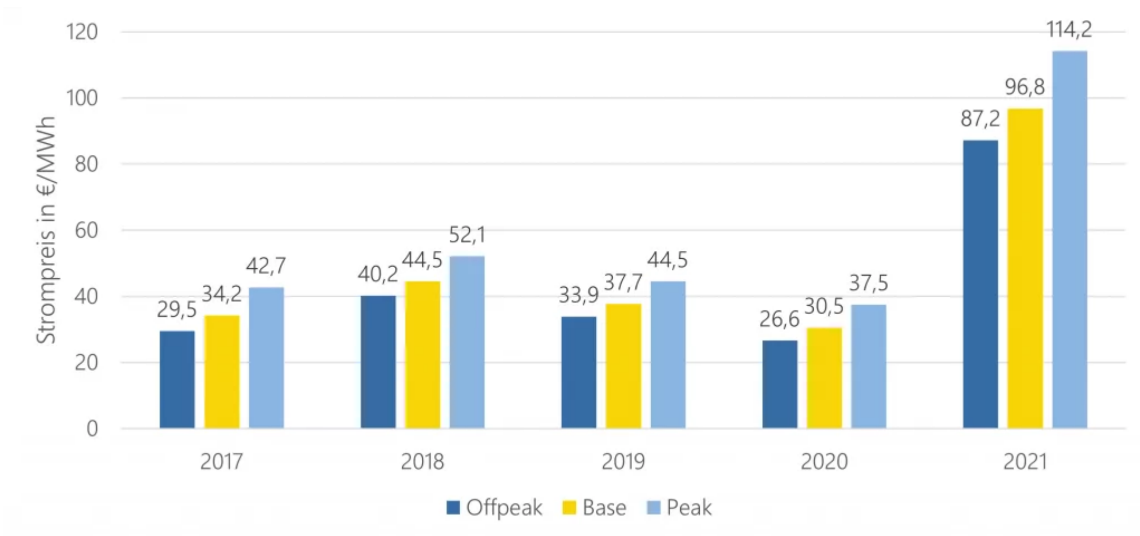


**Figure 40** ***Average EPEX-Spot electricity prices for Germany***

In today's Germany the electricity spot market structure is composed by the markets listed in the paragraphs below.

**Day-ahead market**

The markets in which electricity supply or purchase commitments are preferred in the context of flexibility marketing are the day-ahead market and the intraday market. Both markets are operated for Germany by several power exchanges. In the day-ahead market, which is preceding the intraday market, a market-clearing equilibrium prices are determined daily in a two-sided auction by aggregating all buy and sell bids for each hour of the delivery day.

**Intraday Auction**

Another segment of the spot market are intraday auctions. They take place at different times during the day following the day-ahead auction and allow market participants to buy or sell power for different market-time units. As in the day-ahead market, prices are determined in a two-sided auction. For each MTU of the delivery day, the purchase and sale quantities bid are aggregated within fixed price intervals and sorted by price in ascending order. From the intersection of the supply and demand curves determined in this way, the resulting market clearing price is determined for each delivery period. The market volume in the intraday auctions is significantly lower than the volumes in the day-ahead market. However, due to the lower liquidity as well as the limited ability of conventional generators to follow short-term supply and demand changes, prices are significantly more volatile

**Continuous intraday trading**

The last sub-segment of the spot market is continuous intraday trading. This takes place on several power exchanges. It provides for the continuous purchase and sale of electricity, which is delivered on the same day. As a rule, electricity deliveries and purchases are traded in intraday trading in quarter-hourly, half-hourly and hourly blocks, although it is also possible to trade larger interrelated blocks. Standardized block bids include the "base load block" for hours 1-24 and the "peak load block" for hours 8 to 20. Each contract can be traded across control areas within Germany up to 30 minutes before the start of delivery. Within control areas, trading is possible up to 5 minutes before delivery. The minimum volume for participation in intraday trading is 0.1 MW. A chronological classification of the continuous intraday trading in the daily routine at the power exchange is shown in Figure 41.

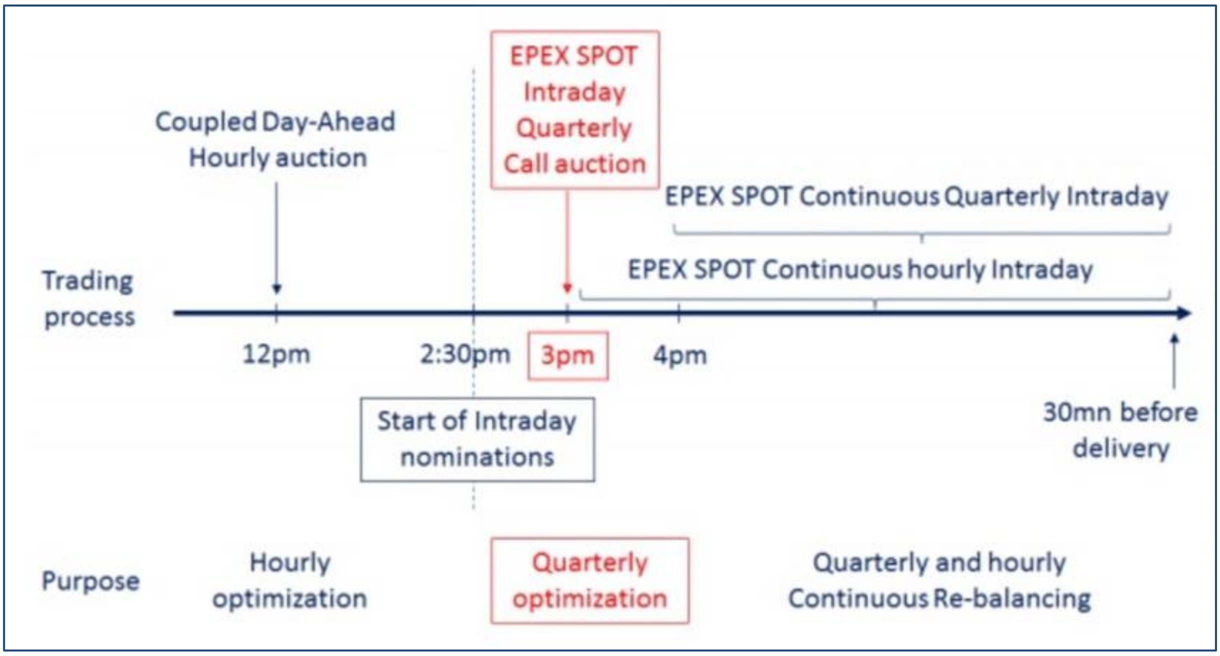


**Figure 41** ***Temporal sequence of electricity trading***

While in the day-ahead market the market price is determined by a two-sided auction procedure, where the last winning bid determines the price for all transactions, prices in continuous intraday trading are determined by a "pay-as-bid" procedure. "Pay-as-bid" means that a trade is always executed at the pre-specified bid price. In the "pay-as-bid" procedure, all buy or sell bids in an order book are independently checked for their exportability. A transaction is always concluded if a suitable counterbid is found for an existing bid, which is characterized by a bid price and a volume. As soon as two orders are executable against each other, they are combined into one trade. An important price signal reflecting market changes immediately before the start of physical delivery is the ID3 index. It is calculated daily for hourly and quarterly contracts and represents the volume-weighted average of all transaction prices in the last three hours before the close of trading. Since most trades are executed during this period, the $ID_3$ index provides a realistic assessment of daily price movements.

In summary, it can be said that continuous intraday trading will become more important in the coming years, especially due to the stricter sanctioning of balancing group deviations. The liquidity of intraday markets will significantly depend on the balancing needs of market participants. It will increase due to the strong addition of renewable generation capacities unless the accuracy of load and feed-in forecasts improves significantly compared to today. This will result in additional revenue potential for flexibility marketers.

The main business actor of this business case analysis are municipal utilities (or in general any power plant operator) that operate CHPs in combination with a heat storage system and peak-load boilers can generate additional revenue by selling electricity on the day-ahead market at optimized times, thereby reducing their heat generation costs. Additionally, the analysis is also performed considering the asset used a battery storage system instead of a CHP plant.

For the business actors involved, participation in intraday trading offers additional profit potential. There, the operator of the cogeneration plant can use the flexibility of his plant to make further electricity sales or buy back electricity quantities already sold on the day-ahead market at negative prices. In addition, the cogeneration plant operator can smooth out any schedule deviations caused by a short-term plant failure by means of a corresponding countertrade on the intraday market and thus avoid balancing energy costs. Finally, he can force the cogeneration plant to be switched off by buying back electricity that has already been sold if the forecast heat load is reduced in the short term or if the storage facility does not have sufficient capacity to absorb excess heat. When it comes to battery storage systems the business case is focused on exploring the potential of different markets to maximize the profit from the asset.

The values for flexibility marketing on existing markets should count as benchmarks for a regional flexibility market. Only if the revenues in this regional flexibility market are at least as high as in the already existing markets ESPs will take part. So, the calculated values in the following business case analysis can act as a benchmark.

*Counterfactual scenario*

Regarding CHPs, most of them are operated purely on the basis of heat demand. That is the business as usual (BAU). That means they run a lot during wintertime. In summer, they are in standby mode. Thus, the question here was how additional marketing on the spot market can generate additional revenues and thus reduce heat generation costs for the connected heat customers.

For large-scale battery storages, the current situation is that they are actually marketed exclusively in the primary control balancing market in central Europe. This is the BAU. In the following business case study, it was investigated whether higher revenues could be achieved by marketing in the spot market.

*Case study*

In the present analysis, multi-stage marketing options on the spot market were simulated and evaluated for a heat-led CHP plant and a battery storage system. In this context, a differential cost analysis was performed to determine the extent to which individual marketing strategies can reduce the average heat generation costs, considering the investment costs. The simulation period covered the years 2017 and 2018.

*Combined Heat and Power*

The marketing simulation of the CHP plant focused exclusively on calculating the theoretically achievable additional revenues by marketing the CHP electricity on the day-ahead market and in intraday trading. Heat forecast uncertainties and unpredictable plant outages were not considered in the calculations. For simplicity, it was assumed that the system always generates the forecasted amount of heat.

The evaluation of the investigated marketing strategies on the spot market was carried out for the CHP plant using a back testing approach. This approach is used to determine what results the individual marketing strategies would have achieved on the spot market under near-real marketing conditions in the past. The optimization calculations were performed based on real price forward curves and real temperature forecasts, and the realized revenues were determined using the associated real market prices. In intraday trading, the theoretically achievable cost savings were calculated using the $ID_3$ price index. It was accepted that an optimization calculation with averaged index prices tends to underestimate the revenue or cost savings potential.

This multi-stage optimization strategy was also used in the optimization of a large battery storage system described later in the paragraphs below.

The CHP plant modelled in this work consists of a total of three heat generators and an atmospheric displacement storage tank. Two identical CHP gas engines from Jenbacher, a gas boiler and a peak load boiler operated with fuel oil are used as heat generators. The two CHP engines can be operated separately. The electricity generated by the CHP units is fed into the local distribution grid. All heat generators are operated with natural gas, which they obtain from the local gas grid. Table 24 shows an overview of the technical parameters.

**Table 24: Technical parameters CHP**

| Parameter | Value |
|---|---|
| **Nominal Power CHP 1** | 1 MW |
| **Nominal Power CHP 2** | 1 MW |
| **Heat Storage Capacity** | 5,8 MWh |
| **Storage Temperature** | 90°C |
| **Storage Losses** | 1 %/h |
| **Max. Thermal Charging Power** | 1,5 MW |
| **Max. Thermal Discharging Power** | 1,5 MW |
| **Outgoing Temperature** | 90°C |
| **Return Temperature** | 62-66°C |

This business case was developed in parallel to FLEXGRID's tools integration on the ATP (WP6), and before the piloting phase of the project started. Therefore, the modelling for the business case was done using the software BoFiT from ProCom. First, all technical components as well as their revenue and cost streams were modelled graphically and translated into a mixed-integer linear program. Considering all restrictions and forecasts, a CPLEX solver calculated the cost-optimal overall schedule using a simplex-based branch-and-bound method.

Simplistically, the topology of the cogeneration plant can be represented as a black box from which a cost stream, a revenue stream, and an electric power stream exit at each time interval. The monetary flows of the CHP system enter directly into the objective function at a higher model level. The electrical power is delivered to the spot market where it is sold at a specified market price. The cost and revenue flows resulting from spot trading transactions also enter into the objective function. In each time interval, an objective function balances results from the difference between the sum of all cost flows and the sum of all revenue flows. The objective function value of the optimization calculation results from the sum of all interval balances in the optimization period.

*Battery Storage System*

The marketing simulation of the battery storage system focused exclusively on calculating the theoretically achievable additional revenues by marketing the electricity on the day-ahead market and in intraday trading. However, in this case the market of comparison will be the primary frequency control market since it is the reference point for flexible battery storage systems.

Table 25 shows the technical parameters of the used battery storage system.

**Table 25: Technical parameters battery**

| Parameter | Value |
|---|---|
| **Nominal Storage Capacity** | 14,5 MWh |
| **Max. Charging Power** | 12,5 MW |
| **Max. Discharging Power** | 12,5 MW |
| **Charging Losses** | 5 % |
| **Discharging Losses** | 5 % |
| **Storage Losses** | 0 % |
| **Max. Depth of Discharge** | 100 % |

| | |
|---|---|
| **Lifetime in Cycles** | 7000 |

*Marketing scenarios*

The scenarios are calculated over a period of two years. The start day of the optimization was January 1, 2017. Based on the start day, a total of 729 daily sequences were calculated. Depending on the marketing scenario, several marketing stages were run through sequentially in a daily sequence. The order of the marketing stages is based on the time sequence of the spot market: first Day Ahead (DA), then Intraday Auction (ID) and finally Intraday Continuous Trading (KH).

**Marketing strategy DA-1h auction**

The reference strategy for the economic optimization of the heat generation schedule includes the time-optimized marketing of electricity in the day-ahead market.

**Marketing strategy ID-15min auction**

Optimizing the heat generation dispatch by marketing the electricity in intraday trading alone in the quarter-hour auction follows the principle of hourly optimization presented earlier. However, due to the higher price volatility in the quarter-hour market, the number of state changes proposed by the optimizer increases significantly compared to the day-ahead scenario.

Because a too frequently starting and stopping of the gas engines would lead to high levels of degradation, the switching capability of the system was constrained by specifying a minimum operating time and a minimum idle time (MBS).

**Sequential optimization DA-1h auction + ID-15min auction**

In sequential dispatch optimization, starting from the day-ahead schedule (DA-1h), additional power trades are executed in the intraday auction to generate additional revenue. In general, however, the additional potential in the quarter-hour market is limited because the thermal storage has little additional heat absorption capacity after day-ahead marketing. Additional power sales are only possible if the system can accommodate the produced heat in storage or deliver it to the heat grid.

**Sequential Optimization DA-1h Auction + ID-15min Auction + ID-KH**

This marketing strategy includes the sequential marketing of electricity in the auction markets as well as in the continuous intraday trading.

For overview, all simulated marketing strategies and their designations are listed in the following list

DA-1h-Auktion
ID-15min-Auktion (MBS 15min)
ID-15min-Auktion (MBS 1h)
DA-1h-Auktion + ID-15min-Auktion (OR)
DA-1h-Auktion + ID-15min-Auktion (MR/MBS-15min)
DA-1h-Auktion + ID-15min-Auktion (MR/MBS-1h)
DA-1h-Auktion + ID-15min-Auktion (OR)+ ID-15min-KH

**Figure 42 Simulated marketing strategies and their designations**

For clarification, the differences between the three versions of "DA-1h-Auktion + ID-15min-Auktion" shall be explained:

In the scenario "DA-1h-Auktion + ID-15min-Auktion (OR)" scenario, electricity is first sold in the hourly auction market. This is followed by an additional sale of electricity in the quarter-hourly market without the possibility of buybacks (OR).

In contrast to this in the "DA-1h-Auktion + ID-15min-Auktion (MR/MBS-15min)" scenario, buybacks are allowed, with a minimum standstill and a minimum operation time of 15min each (MBS-15min).
By calculating the scenario "DA-1h-Auktion + ID-15min auction (MR/MBS-1h)", the aim was to investigate how a prolongation of standstill and operating hours to at least 1h affects the achievable cost savings (MBS-1h).

*Case study results*

*Combined Heat and Power*

The results of the simulations are presented in Table 26 for the scenarios considered.

**Table 26: Additional revenues CHP 2017/2018**

| Vermarktungsvariante | ΔLCOH [€/MWh$_{therm}$] | Δc [€] | ØΔc [€/a] |
|---|---|---|---|
| DA-1h-Auktion | -3,35 | 80.222 | 40.111 |
| ID-15min-Auktion (MBS 15min) | -3,87 | 92.614 | 46.307 |
| ID-15min-Auktion (MBS 1h) | -3,68 | 88.197 | 44.099 |
| DA-1h-Auktion + ID-15min-Auktion (OR) | -3,45 | 82.733 | 41.367 |
| DA-1h-Auktion + ID-15min-Auktion (MR/MBS-15min) | -3,78 | 90.588 | 45.294 |
| DA-1h-Auktion + ID-15min-Auktion (MR/MBS-1h) | -3,55 | 85.061 | 42.531 |
| DA-1h-Auktion + ID-15min-Auktion (OR)+ ID-15min-KH | -3,69 | 88.363 | 44.182 |

Δc are the total additional revenues for the 2-year period and ØΔc are the mean additional revenues per year. The averaged value can be assumed to be representative of the long-term average because gas prices and electricity revenues were very different in 2017 and 2018.

Table 27 shows the percentage savings from participating in the additional markets compared to the reference scenario with hourly-only auction (DA-1h Auction). It is noticeable that the hourly auction already brings about 90% of the additional revenues and the other marketing variants only have a comparatively small effect.

**Table 27: Additional revenues compared to DA-1h auction as reference**

| Vermarktungsvariante | ΔDA-h [%] |
|---|---|
| DA-1h-Auktion | 0 |
| ID-15min-Auktion (MBS 15min) | -13,4 |
| ID-15min-Auktion (MBS 1h) | -9 |
| DA-1h-Auktion + ID-15min-Auktion (OR) | -3 |
| DA-1h-Auktion + ID-15min-Auktion (MR/MBS-15min) | -11 |
| DA-1h-Auktion + ID-15min-Auktion (MR/MBS-1h) | -5 |
| DA-1h-Auktion + ID-15min-Auktion (OR)+ ID-15min-KH | -9,2 |

Basically, it should be noted that in the case of marketing in the intraday auction in 15-minute intervals, the CHPs are started and shut down very often. These start-up processes mean a high level of wear and tear. From this point of view, the additional revenues are to be considered theoretical since the costs for premature wear and tear have not been included in the optimization function. Therefore, before participating in the quarter-hourly market and the intraday market, it should be carefully examined whether the additional burden on the plants can be justified by the possible revenues.

Figure 43 and Figure 44 show the average monthly daily switching cycles for CHP1 and CHP2, respectively, for the period under consideration. A seasonal effect is clearly visible, with pronounced maxima up to 14 switching cycles per day in the ID-15min auction scenario (MBS 15min).

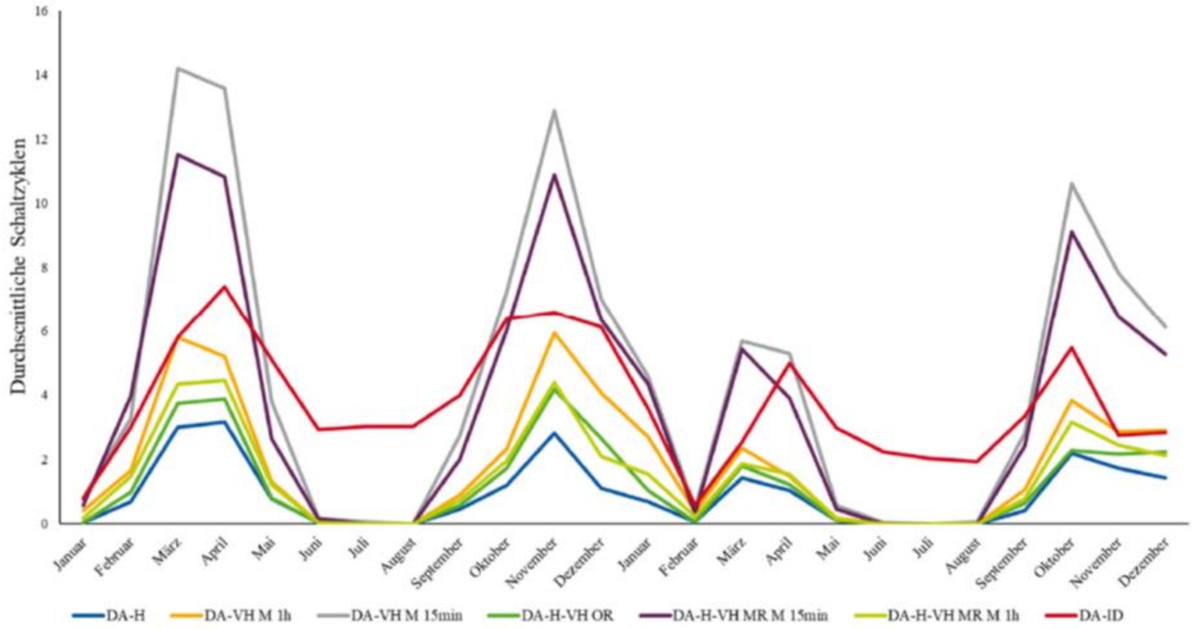


**Figure 43** ***Average switching cycles CHP1***

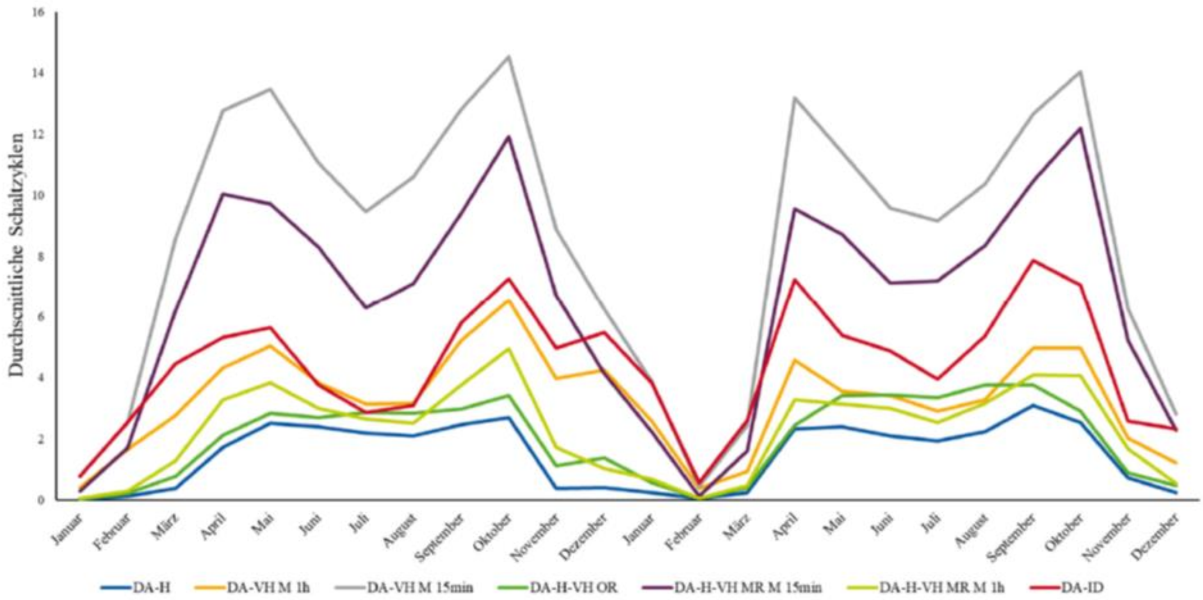


**Figure 44** ***Average switching cycles CHP2***

*Battery Storage System*

Table 28 summarizes the transaction gains ($G_T$) for the different marketing scenarios. Also shown are the daily full load cycles ($Z_{Voll}$), which are of particular importance for the lifetime of the battery. According to the operator, when the batteries are used in primary control, they are stressed at approximately 0.5 full load cycles per day. When the battery participates in the sports markets, the battery is stressed at a much higher rate, resulting in a significantly shortened lifetime. Transaction gains range from €100,000/year to €600,000/year, depending on the scenario. These are all significantly lower than the potential revenues of the battery storage system in the primary control market, in which about 1.5 million €/year could be realized for comparison.

Even with falling prices in the primary control market, it can be expected that it will not be worthwhile for a battery storage system to participate in the sports market in the foreseeable future. The benchmark is and remains the primary control market. Even for a regional flexibility market this must be the benchmark.

**Table 28: Transaction gains battery**

| Vermarktungsvariante | $G_{T,2017}$ [€/a] | $G_{T,2018}$ [€/a] | $Z_{Voll,2017}$ [1/d] | $Z_{Voll,2018}$ [1/d] |
|---|---|---|---|---|
| DA-1h-Auktion (Spread 0 €/MWh) | 117.961 | 132.602 | 2,02 | 1,97 |
| ID-15min-Auktion (Spread 0 €/MWh) | 404.216 | 434.397 | 6,39 | 6,02 |
| ID-15min-Auktion (Spread 5 €/MWh) | 382.048 | 416.616 | 4,24 | 4,21 |
| ID-15min-Auktion (Spread 10 €/MWh) | 337.403 | 374.290 | 2,93 | 3,04 |
| ID-15min-Auktion (Spread 15 €/MWh) | 292.861 | 327.643 | 2,09 | 2,22 |
| DA + ID-Auktion (Spread 0 €/MWh) | 380.380 | 405.012 | 6,14 | 5,77 |
| DA + ID-Auktion (Spread 5 €/MWh) | 357.559 | 384.281 | 4,36 | 4,29 |
| DA + ID-Auktion (Spread 15 €/MWh) | 262.420 | 293.849 | 2,2 | 2,41 |
| DA + ID-Auktion + ID (Spread 0 €/MWh) | 591.758 | 581.182 | 6,29 | 5,76 |
| DA + ID-Auktion + ID (Spread 5 €/MWh) | 542.126 | 533.860 | 5,37 | 4,99 |
| DA + ID-Auktion + ID (Spread 15 €/MWh) | 409.893 | 402.454 | 3,06 | 3,01 |

*Conclusions*

In this analysis, the use of a heat-driven cogeneration plant with thermal storage, as well as the use of battery storage in the spot market was modelled. The values calculated can be treated as a benchmark even for a regional flexibility market as they set the baseline for revenue expectations of a FSP. The optimization approach was an optimization in the hourly market using the sliding window method over 2 days followed by a sequential optimization in the different intraday sub-markets. Data basis were real price series of the years 2017 and 2018.

For the CHP with thermal storage, significant additional revenues amounting to an average of € 20.000 per year and MW can be realized by participating in the day-ahead hourly market. Participation in the intraday auction market as well as in continuous intraday trading can still increase revenues by about 10%, but only at the price of a high switching frequency of the CHP. It is unlikely that the associated degradation of the CHPs will be compensated by the additional revenues.

In the case of batteries, deployment in the spot markets leads to a significant deterioration in revenue compared to participation in the primary control market, with much greater degradation of the battery at the same time. Therefore, deployment of battery storage in the spot market does not make sense for larger units in the foreseeable future. For small units, however, it is the only way to generate marketing revenues, since the minimum size for participation in the primary control energy market is 1 MW. For smaller units, the only option available to achieve this minimum size is pooling with other generation units. However, the prequalification procedure required for this is extremely complex. Only a few flexibility marketers offer this option - and often only for plant sizes from 500kW. Below that, the effort is usually not worthwhile.

In the original project application for FLEXGRID, it was formulated that the FLEXGRID ATP should enable the marketing of flexibilities. This meant originally both: Existing markets at the power exchanges and balancing markets as well as new - today widely non-existent - regional markets. If FLEXGRID ATP were to provide the possibility of marketing on power exchanges, then, according to our analysis, 20.000 € per MW could be achieved per year for a CHP unit. For the battery storage mentioned, it would be 1.5 million € for 12.5 MW nominal power or 120.000 € per MW and year in the primary control market. In contrary for marketing in the spot market only 46.500 € per MW and year.

So that would be the potential contribution of FLEXGRID ATP, if this software provided these marketing possibilities. And at the same time, that would be the benchmark for regional markets. Because an (ESP) will always choose the market that brings the highest revenues for his assets. So, if FLEXGRID were to lead to the creation of regional markets, the revenues that could be generated there would have to be at least as high. Otherwise, no FSPs would participate in these new markets.

### 2.4.3 Value proposition quantification

The conclusions from this business case show that, at least for ESPs managing CHP plants or energy storage systems, the potential revenues from optimizing participation in multiple markets are not straight forward attractive enough to purchase the service. This conclusion considers an experienced energy actor who is already participating in energy market with their assets. In the conclusions of the business case, the maximum value per MW and technology is presented. Given the case that the asset owner is not experienced in the marketing of their assets, e.g., energy communities, there is potential to give value using the FLEXGRID tool.

**Table 29: Value proposition quantification analysis**

<table>
<tr><th></th><th colspan="2">CHP</th><th colspan="2">Battery Storage</th></tr>
<tr><td>Business as Usual</td><td>Revenues from Day Ahead</td><td>20.055 €/MW year</td><td>Revenues from Primary Frequency Response</td><td>120.000 €/MW year</td></tr>
<tr><td rowspan="3">FLEXGRID</td><td>Revenues from Day Ahead</td><td>0 €/year</td><td>Revenues from Day Ahead</td><td rowspan="2">46.500 €/MW year</td></tr>
<tr><td>Revenues from Intraday</td><td>23.150 €/MW year</td><td>Revenues from Intraday</td></tr>
<tr><td>Service - Maximize ESP’s stacked revenues</td><td>--</td><td>Service - Maximize ESP’s stacked revenues</td><td>--</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| | **Increased wear and tear** | -- | **Battery degradation** | -- |
| | **Opportunity Cost** | 3.150 €/MW year | **Opportunity Cost** | -73.500 €/MW year |

As mentioned in the business case, in the case of CHP plant the extra revenue should cover both the additional wear and tear of the plant and the license to use FLEXGRID' service. However, when considering that maintenance costs of CHP are reduced with size[40], but absolute revenue for the plant will increase, there might be a size threshold where the value proposition start to make sense for CHP plants. The following table present the opportunity cost for FLEXGRID's maximize stacked revenue service depending on the size of the CHP plant, scaled from the business case results.

**Table 30: Potential revenue of the FLEXGRID user considering different size of asset**

| CHP | 2 MW | 10 MW | 25MW | 50 MW |
|---|---|---|---|---|
| **Additional revenue from FLEXGRID** | 6.300 €/ year | 31.500 €/year | 78.750 €/year | 157.500 €/year |

However, the increase in maintenance costs is still unknown and could have a significant impact on the value of this service for CHP plants.

On the other hand, for the battery storage unit according to the business case today energy storage maximize revenue and minimize degradation by participating in the FCR market. However, participation of energy storage in balancing markets can be hindered in some countries by regulatory barriers. Furthermore, the IEA stated on its last report regarding energy storage systems[41] that "the business case for storage improves greatly with revenue stacking". Additionally, IEA also highlights how new market products that use the whole potential of battery storage systems can help developers monetize the value of storing electricity. From this perspective, FLEXGRID's developed tool would allow asset owners to participate in multiple markets, even in DLFMs where the business case can be quite profitable, especially for energy storage units. With that said, from the business case analyzed the results show that battery storage assets over 500 kW will maximize their revenues from FCR market participation. However, FLEXGRID' service could have potential for small users seeking to maximize the revenues of their battery storage systems and/or for users not experienced with asset scheduling and market participation. With that said, this change of customer segment means a modification of the business model canvas.

To conclude with the analysis of the specific service, even if in the business case scenarios analyzed there is not enough value to commercialize the FLEXGRID tool, the conclusions extracted from it show that the tool can provide value to different type of assets and energy actors.

If the focus is put in the value proposition of FLEXGRID's ecosystem. Along the different business cases analysis, it has been shown how a) DSOs and TSOs are highly interested in having access to the untapped potential of local flexibility, and b) the value for all market actors of implementing a platform allowing to manage and trade flexibility in an integrated and simple way. As mentioned before the most benefited from the implementation of such ecosystem would be aggregators of end-users, since FLEXGRID would give them a platform to sell their flexibility openly and competitively. Allowing them to maximize the value of it through a competitive market.

[40] US Department of Energy: Combined Heat and Power Technology Fact Sheet Series - Combined Heat and Power Technology Fact Sheets Series: Fuel Cells (energy.gov)

[41] IEA: Energy Storage - Energy Storage – Analysis - IEA

**<u>FLEXGRID H2020 Contributions</u>:** The analysis of the business model *FLEXGRID platform for FlexSuppliers* has provided relevant insights of how FLEXGRID services can help flexibility suppliers maximize the value of their flexibility. The business case where an *ESP optimizes its performance in day-ahead and intra-day energy markets* outcomes give relevant insights on how an ESP should orchestrate its portfolio within multiple markets to maximize its profits. The main results from the study are that for the assets analyzed (**CHP** plant and a **BESS**), the offering from FLEXGRID business is attractive but with a lot of uncertainties. For the CHP, FLEXGRID increased the revenues up to 3.000 €/MW·year but the plant operator was **concerned about the wear and tear** due to the newly optimized schedule. In the case of the **BESS**, results show a **maximum profit in the FCR market** (in Germany). However, the FLEXGRID service would become relevant if BESS were allowed to participate in multiple markets at the same time.

These findings show how traditional assets, and new technology solutions design to play an active role in the power grid. This might not be the best customer segment for FLEXGRID's revenue stacking service. Instead, the offering could be directed towards actors such as Aggregators or Retailers whose flexibility potential comes from assets (residential users, small generation units, etc) and do not have an active role in the power system

## 2.5 Business Model Quantification: Aggregator using the FLEXGRID functionalities to provide increased value to prosumers

### 2.5.1 Business Model

The fourth and final business model is that of a software provider that sells FLEXGRID services to FlexSuppliers, particularly focusing on services for Aggregators and Independent Aggregators. When compared to the one presented in Figure 45, this business case is focusing on those services where the revenue streams are more complex because FLEXGRID aims to implement a shared revenue model. As with the previous business models, this one has also been modified to focus the exploitation strategy towards closer-to-market services and align with the work done in D8.3 chapter 3.

The business model presented is a multi-sided business model, where there is a service exchange, both between prosumers looking to sell flexibility, as well as between FlexBuyers who want to buy FlexServices to support their own operations (e.g., DSOs, TSOs). The customer segmentation is complex, on the one hand the main actor allowing the viability of the business model is the Aggregator. However, due to the implemented shared revenue model, the aggregator is seen as a Channel and a Key Partner to implement the business model. The final customers instead are the FlexAssets owners (Prosumers), and the FlexBuyers, users of the flexibility sold by the aggregator.

Since the service will be integrated within the Aggregator business model, the value propositions are also showing value for it. The value proposition *Increased revenue from a FlexAsset* is directed to the Aggregator and the FlexAssets (if the Aggregator has a shared revenue model with the FlexAssets. Additionally, FLEXGRID is also interested in that value proposition, since in this business model the revenue streams are based on shared revenue models between Aggregator and FLEXGRID. A similar thing happens with the value propositions *Minimize Prosumer discomfort* and *Auction-based valuation of flexibility,* where the interests of all the actors are aligned (up to a certain extent). From the FlexBuyer side, the FLEXGRID value proposition is an easy integration with multiple FlexAssets and Aggregator platforms. This would make available local flexibility for FlexBuyers, whether in a market-based manner or through bilateral agreements with Aggregators.

Finally, the chosen revenue streams for this business model are "Subscription-based". The core idea of this business model is to integrate FLEXGRID services within an Aggregator platform, to offer them to FlexSuppliers (Prosumers) and sell the obtained flexibility to FlexBuyers. To do so FLEXGRID aims to implement a shared revenue model where from the revenues generated by the FLEXGRID services a part of it goes to the Aggregator and the rest to FLEXGRID. This revenue model aims to ease the partnerships with aggregators, by linking the cost of the services to their performance. At the same time, this strategic partnership with Aggregators would allow FLEXGRID to reach FlexAssets and start creating a network of FlexBuyers aware of the FLEXGRID ecosystem.

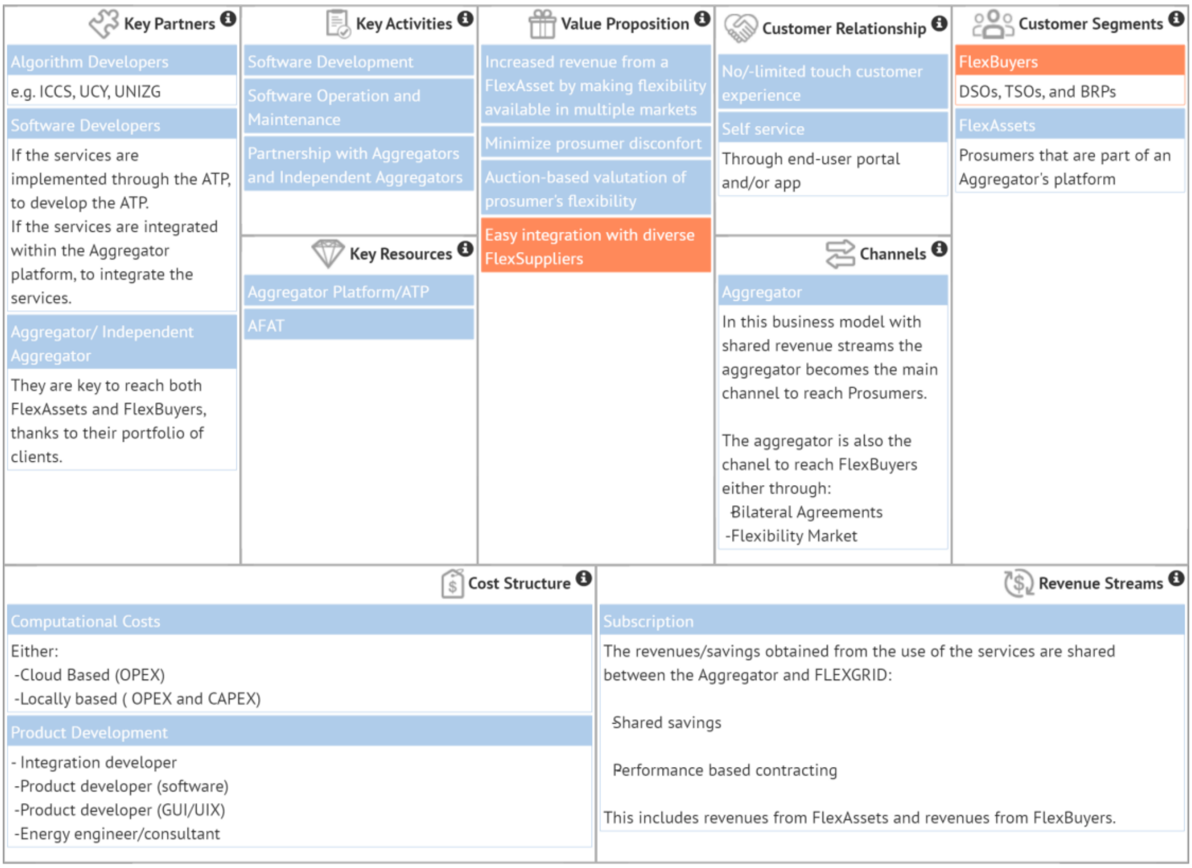


**Figure 45: Business Model Quantification: Aggregator – using the FLEXGRID functionalities to provide increased value to prosumers**

### 2.5.2 Business Cases

*Aggregator optimizes aggregated FlexAsset portfolio to sell flexibility*

*Context*

The number of EV's are increasing rapidly in many European countries, with Norway leading the transition of battery EV's. The "fuel" required is now available in every home or office. This requires investments in charging infrastructure which could be privately owned or installed by a charging point operator (CPO). This business case focus on an CPO selling **charging-as-a-service** to its customers. The CPO operates and maintains the charging points and the costumer gets a charged car. With a large amount of EVs connected to the grid this creates opportunities to participate in the TSOs balancing markets and/ or local flexibility markets.

This business case is similar to C22 mentioned in D8.2: Optimize the operation of Flex Assets considering their participation in different markets. The time horizon in this analysis is one year. It is included some reflections related to the coming years.

*Business case description*

This business case is considering a fictional charging point operator. The charging point operator's main business is to provide charging points and operate them for apartment buildings, businesses,

hotels, and parking lots. The charging power offered is usually 22kW, which provides flexibility to modify when to charge the cars as most cars are parked for multiple hours and do not require immediate charging and peak power for the whole charging session. Many cars are charging at lower power as multiple chargers dynamically share a capacity limit. It could be more than one shared capacity limit within a location. Utilizing flexibility from EV charging sessions is an untapped business opportunity and could provide additional income for the CPO without interfering with their costumers' charging needs.
The business case is reliant on technology enabling 2-way communication between the vehicle and the charging point and/or the industrial control system (ICS). The viability of the business case is highly dependent on the market(s) considered as both the availability of parked EVs and the ability to control the charging is dependent on the market requirements.  However, the requirements for TSO markets, as FCR and aFRR, are under review looking at participation requirements. The trend in Norway's neighboring countries has been to reduce the capacity requirements. To simplify it this business case focus on the available existing markets. Where both capacity and energy activation markets are considered.

*Counterfactual scenario*

The CPO's current business model is not dependent on any FLEXGRID solution. However, without the flexibility trading solutions the CPO will not be able to participate in energy markets and it can be seen as a missed business opportunity, or a lost revenue stream. It might also become a competitive disadvantage with other CPOs entering the TSO and flexibility markets.  Making aggregation of loads possible enables the CPO to operate in local flexibility markets and in TSO markets. This is a new revenue stream for the company and depending on the markets chosen with little or no impact on the service the CPO already offers.

*Case study*

In this case study the flexibility from the CPO is offered to different reserve markets to investigate the feasibility and profitability of participating with flexibility.  The focus has been to investigate the revenue potential of the flexibility and to address some of the costs related to making the flexibility available. The CPO in question operates "charging as a service" meaning that the costumer could expect a minimum additional range after each charging session based on the length of the charging session.

Within the charging as a service concept the CPO promise a certain additional range after each charging session. However, depending on the contract with the car owner the charging obligation may be deviated from e.g., based on the SOC of the EV 10 hours a year against a reduced fee for charging as a service. This allows the CPO to participate with more reserves or reserves of higher quality when participating in the reserve markets.

The analysis is based on the prices in Norway's NO1 price zone. With previous winters prices as reference this analysis investigates the potential earnings from participating in the reserve markets. First the RKOM market was evaluated and then the FFR market was analyzed with the same amount of flexibility.

One assumption is that the CPOs solution support advanced control with two-way communication (ISO15118). This enables V2X and is a necessity for operating in the reserve and flexibility markets. Furthermore, it has potential to exceed this simplified business case e.g., enabling increased consumption and not only reduction of consumption, but this is also not investigated in this case study.

**Table 31: CPO details**

| CPO | |
|---|---|
| **Charger capacity** | 22kW |
| **Shared capacity limit** | 50kW |
| **Locations** | 60 |
| **Total capacity** | 10 MW |
| **Minimum capacity available as flexibility** | 1 MW |

The total capacity of each location presented in Table 31 depends on the number of shared capacity limit chargers at the location. This number will vary and only the total capacity is of interest in this analysis. The minimum capacity available as flexibility is used in the following calculations.

**Regulerkraftopsjonsmarkedet (RKOM)**

RKOM is a capacity market for mFRR in Norway and is both a weekly market and a seasonal market for the winter period. In the weekly market the TSO evaluates and procures reserves based on the needs in each price zone, it can be zero reserves required. This analysis will primarily focus on the seasonal market for the winter period where the flexibility is offered as a reserve. Based on historical needs the TSO predicts the seasons required capacity. Within the RKOM seasonal market there are two markets RKOM-H, where H stands for "high quality" and RKOM-B where B stands for "limited quality". Last winter the reserves in NO1, NO2 and NO5 was procured together. Price and volume are found in Table 32.

**Table 32: RKOM market**

| | **RKOM-B** | **RKOM-H** |
|---|---|---|
| **Time period** | 2021 Week 44 – 2022 week 17 | 2021 Week 44 – 2022 week 17 |
| **Volume** | 809 MW | 140 MW |
| **Price** | 2.4 EUR/MW/h | 10.5 EUR/MW/h |
| **Limit on duration** | Yes, compensation vary with limitation | No |
| **Rest before next activation** | Yes, compensation vary based on hours of rest | No |

The revenues are multiplied by a factor (<1) depending on limitation(s) of the assets. e.g. if a CPO can only accept a limit of duration for 1 hour without charging then compensation is then multiplied by 0.8. One hours is the minimum and there are more steps with higher compensation if the limit of duration is increased. The CPO also must consider rest before next activation which is the possibility of being activated again after immediately. If the CPO find it unlikely or consider rest before next activation to not impact their service, it may accept to be activated many times in a row. E.g., if the CPO accepts not to have any rest before the next activation, then the compensation is multiplied by 1. If the CPO is risk averse it will only accept 8 hours before the next activation, then the compensation is multiplied by 0.8. To sum up, the duration and rest limitations are multiplied to find the total compensation. Meaning that if the CPO only accepts 1 hour without charging and requires 8 hours before the next activation the compensation will be multiplied with 0.64.

$$Compensation\ Factor = V_f \cdot H_f \cdot (MW) \cdot (Price)$$

$V_f$, is the time the asset needs to recover from a flexibility activation. The duration, $H_f$, is the operating time, in hours, the flexibility asset can deliver flexibility when activated. The whole matrix is found in Table 33.

**Table 33: Compensation factor**

| **Duration** | Duration > 4 hours | 4 hours | 3 hours | 2 hours | 1 hour |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| $V_f$ | 1 | 0,98 | 0,95 | 0,9 | 0,8 |
| **Rest period** | No rest period | 1 or 2 hours | 3 or 4 hours | 5 or 6 hours | 7 or 8 hours |
| $H_f$ | 1 | 0,98 | 0,95 | 0,9 | 0,8 |

Depending on the number of customers with clauses related to charging obligation deviation in their contracts the CPO could participate in RKOM-B or RKOM-H. The CPO is required to always have the reserves available if a bid in the market is accepted. This risk is not assessed in this analysis.

**Fast Frequency response (FFR)**

The FFR market is a seasonal summer market in Norway. This allows participants to operate in the RKOM market during the winter and in FFR during the summer, if their assets are qualified. As of today, most assets are not suitable for FFR as the response time required us of less than a second. FFR has two products flex and profile. A CPO with lots of charging points may participate, but the difficulty is to provide the expected amount of reduced power. The market is frequency based and if the measurements are below 49,7 or 49,5 depending on the product the assets participating should activate. This requires special equipment. On the other hand, it is not noticeable to the costumer if an activation occur due to the very short activation time and no customer agreement is needed.

**Table 34: FFR market**

| | FFR flex | FFR profile |
|---|---|---|
| **Description** | One week notice up front from TSO to be prepared to deliver if required. Could be asked to deliver in any of the weeks in the time period. | A weekly profile where reserve is expected to be delivered during the night of weekdays and all Saturday and Sunday. |
| **Time period** | May – October, the TSO select when needed | May – October, delivery throughout the period |
| **Hours** | 400 hours | 1302 hours |
| **Volume** | 109,5 MW | 45,2 MW |
| **Price** | 49,5 €/MW/h | 15 €/MW/h |

In Table 34 the procured volumes and correspond prices from 2022 are presented.

*Case study results*

**RKOM**

The revenues are dependent on which market the CPO wants to participate in. Using the 2021-2022 when RKOM season was procured for 26 weeks and required from 05:00-24:00 in weekdays. The revenues from the seasonal RKOM market are summarized in Table 35.

**Table 35: RKOM season revenues**

| | RKOM-B | RKOM-H |
|---|---|---|
| Revenue (1 MW) | 5.928 € | 25.935 € |

If the asset is activated, it is obliged to participate in the mFRR market. The revenues form mFRR are historically minor compared to the capacity payments and are not include in the revenues here. However, it is an additional income worth investing more in depth. It should be noted that the revenues from RKOM-B in Table 35 is the upper limit as limitation on duration and/or rest before next activation will reduce the payment. With maximum limitation on rest and duration the compensation is reduced to 3.794 €. This is the yearly revenue and with more charging points and costumer the CPO may participate in the ROKM-H with considerably higher payments. 25.935 € per MW is what a bigger CPO can expect from participation in the market with the condition that enough costumer agrees to the contract.

The expenses are mainly personnel if the CPO already have a cloud-based system for operation of the chargers. The mFRR could in theory be operated manually. However, to decrease the cost when scaling up the job is likely to be automated against the market and the CPOs charging points, but this would require development or third-party software. The costs are hard to estimate but it is likely to be higher than the income in the development phase. With an automated system running the system only required to be maintained this is a small expense compared to the potential revenues.

**FFR**

The FFR market would require investments in technical equipment at each location. As the Table 36 shows this is a costly operation. This can only be done at the biggest locations with a relatively high baseload. In addition, batteries to provide additional capacity if deactivating the chargers is not sufficient may be relevant in some locations.

**Table 36: FFR costs**

| Service/ product | Cost |
|---|---|
| Frequency equipment | 2.000-10.000 € |
| Installation frequency equipment | 1.500-2.500 € |
| BESS (100 KW) | 40.000-65.000 € |
| Installation BESS | 1.000-2.000 € |

Table 37 presents the income from the different FFR markets. Once the technical equipment is installed the process is fully automated and would only require supervision to make sure that the activations are working correctly. The income from the market is low compared to Norway's neighboring countries and with more intermittent renewables the market is expected to be even more important implying higher volumes acquired. The FFR is only a summer market allowing the assets to participate in in other reserve markets outside that period or in markets proposed by FLEXGRID.

**Table 37: FFR revenues**

| | FFR Flex | FFR profile |
|---|---|---|
| Revenues (1 MW) | 19.800 € | 19.540 € |

*Conclusions*

As RKOM-H has unlimited rest and duration this is probably an unacceptable risk for the CPO. However, an aggregator with the CPO in its portfolio may see this as an opportunity. With the current price differences in the RKOM-B and RKOM-H this rises the questions if a CPO could have even higher return as a part of an aggregator portfolio.

The FFR market requires a similar response each time it is activated and may therefore be difficult to operate as a single CPO. Especially without battery as a part of the charging infrastructure offered in the different locations. The participation in the FFR may be difficult for a CPO alone, but again a CPO could be a part of a portfolio.

Both the RKOM and FFR cases has a good revenue potential. The profit sharing with costumers may be beneficial or even necessary.

### 2.5.3 Value proposition quantification

The conclusions from this business case show that FLEXGRID services can offer value to aggregators in general, and CPOs more specifically to diversify their revenue streams and have a more profitable business model. In the following paragraphs the results presented above are extended to consider the business model as a service provider for CPOs. Furthermore, different relations between CPOs and end-users are considered to see the impact of the CPO business model on the viability of FLEXGRID as a service provider. In this analysis it has been decided to focus the CPO market participation in RKOM services due to their well stablished nature, and more precise information regarding potential costs and revenues from market participation.

The following is a prospective analysis to understand the potential of FLEXGRID services to penetrate the CPO market with some of its services. The following paragraph presents the framework where the analysis will be developed. First and foremost, it is considered that the CPO has 10 MW of EVs willing to participate in this kind of contract. Using the 22 kW charging power per station this means around 500 clients willing to participate. However, as stated in the business case analysis not all of them will be able to deliver flexibility at the same time, for this reason it has been considered that the CPO participates with bids of 10% of the size of its flexible portfolio.

Finally, in the analysis a shared revenue (through savings) model will be implemented by the CPO to attract more clients to participate in the scheme or subscribe to its services. The shared revenue agreement consists of equally sharing with clients 30% of the fixed capacity payment revenue from market participation (to avoid risk). Any extra revenue made from asset activation will be kept by the CPO. The following table shows potential revenue from asset activation during the years 2020, 2019, and 2018, in the NO1 zone.

**Table 38: Activation revenue from the mFRR market 2018/19/20.**

| Year \ Case | **mFRR** Always activated[1] | **mFRR** 1h-a-day activation[2] |
|---|---|---|
| **2020** | 26.936 €/MW | 2.882 €/MW |
| **2019** | 36.968 €/MW | 7.979 €/MW |
| **2018** | 39.080 €/MW | 7.704 €/MW |

1. In every event throughout the year when Statnett needs flexibility, the asset is activated
2. The activation hour is the first hour of the day that Statnett requires flexibility

As can be seen in the previous table 2020 was the “worst year” for mFRR provision, because it was a year with high amount of rain which made hydro power to increase their availability to provide flexibility, thus lowering market prices. The analysis will proceed using the numbers from 2019, since it shows similar prices to 2018. Nevertheless, FLEXGRID should consider the instability of markets as a potential risk for its business model and try to take risk mitigation strategies for this kind of events.

So, the following tables show the projection of business case, with the following circumstances: best case means that the CPO is activated all the time Statnett needs balancing services, and worst case represents one activation per day.

**Table 39: Value proposition quantification analysis.**

| Market | | RKOM-B Best Case | RKOM-B Worst Case | RKOM-H Best Case | RKOM-H Worst Case |
|---|---|---|---|---|---|
| FLEXGRID | **Revenue:** | | | | |
| | Capacity payment yearly profit | 5.928 €/MW | 3.794 €/MW | 25.935 €/MW | 25.935 €/MW |
| | Utilization payment yearly profit* | 36.968 €/MW | 7.979 €/MW | 36.968 €/MW | 7.979 €/MW |
| | **Costs:** | | | | |
| | Revenue shared with FLEXGRID (x %) | -- | -- | -- | -- |
| | Yearly Revenue shared with clients (30%) | 1.778 €/MW or 3,56 €/client | 1.138 €/MW or 2,28 €/client | 7.780 €/MW or 15,56 €/client | 7.780 €/MW or 15,56 €/client |
| | **CPO revenue (before FLEXGRID)** | 41.118 €/year or 3.426 €/month | 10.636 € or 886,25 €/month | 55.123 €/year or 4.593 €/month | 26.134 €/year or 2178 €/month |

* Estimate. The real value will vary from year to year and depending on the activation hours.

The results obtained in Table 39 can be promising (in some cases) for both CPO and FLEXGRID services; however, the subsequent question is if this gives a competitive advantage to the CPO, will the client be willing to take the risk for a discount on the service that goes from 2,3 € to 15,5€ per year? The fact that according to this initial analysis the potential benefits for the CPO are high, give room to explore the sharing of revenue from the activation payments. The sharing % applied in the new analysis is the same 30% but now it includes both revenue streams. This different model will jeopardize potential FLEXGRID revenues, however if the CPO does not see the service as a gain creator, then zero revenues will be generated by FLEXGRID.

**Table 40: Extended value proposition quantification analysis**

| Market | | RKOM-B Best Case | RKOM-B Worst Case | RKOM-H Best Case | RKOM-H Worst Case |
|---|---|---|---|---|---|
| FLEXGRID | **Revenue:** | | | | |
| | Capacity payment yearly profit | 5.928 €/MW | 3.794 €/MW | 25.935 €/MW | 25.935 €/MW |
| | Utilization payment yearly profit* | 36.968 €/MW | 7.979 €/MW | 36.968 €/MW | 7.979 €/MW |
| | **Costs:** | | | | |
| | Revenue shared with FLEXGRID (x %) | -- | -- | -- | -- |

| | | | | | |
|---|---|---|---|---|---|
| | Yearly Revenue shared with clients (30%) | 12.869 €/MW or 25,73 €/client | 3.532 €/MW or 7.06 €/client | 18.871 €/MW or 37,74 €/client | 10.174 €/MW or 20,35 €/client |
| | **CPO revenue (before FLEXGRID**) | 30.027 €/year or 2.502 €/month | 8241 €/year or 687 €/month | 44.032 €/year or 3.669 €/month | 23.739 €/year or 1.978 €/month |

The results form Table 40 show an improved scenario for CPO clients in most of the cases. However, it is still up to the CPOs to decide if this strategy could become an additional revenue stream. The viability of FLEXGRID' services is significantly reduced in this second scenario, but there is one last element where FLEXGRID can help to make the service more profitable for the CPO and thus for FLEXGRID itself. Up until this point the CPO has participated with 10% of its flexible portfolio to ensure delivery if activated; however, its revenues could increase if it would participate with, for instance 30% of it. This higher risk strategy could be assisted by FLEXGRID's load forecasting engine. In Table 41 the results of a higher market participation can be seen, based on the initial assumptions (or results in Table 39).

**Table 41: Potential revenues with higher market participation.**

| | | **RKOM-B** Best Case | **RKOM-B** Worst Case | **RKOM-H** Best Case | **RKOM-H** Worst Case |
|---|---|---|---|---|---|
| **20%** | **CPO revenue (before FLEXGRID)** | 7.001€/month | 1.867 €/month | 9835 €/month | 5004 €/month |
| **30%** | **CPO revenue (before FLEXGRID)** | 10.576 €/month | 2.848 €/month | 15.077 €/month | 7830 €/month |

So, with higher risk there is a higher reward. However, it has to be considered that it has been assumed clients are paid for their capacity, and therefore their payment hasn't changed. Therefore, part of these extra revenues should probably go to the end users instead of the CPO or FLEXGRID's services.

The results show that the opportunity cost for the CPO of providing ancillary services through its EV charging station portfolio exists. Whether it is big enough for FLEXGRID's services to be viable or not depends significantly on the CPO business model and the pricing set for FLEXGRID services. Furthermore, one of the key elements of FLEXGRID stacked revenue maximization service is its capacity to optimize the bidding in multiple markets. In the case of the Norwegian markets RKOM and FFR this behavior is not possible since the procurement of the service is done through seasonal and weekly tenders, and in most cases the market rules forbid assets to participate in other markets. This situation is not exclusive of the Norwegian balancing market, and it can be a hinderer to the value of FLEXGRID's tools. With that said, these challenges should be addressed in the coming years by regulatory entities. For instance, on the already mentioned public consultation process to create new DR network codes, multiple market participation is a topic that is explicitly mentioned by the EC as one to be addressed (as *value stacking and interaction between markets*).

**<u>FLEXGRID H2020 Contributions</u>:** The analysis shows that an Aggregator using the FLEXGRID functionalities can provide an increased value to prosumers. The business case studied presents a **CPO seeking to optimize its portfolio of EV chargers**. Furthermore, the business case analysis is performed using data from the Norwegian ancillary services markets. The results from the analysis show interesting points about how regulatory frameworks, market structures, and ESPs business models can affect FLEXGRID business model.

The Norwegian regulatory framework limits participation in ancillary services markets can be something limiting opportunity for a CPO to be part of an aggregated portfolio. However, there are different deadlines allowing the CPO to assess which markets is most profitable. If the bid is not accepted, it is possible to participate in another ancillary market depending on your asset's capacity. Additionally, it is possible to compare profits from activation and capacity markets. Only looking at the capacity markets interesting business opportunities have been identified within the RKOM-H market and FFR market with potential revenues for the CPO of up to 60.000 €/MW·year.

## 2.6 Future work

The definition of business models and the study of the most relevant business cases associated to them has allowed FLEXGRID to have a better understanding of the strengths and limitations of the developed services and tools. The fact that industrial partners have led or actively contributed to the analysis process, has given valuable insights on the current business interests of various power system actors. The collected information along the business modelling process is useful to reshape the business models initially defined in D8.2, but also to identify which of the services developed have best market potential and how to bring them from their current TRL to being market ready. The information gathered in Chapter 2 is used in the following chapter to shape FLEXGRID business and exploitation plan.

However, business modelling and business case analysis is an iterative process and there are interesting threads of research starting from the work already developed. In the business model *FLEXGRID platform for flexibility market operation*, future work needs to be done to properly assess the business case for auction based DLFMs. Furthermore, to consolidate the prospective results obtained in this deliverable, it would be interesting to expand the business case analysis to more complex grids, new assets and orderbooks. In the business model *FLEXGRID platform for DSOs (and TSOs)* further research needs to be done on the replicability and business models linked to the Peak Shaving business case, and it would be relevant to explore in further detail the use of distributed flexibility by TSOs (particularly in the Croatian case). Finally, in the business model associated to the Aggregator and CPO, further research needs to be done expanding the pool of assets tested and also studying the replicability and business potential of such services in other countries with different market structures and regulatory frameworks.

# 3 FLEXGRID business and exploitation plan

Complementary and in line with the analysis done in chapter 2, where the economic value of the solutions developed and the viability of the business models are evaluated through the quantitative analysis of business cases, the following chapter links the business cases analyzed and the future exploitation of the FLEXGRID services based on a quantitative analysis, too.

In a first step, both real business cases and services developed in FLEXGRID are aligned to provide a deeper analysis on the exploitation of FLEXGRID's results. Based on the FLEXGRID KERs defined in D8.2 (M18) and the Cost Benefit Analysis (CBA) demonstrated in this report's Annex, it would be straight-forward to link current business cases that stakeholders may use with their business needs to enhance their businesses with new products and services.

Most of FLEXGRID modules have reached TRL 5 and are linked with current possible markets. However, given the fact that FLEXGRID is a low-TRL project, the novelty of the algorithms does not allow all the services and products developed in FLEXGRID to be compatible with current business models and the regulatory/market framework. Regarding the FMCT module, a reactive (DLFM) architecture is assumed because it is compatible with today's EU regulatory framework. This reactive DLFM follows the existing day-ahead energy (MO) and reserve markets (TSO), while it precedes the existing near-real time balancing market (TSO). The FST services are applicable for the (existing) no-DLFM architecture (i.e., there is no DLFM but only the existing markets), which is the current regulatory situation in Europe although FLEXGRID can work and provide its services in a DLFM context, too. The AFAT module maximizes aggregators'/retailers' revenues by optimally responding to FlexRequests and minimizing their associated payments to end users, as well as by proposing personalized FlexContracts (not currently available in the market) and automatically/dynamically creating a FlexOffer.

To align the current work and the future exploitation possibilities of the products developed, a strategy on how FLEXGRID can achieve higher TRLs is also presented in this chapter. It is based on the needs received from stakeholders and the possible developments that FLEXGRID research and industrial partners can accomplish. Of course, the standards and the framework should be aligned with FLEXGRID objectives and novel markets' description.

The specific individual exploitation plans for each partner and all the specific algorithms can be found in D8.2 (M18). To complement the previous work and not have duplicate information, the analysis of this report focuses on the FLEXGRID platform as a whole and how the FLEXGRID products can be further exploited and integrated with current market tools, products, and platforms.

## 3.1 What problem does FLEXGRID address?

The main feature of the ATP is the possibility to integrate and operate flexibility markets considering the needs of different stakeholders coming from different sides of the market such as FlexDemand side (i.e. System Operators), FlexSupply side (i.e. ESPs, aggregators) and market operaters (i.e. FMOs). The types of platform users are ESPs, aggregators, DSOs/TSOs and FMOs. Using the ATP services, these stakeholders will have the opportunity to participate in different flexibility markets in a simple and effective way, moving from BAU cases to new possible business opportunities that are emerging (as described in section 2) and in section 3.2 below). The following table shows how the final business cases analyzed and the FLEXGRID solutions are related.

**Table 42 Business cases related to FLEXGRID Services**

| Business Cases | | Module | FLEXGRID service |
|---|---|---|---|
| 1 | FMO using advanced algorithms to provide congestion management using active power reserves | FMCT | Pay-as-bid & Auction based market clearing |
| 2 | DSO using the FLEXGRID ATP to predict and shave peak power demand | FMCT | Load Forecast & Make a FlexRequest[1] |
| 3 | DSO requests flexibility by a local market to avoid grid enhancement | FMCT | Make a FlexRequest[1] |
| 5 | ESP optimizes its performance in Day-Ahead and Intra-Day energy markets | FST | Stacked Revenue maximization |
| 6 | Long-term economic analysis of TSO using DN-level flexibility through a DLFM | FMCT | NA |
| 7 | Aggregator optimizing aggregated FlexAsset portfolios to sell flexibility to several markets | AFAT | Manage a FlexRequest |
| | | AFAT | Create a FlexOffer |

1. There is no specific UCS for Make a FlexRequest, but in WP5 (specifically D5.3) it is described, and it is included it on the ATP via a new GUI for the DSO.

Looking towards the implementation of the FLEXGRID ecosystem, the following paragraphs aim at linking the analyzed business models and business cases with the business and exploitation plan of the FLEXGRID platform.

In the short term the FMO will be able to use advanced algorithms to provide congestion management services to DSOs by using active power reserves from the FLEXGRID FMCT toolkit. Additionally, the DSO will be able to use FLEXGRID to avoid grid enhancement via FMCT and creating more reliable and optimal flexibility requests. Currently, the implementation of local flexibility markets is at initial stages and as described in 2.3.3 for the specific case of St. Peter, the business case of local flexibility markets or new investment in grid infrastructure, is highly dependent on the needs of the regional grid. By using FLEXGRID tools the DSO can save costs while, in some cases, increase the share of generation and/or demand connected to the gird.

Regarding the business case where the ESP optimizes its performance in day-ahead and intraday energy markets it can be concluded that for batteries, deployment in the spot markets leads to a significant decrease in revenue - compared to participation in the primary reserve market. Therefore, the need of participation in flexibility markets is crucial to have profits for battery storage. Through the (DLFM) proposed by FLEXGRID project, **the ESP will be able to have enough revenues to change their participation from primary reserve to this new market**, as in current primary reserve market the revenue can be 120,000€ per MW and year (based on section 2.4.2 conclusions) and in DLFM market (by using FLEXGRID ATP) it would be a revenue around 278,500 € per year and MW.

The aggregator can achieve new revenue streams by using FLEXGRID AFAT to optimize aggregated FlexAsset portfolios and sell flexibility to several markets. In that context, the technology from which the aggregator provides the flexibility (e.g., type of storage technology, type of curtailable/shiftable loads, type of flexible generation, etc.) is not relevant from the market perspective, but it is the **quantity and the time** in which the flexibility is delivered. With the information regarding the flexibility portfolio and FlexRequests as input from the market, the independent aggregator user will be able to utilize the service to decide if a FlexRequest is accepted. From the perspective of a CPO (as defined on section 2.5.1), being able to act as an aggregator of charging points or using their EV charging points as FlexAsset would guarantee the advantages of selling charging-as-a-service to its end users.

Due to the novel future markets and services defined by the FLEXGRID project, the exploitation of the developed services will not only depend on the current business models/cases but also on the future market possibilities. Based on the analysis performed in D8.2, which have been refined in the Chapter

2 of this deliverable, in the following paragraphs the exploitation analysis of the different modules is presented to better understand how FLEXGRID services can be deployed in the current market framework, and how the FLEXGRID ecosystem can help to shape future markets, by assisting to cope with grid needs and new business opportunities for FlexSuppliers.

## 3.2 Target market of the FLEXGRID solution

In the previous D8.2 (M18), the exploitation plan of the individual components identified as KERs of FLEXGRID was presented, as well as the exploitation plan for the main modules of the ATP. In this section, a detailed exploitation plan for the platform as a whole and for the three main modules (AFAT, FST and FMCT) is defined by characterizing each product in a qualitative and quantitative way considering the main actors involved in the market following:

Market definition and market trends:

- Which is the objective market of interest *(Inputs form D8.2 and D6.2)*
- How the market is evolving *(Inputs form D8.2 and D6.2)*
- Market size for the product.

Potential customers and early adopters:

- Users who are willing to pay for the application *(target user from D8.2)*
- Most promising users that are going to use the application in the near future.

Value proposition per customer:

- Why the customer will use the tool *(Inputs from D8.2-Section 4.2)*
- Value proposition tables (*Inputs from D8.2-Section 4.2)*

Cost Benefit Analysis results:

- Why the tool will be profitable for the user? How much will be the costs for market uptake? Will the respective expected revenues be enough in order for FLEXGRID service to be economically viable? Based on section 2 results, specific CBA template and detailed quantitative figures presented in this report's annex.

Potential competitor:

- Who are the "competitors"? What are their strengths and weaknesses comparing to the application developed in the project? *(Inputs from D8.2)*

Exploitation Strategy:

- Focus on the strategy followed to achieve the maximum impact after the project's lifetime (i.e. how the individual partners can effectively collaborate in order to enhance the FLEXGRID services to a higher TRL).

The reduction of the KERs to the three main modules (i.e., AFAT, FST, FMCT) plus the platform as a whole (i.e. ATP) gives a better overview of the future potential business opportunities. Although the services described in D8.2 are available as stand-alone services (also described in D6.3) defining the exploitation strategy per module, the exploitation of the platform as a whole is expected to be more profitable due to the interactions among the involved stakeholders (cf. "win-win" business contexts).

### 3.2.1 ATP

The ATP is the IT platform through which an energy sector stakeholder can optimally design a market according to its requirements. The ATP is oriented to the different market actors and from an exploitation perspective it brings a huge market to be distributed to. The modular-by-design architecture ensures compatibility of the proposed ATP with current and future applications making it possible to build different business models around each module. As shown in the figure below, the different market actors will have the possibility to manage one or more modules by means of the ATP. For example, the FMO will use the FMCT module to do a market clearing, the DSO would be able to use both FMCT and FST to manage their flexibility requests and the ESP (aggregators, retailers) will be able to use AFAT and FST to achieve optimal solutions for trading their available flexibility in the various markets.

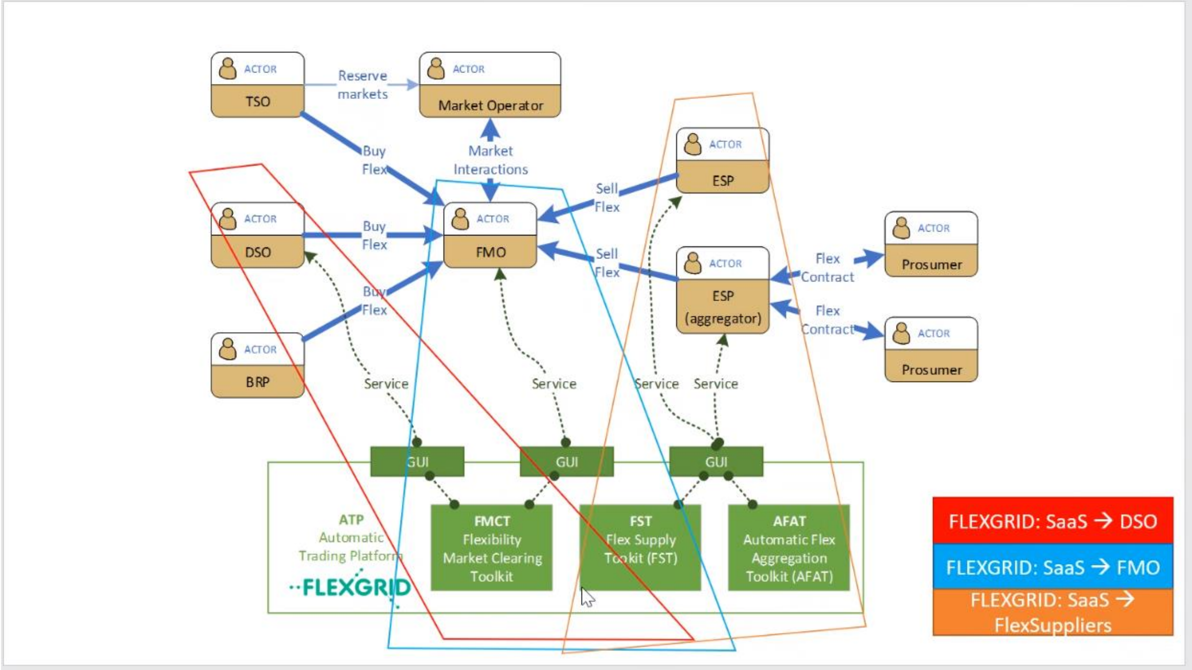


**Figure 46 Interaction between electricity market actors and ATP**

In full market operation, FLEXGRID's ATP should be independent of any participating market party (i.e., ESP, TSO/DSO, aggregator, etc.) or else no market stakeholder or grid owner can be a major owner of FLEXGRID marketplace. So, the customer of the FLEXGRID platform (as a whole) will be a novel market actor as for example the Flexibility Market Operator (FMO) defined on the FLEXGRID context, or traditional MOs expanding their product offering. In addition, B2B partnerships need to exist for various business cases (or else value propositions) to be realized.

In the following table, the main relevant information for the exploitation and business plan related with the ATP can be seen, spanning from the market needs and potential consumers, to the further exploitation strategy and the cost-benefit analysis.

**Table 43: ATP characterization table for exploitation**

| KER name | Automatic Trading Platform (ATP) |
|---|---|
| Module/algorithms | AFAT, FST and FMCT |
| Market definition and market trends | |
| Objective | For the 2 and 3 years after the project ends the main objective markets to integrate the platform will be the ones where ESP, Aggregator and DSO operate. |
| Future | In the long term, the Flexibility Markets will be the main focus for the market actors due to the needs of the grid as a consequence of the increment of RES and new element to manage the grid (EV, BESS…) In that way, most of the algorithms already integrated are well orientated to future markets. Additionally, the flexible architecture of the platform will allow the integration of the different modules in new or current tools, enhancing their characteristics in terms of optimization and control. |
| Size | The market of flexibility trading platforms has been growing up in the past years. New regulations, together with new policies and business opportunities, are causing the growth in offer of flexibility platforms (of different nature). Nowadays, very few flexibility platforms are trying to offer a full ecosystem such as FLEXGRID's, and none of them has done it yet. As of today, the main customer segment for which the ATP as an integrated product is targeted are new market actors, such as FMOs. But if we |

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|---|---|
| | focus on even more realistic market actors that can take advantage of the ATP, it is possible to start the exploitation plan by contacting with several of ESPs or DSO/TSO and offer them the tool trying to reach a **25% of total small DSOs** (550 small DSOs) of the current market share. The integrated tools in the ATP do not require a market-based approach to flexibility (except for the DLFM algorithms) and therefore DSOs and ESPs can highly benefit from the rest of the services even without the implementation of an DLFM. |
| Potential customers | |
| Objective users | FMO (main owner), MO, DSO, TSO ESP/Aggregator. |
| Early Adopters | FMO is the most promising user of the ATP as they have most of their needs covered by the different modules of the ATP. ESP/Aggregator would be also one of the actors with higher potential to benefit from the ATP services due to their potential lack of expertise. DSOs and TSOs can find interesting the ATP and can be a future user but some of the functionalities offered by FLEXGRID are similar to other applications already in the market. |
| Value proposition | |
| Customers gain | The customer will be any market actor such as ESPs, Aggregators, DSOs, TSOs, etc. The main gain for them will be:<br>• A more efficient operation of DLFM thanks to the improved market clearing.<br>• A new way for the different actors to interact between each other. For example, the DSO will be able to publish flexibility request to be covered by other actors, being the first steps for future contracts.<br>• Specific modules to be used for specific needs<br>• Easy integration with current and new platforms thanks to the modular -by-design definition of the ATP. |
| Owner's gain | New market actors, working as flexibility market operators will be the owners of the platform.<br>Additionally, to the revenues from their customers, the FMO will have:<br>• A more efficient market clearing (considering constraints) and increase the market reliance.<br>• A common platform to easy interact with other actor and have the information available in a secure place.<br>• Visibility of the interaction between FlexAssets and the market.<br><br>Finally, the modular design of the ATP allows each customer to take advantage of the specific modules it is interested in, without the need of managing the whole platform. Also, the licensing of code and algorithms is a possibility that will allow customers to integrate the FLEXGRID algorithms and APIs in the backend of their platforms. |
| Cost benefit analysis | |
| The ATP is composed by three main modules making their profitability depending on the final use of each one. The owner of the ATP would have a real profit if the number of users willing to pay for the services increase during the months. The CBA presented on the annex shows the numbers for which the ATP platform starts being profitable for its owner showing that if only one user per services will pay for the application there would be no benefits. At least 2 or 3 user per services should pay the defined license fee for the ATP to be beneficial on its first year. | |
| Potential competitor | |
| FLEXGRID ATP's offering does not have any direct commercial competitor. FMOs such as nodes are developing similar ecosystems around their core product, the local flexibility market. However, differently from FLEXGRID these ecosystems are focused on easing flexibility market participation. Besides that, it is also important to acknowledge the existence of commercial software alternatives to some of the modules integrated on the ATP. However, even if they can be direct competitors, from FLEXGIRD we see the "all-in-one" approach of the ATP a differentiating factor, which helps with the competitivity of FLEXGRID offering. | |

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| On the research side, there are more potential competitors. Platforms with similar strategies have been already developed in projects as WISEGRID, INVADE, CROSSBOW or SOCIALENERGY. These can represent a threat to FLEXGRID's business model. |
| Further exploitation/fundings |
| The exploitation path for the FLEXGRID ATP, in the short term, will focus on the "modular by design" approach to promote and achieve more interested stakeholders through the offering of integrating some of the FLEXGRID algorithms in their current tools, and presenting them new tools/services that can help them reach their business goals. To do so, FLEXGRID is planning to:<br>• Promote DEMO videos and workshops to show potential customers the services that the ATP offers.<br>• Participate in international and national events to increase the potential customers knowing the ATP features.<br>Additionally, to the commercial activities, FLEXGRID's exploitation strategy for the ATP also aims towards further research projects to increase the TRL of the platform, and further shape it to the needs of the market. To do so, FLEXGRID is planning to:<br>• Utilize the FLEXGRID ATP prototype to carry out techno-economic research activities in future projects, and to test the financial feasibility of practical business cases.<br>• Explore the possibility for integrating FlexOffer properties into existing wholesale market product specifications. |

### 3.2.2 AFAT

The Automatic Flexibility Aggregation Toolkit (AFAT) provides the main functionality of managing 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.** The tool deals with the high penetration of RES and the need for an economically sustainable business model for newly emerging actors. By using AFAT, the aggregator user will also be able to understand which is the best option for the flexibility contracts that is provided to a diversified portfolio of end users.

**Table 44 AFAT characterization for exploitation**

| KER name | Automatic Flexibility Aggregation Toolkit (AFAT) |
|---|---|
| Module/algorithms | AFAT consists of 3 service offerings, namely:<br>• AFAT service #1 (Manage a FlexRequest)<br>• AFAT service # 2 (Manage a B2C flexibility market)<br>• AFAT service #3 (Dynamic FlexOffer creation) |
| Market | |
| Objective | Orientated to solve the technical grid challenges caused by high penetration of RES and the need for an economically sustainable business model for newly emerging actors towards providing novel flexibility services to various stakeholders. The managed flexibility can satisfy technical needs concerning **system operation** (TSO/DSO), provide better **balancing opportunities for trading** (BRP) and provide the requirements for **non-dispatchable generation** (RES) to participate in energy markets. |
| Future | New B2C flexibility market proposed within FLEXGRID which can operate in unison with existing electricity markets. Balancing markets operated with real time optimizations |
| Size | The size of the Distributed Flexibility Assets' market is continuously growing. For example, the small-scale solar PVs installation rates are growing as well as the battery storage units that end users install in their own premises. At the same time, the capacity of controllable small-scale loads is also growing while the market share of Electric Vehicles will soon surpass the respective market share of conventional cars. This market trend is expected to continue with a much higher pace in the EU area given the fact that Russo-Ukrainian war is expected to last and the need for Europe's energy autonomy and sovereignty has become more evident than ever before. As a result, EU citizens (backed up and financially subsidized by their states) are expected to invest on new DFAs in order to lower their electricity bills and have a more active role in the energy ecosystem. Large EU utilities/telecom operators are now investing |

| | |
|---|---|
| | large amounts of money for establishing new aggregator companies and the same holds for SMEs/start-ups that want to find their own market share in the B2C flexibility market by offering novel services. This is where FLEXGRID AFAT services come into the play relying on advanced mathematical models and algorithms to offer added value services to aggregator companies. |
| **Potential customers** | |
| Objective users | Aggregators or retailers working as a flexibility aggregator. |
| Early Adopters | Virtual Power Plant by representing a set of DERs in the market, existing aggregator/retail companies that want to apply a more personalized pricing policy to their end users |
| **Value proposition** | |
| Customers gain | Customers as DSO, TSO or BRP would be able to receive more optimized flexibility offers and manage flexibility more efficiently. |
| Owner's gain | Aggregator users can utilize the (AFAT) to make efficient FlexOffer in near-real-time balancing markets and DLFMs, efficiently respond to FlexRequest requiring activation of FlexAssets within their portfolio and efficiently operate and manage a B2C flexibility market. |
| **Cost Benefit Analysis** | |
| After making all the required calculations, the total expected OPEX for AFAT service offering as a whole is 158,800 euros, while the expected work effort is expected to be 25.5 Person Months for one year projection. On the other hand, the expected revenues will be 224,800 euros, which means that the FLEXGRID AFAT's expected profit equals to 66,000 euros or else ~29-30% profit margin. This estimation is quite promising towards bringing FLEXGRID AFAT services at a higher TRL and thus closer to the market uptake after the end of the project's lifetime. The specific CBA per service and as a whole is further explained in the annex of this report. | |
| **Potential competitor** | |
| FLEXGRID consortium has already performed an extensive market analysis (including SWOT) analysis in order to identify the related commercial products/services and research works that are available in both the industrial and academic communities (cf. chapter 1 of previous D8.1 delivered in M6). Moreover, in chapter 2 of previous D3.1 delivered in M12, a detailed survey on B2C automated flexibility aggregation architectures, advanced DFA market solutions are available. Based on these surveys, our competitors are expected to be large utilities/telecom operators, which are now investing large amounts of money for establishing new aggregator companies, while there are several SMEs/start-ups that want to find their own market share in the B2C flexibility market by offering novel services. FLEXGRID has communicated its AFAT-related results with several such companies in the context workshops/special sessions/webinars/DEMO days that have taken place in the context of Task 8.4 work (see more details in chapter 6 below). | |
| **Exploitation strategy** | |
| UCY and ICCS provide the AFAT's backend service. ICCS developed AFAT services 2-3 and UCY developed the AFAT service 1. Collaboration is needed with ETRA, who develops the respective GUI (i.e. AFAT frontend service). Each AFAT's backend service can be offered on a standalone basis or as a bundle of services. This provides the opportunity to the partners to seek for future business opportunities both in an individually as well as collaborative manner. | |

### 3.2.3 FST

FlexSuppliers' Toolkit currently consists of four services primarily focusing on the profit-oriented (ESP). FST is integrated into the ATP FLEXGRID platform with accessibility to an eligible group of users - according to the paid subscription and preferences.

The table below provides the most relevant information for the exploitation and business plan related with the FST, going from the market needs and potential consumers, to the further exploitation strategy and the cost-benefit analysis.

| KER name | Flexibility Supply Toolkit (FST) |
|---|---|
| Module/algorithms | OPEX/CAPEX Minimization, ESP's Stacked Revenue Maximization, Market Price Forecasting |

| Market | |
|---|---|
| Objective | As the FST is an integral part of the ATP FLEXGRID platform, the main objective is firmly connected with ATP's main objective. More specifically, FST's goal is to attract ESPs to use FST services on a regular basis, and, more generally, to promote ATP FLEXGRID platform functionalities among all interested stakeholders. |
| Future | FLEXGRID project, ATP FLEXGRID platform, and FST services have been developed presuming increasing importance of the local-level flexibility markets. Hence, the future should only bring higher utilization of FST services to adequately develop business strategies having in mind both transmission-level and local-level markets. |
| Size | Local-level flexibility markets are still in their infancy stage compared to the potential they exhibit. Hence, there is a firm belief that the size of the market should increase considerably. Potential risk may present liquidity issues depending on the market structure and its characteristics. |
| Potential customers | |
| Objective users | ESP/Aggregator |
| Early Adopters | FST is specifically tailored for flexibility suppliers, hence the most promising users are: ESPs/Aggregators. The range of services that the FST offers provides them valuable tools for optimal business strategy under high-RES penetration, and introduction of novel power market entities such as distribution level flexibility market. |
| Value proposition | |
| Customers gain | FST may accelerate the introduction of novel distribution-level flexibility markets. Moreover, it offers ESPs/Aggregators a tool to create optimal business strategies considering both short- and long-term objectives. |
| Owner's gain | Higher utilization of flexibility services, accelerated introduction of distribution-level markets, reliable energy supply, increased profits |
| Cost Benefit Analysis | |
| The analysis has shown the minimum capacity threshold under which the costs outrun the profits. Generally, we have structured all four services in a commercially viable manner, estimating profits from the first year with a constant increase of number of customers and volume of managed assets. By considering the four services available for FST it would be possible to have a benefit around 77,000€ for the first year of exploitation considering the costs and the possible revenues with the new markets and actors. The information regarding each service and the assumptions made to extract the following conclusion are defined on annexes. It is crucial to understand that for the number used to perform the CBA each service is limited by the assets available, and as explained in annexes each services has a threshold below which it is no profitable to use FST services. | |
| Potential competitor | |
| Platforms that have already been developed in projects such as WISEGRID, INVADE, CROSSBOW, SOCIALENERGY. Similar interfaces and tools for the electricity market actors flexibility optimization. Also, other commercial solutions that are now in their R&D phase. | |
| Exploitation strategy | |
| The FST can be exploitable by means of using each FST's backend service (developed by ICCS and UNIZG) with the GUI developed by ETRA for ESP to improve their benefits in electricity markets. In addition, the FTS can be exploitable in future innovation projects for improving the research already done in forecasting algorithms | |

### 3.2.4 FMCT

The FMCT is the main tool for the FMO user to clear the flexibility market. The FlexOffers are generated via the FSP from the ESP users and FlexRequests come from the DSO user. These bids are sent to the FMCT to clear the DLFM in a network-aware fashion.

The FMO user runs the FMCT to clear the market, while the DSO and ESP users can only view the results of the market clearing, i.e., accepted FlexRequests and FlexOffers.

In Figure 47, the different market actors and their use of the FMCT are illustrated. The DSO user can send FlexRequests, the ESP user can send FlexOffers. The FMO can use the market clearing algorithms (UCS 1.1, 1.2, and 1.3) to achieve social welfare optimal solutions for the DLFM market clearing.

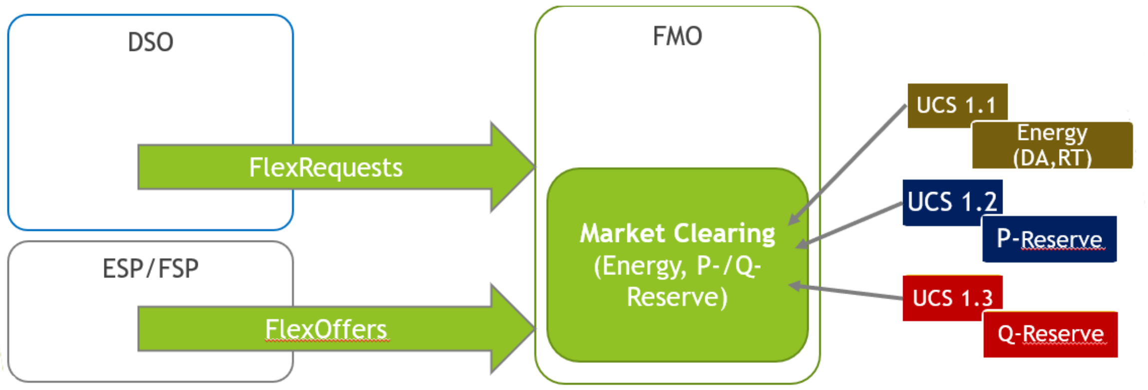


**Figure 47 FMCT for UCS 1.1,1.2,1.3**

Hereafter, the relevant information for the exploitation and business plan related with the FMCT is gathered, going from the market needs and potential consumers, to the further exploitation strategy and the cost-benefit analysis.

**Table 45 FMCT as a KER**

| KER name | Flexibility Market Clearing Toolkit (FMCT) |
|---|---|
| Module/algorithms | Auction based market clearing, Continuous (Pay-as-bid) market clearing |
| Market | |
| Objective | For the 2nd and 3rd year after the project's end, the main objective markets are Market Operator (MO) and specifically Flexibility Market operators (FMOs) to operate a flexibility market in a much more advanced way. |
| Future | Flexibility markets are currently mainly limited due to regulations and the immaturity of market participants, so the FMCT has the potential to be deployed as a tool in those markets after implementation of market-specific adaption allowing in the long term, all Distribution Level Flexibility Markets (DLFMs)to be the new target markets. These DLFMs are currently evolving, and the FLEXGRID algorithms are prepared to be deployed in those future markets. |
| Size | Local flexibility markets have been under development within the electricity ecosystem for the last lustrum, and nowadays more and more actors are showing interest on them. Last July ACER and the EC have started the consultation process to set guidelines on demand response. This document is expected to have a relevant impact on the potential market size of LFMs. Therefore, the uncertainty within the regulatory framework makes it hard to determine market sizes yet; however, the need for local flexibility is increasing and LFMs will be one of the potential solutions to have access to it. |
| Potential customers | |
| Objective users | FMO, DSO, ESP/Aggregator |
| Early Adopters. | The FMO is the most promising user of the FMCT as they have most of their needs covered by the different modules of the FMCT. DSO and ESP/Aggregator users can visualize the results and use the offline mode and case studies to understand the possibilities of clearing the market by the FMCT module on the ATP. |
| Value proposition | |
| Customers gain | FLEXGRID FMCT enables more efficient operation of a DLFM by providing an improved market clearing that considers network constraints in energy and reserve market clearing. This has the potential to increase the social welfare. |
| Owner's gain | More efficient market clearing (considering constrains), increasing the value proposition of the FMO and allowing for higher margins of the FMO. |

| | |
|---|---|
| | Common platform for the different actors that is easy to use and makes it easy to interact with the available information. Data are available in an easy way for the different users. |
| Cost Benefit Analysis | |
| The FMCT is profitable when the revenue of the FMO exceeds the long-run marginal cost of operating and clearing the market. In the case of reactive power market, the “cheapest” solution is to accepts Q-ENS which is not possible physically, but which is market-optimal although it means the revenues from that are coming out to be negative for the DSO. At this stage the cost benefit analysis for FMCT is not as profitable as expected as for the other tools. | |
| Potential competitor | |
| Platforms already developed in projects as WISEGRID, INVADE, CROSSBOW, SOCIALENERGY. Similar interfaces and tools for the electricity market actors flexibility optimization. In FLEXGRID, the flexibility market clearing algorithms additionally consider the network constraints which gives a competitive advantage with respect to existing projects. N-Side application also have similar characteristics and now it is merged with EPEX Spot within the LocalFlex platform. | |
| Exploitation strategy | |
| DTU provides the FMCT's backend service. Collaboration is needed with ETRA, who develops the respective GUI (i.e. FMCT frontend service). As an individual model inside the FLEXGRID platform the FMCT can be exploitable as an independent tool to continue the research on the future of optimal power flow algorithms and also for a commercial purpose including the advance OPF algorithm in other platforms for TSOs/DSOs in order to evaluate line congestions or voltage deviations, and the need for flexibility associated. | |

## 3.3 Go-to-market Plan

Towards launching a new product in an existing market and testing the new product's market for growth related to FLEXGRID developments, it is needed to define a draft strategy plan for the market. In that way, this section introduces the main ideas on how the “go to market” plan should be for a successful exploration of the ATP in the future. In this section, the following things are analyzed: i) what is the “use model” and how the KERs will be put in use (made available to "customers" to generate an impact), ii) what is the time to market and what will be the eventual price so the solution (based on the CBA analysis previous mentioned) will be profitable iii) specific examples of how the different modules of the ATP will be exploited from and industrial partners’ perspective, and iv) the needed developments to run from current TRL 5 to a higher TRL (8 – 9).

### 3.3.1 TRL analysis

None of the FLEXGRID developments are at the range of TRL above 5 as FLEXGRID is a research innovation action (i.e. low-TRL project focusing on advanced mathematical models and algorithms) with demonstration activities for the validation of the products. The purpose of FLEXGRID is to exploit recent theoretical advances to allow the easy and rich interaction between energy sector stakeholders, by proposing innovative and highly competitive Energy Services (ESs) for each one of them and integrate the algorithms in a modular by design platform allowing future integration with existing and new platforms. Regarding the TRL for the pilots the project achieves TRL 6 by using industrial partners’ real-life infrastructure and assets and TRL 4-5 for the most complex algorithms to be tested and validated on lab infrastructure by using real-life datasets.

The figure below briefly shows the current FLEXGRID TRL levels and the need for increasing it in the future.

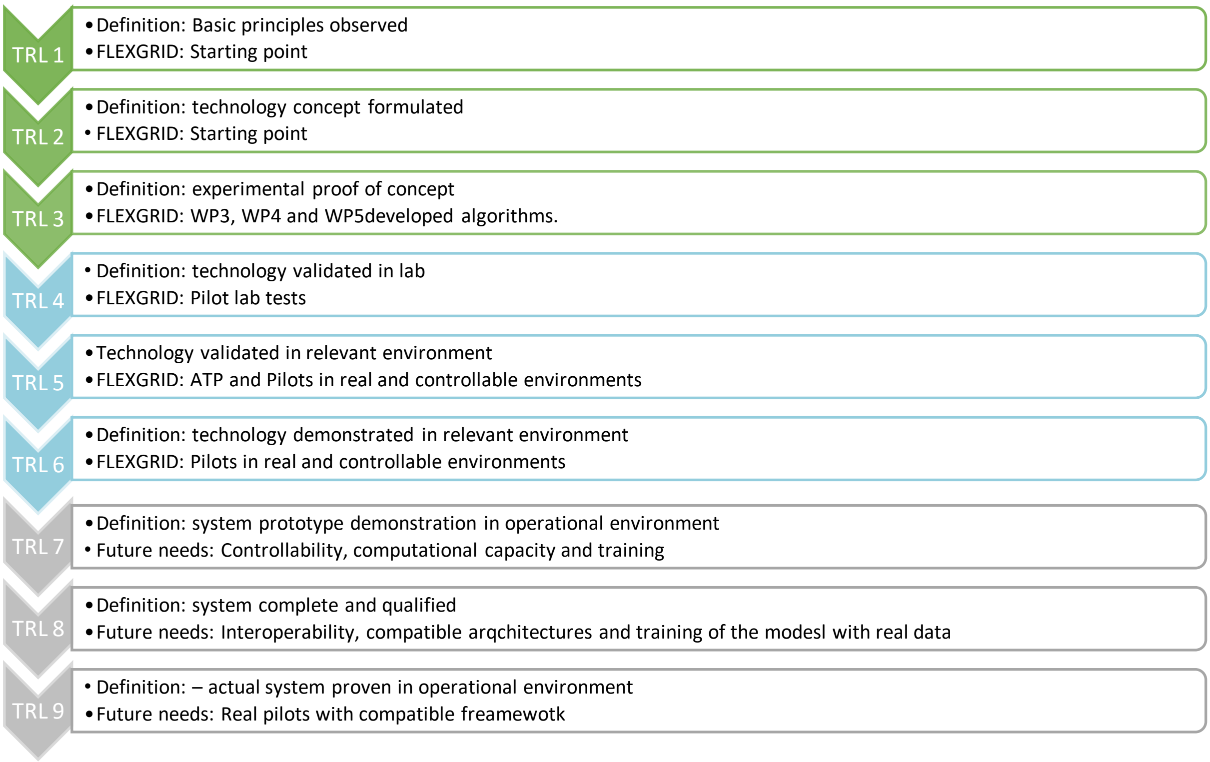


**Figure 48: TRL FLEXGRID current levels and future needs**

Thanks to the modular by design architecture that ensures **compatibility of the proposed ATP platform with the legacy technology** of current energy sector stakeholders (e.g. DSO/TSO SCADA systems) it is possible to future enhance both the algorithms and platform to increase the TRL. By a Go to market strategy for the whole FLEXGRID platform the products (AFAT, FST, FMCT and ATP) can achieve TRL 8-9. Both algorithms (at TRL 3-4) and whole platform (TRL 5-6) should follow different steps to achieve higher TRL. The main developments needed are listed below.

**Algorithms: from experimental proof of concept (TRL 3) to prototype and large-scale pilot tests (TRL 6-7)**

FLEXGRID research partners have produced a large number of research papers that have been published in prestigious scientific journals with high impact factor (see more details in chapter 6 below). These publications have already a lot of views and citations throughout the world and have already begun to have an impact in the international academic sector. A clear plan has already been established in order to enhance this work from proof-of-concept results to more tangible and validated results in the future. The first step has been done by integrating an offline version of FLEXGRID algorithms in the ATP (WP6). By the term "offline", we mean that the input data that are used are based on past (historical) data and thus serve for "what-if" simulation scenario analysis. Within WP7 context, we have utilized real-life data from the two testing sites applying thus FLEXGRID intelligence in real distributed flexibility assets and not just real historical data. As a next step, an "online" version of the algorithms should be integrated in the ATP. By the term "online", we mean that the real datasets produced in real-time will serve as input data for the algorithms to run. This in turn means that additional APIs should be developed in order to directly communicate with the distributed flexibility assets in order to both monitor and control them via the ATP in both real-life and real-time conditions.

**Platform: from validation and demonstration (TRL 5-6) to prototype and market (TRL 7-9)**

This is a list of major actions that need to take place towards bringing FLEXGRID intelligence in higher TRLs:

- Training models are needed in order to deal with decision making problems under uncertainty

- Real datasets that are fed automatically into the FLEXGRID database. That implies having more storage capacity and good data quality to perform the algorithms.
- Optimization of the calculations (reduce time) – Go to real time calculations when possible
- Parallel computing: Being able to parallelize algorithmic processes in an automatic way via the use of cloud computing paradigm. This is expected to be very helpful with handling vast amounts of data and processes.
- **Increase server capacity**: new business models and activities to interact with markets will require more capacity for processing data. In that context the use of central data bases with higher capacity will be essential to increase the TRL of the tools and achieve to process real time data.
- **Interoperability**: moving on the module by design approach, more interoperability aspects should be supported and analyzed with current tools to achieve more integration between tools. For example, FLEXGRID platform should be able to communicate with several types of FlexAssets, legacy systems, communication infrastructures, etc.
- **Controllable assets**: the possibility of controlling and managing the different assets used for the relevant FlexRequest and FlexOffers will be crucial for increasing TRL of the platform.
- **User friendly interfaces:** continues working of the interfaces to achieve easy and intuitive tools will allow not only the TRL to increase but be communicated to a higher number of stakeholders. This would be one of the strategies to follow in order to create a commercial prototype.
- **Standards**: Align the developments with current and future standards and framework should be needed in following stages of development to create a product to be used in the market. For example, which is the exact data format to be adopted for information exchange between different S/W agents and systems, which is the exact communication protocol that should be followed, etc.
- **Data security and GDPR**: All data should be anonymized; the collected data will be kept on a secure server following the EU GDPR standards.

### 3.3.1 Market potential from industrial partners

The following paragraphs provide the industrial consortium partners vision on the FLEXGRID solution and its potential marketability:

**Market Operator – Nord Pool Consulting (NPC)**

From a market operator point of view, it is mainly the FMCT module which is of interest for exploitation purposes. The key is that a market operator needs to act as a neutral counterparty in any potential marketplace transactions to earn trust from market participants. Therefore, it should not engage directly in any bilateral negotiations with end customers and hence, the other modules are of less relevance for a market operator. However, as mentioned previously, NPC acknowledges the importance of the complementarity of the FLEXGRID modules, which work optimally when applied as a common solution and can thus serve the business interests of the MO in an indirect way given the fact that both sides of the market stakeholders' business interests are co-optimized.

Potential target customers are essentially most electricity market operators which seek to expand their business into the flexibility market domain. There have been multiple attempts during the last years to establish such markets in a commercially viable manner. However, only recently the interest has picked up, not only in Europe but also in other parts of the world characterized by an increasing amount of VRE sources connected to the grid.

The exploitation potential can be two-fold. The offered solution can either be commercialized through a SaaS model through charging license fees for the usage of either certain modules or the system as a whole. Alternatively, marketplace operators can engage directly in specific countries or regions and establish themselves as a pioneer offering novel solutions. For NPC, the most likely strategy would be the former, mainly as a result of the lower operational risk involved with a SaaS solution. This would mirror the strategy chosen by NPC's mother company Nord Pool for engaging in new market areas that are both, geographically and strategically included in their core area of business.

**Flexibility Market Operator - NODES**

The FLEXGRID ATP as a trading platform, despite integrating a broad and diverse set of services to various stakeholders, may be too big and hence expensive to be offered as a product for most stakeholders with one core business.

Each module on its own, however, and depending on the stakeholder and its role in the market may offer a valuable possibility to simplify and optimize the daily operational business.

As a flexibility market operator, for NODES the major focus lies on the developed algorithms and the assumptions and preconditions as well as the data requirements of the FMCT. Given the (im)maturity level of flexibility markets and regulatory restrictions in different countries, at this point the diverse approaches of various flexibility market platforms are valuable and are constantly developed. A future perspective may therefore be the combination of two platforms or the combination of specific platform (or tool) features.

**Distribution System Operator - bnNETZE**

bnNETZE sees potential for a software product like FLEXGRID's ATP in the area of flexibility marketing. Excellent concepts and algorithms have been developed within FLEXGRID. A first version for an ATP is also available.

In Germany, however, the mandatory approach of "Redispatch 2.0" is followed by the legislator at all levels of the distribution network. All generators with 100 kW or more must be controllable by the distribution grid operator. For example, to counteract grid congestion or local voltage problems. The operators of these generation plants receive individually calculated financial compensation for the period of curtailment. The calculation logic is complex and regulated in a national set of rules that is binding for all grid operators. Market principles are not applied here. Thus, regional flexibility markets for solving technical problems in the distribution grid are not of high interest for the German market.

However, the currently very high electricity prices make the marketing of flexibilities via the existing power exchanges and the balancing energy market very interesting. Here, additional revenues can be generated for plant operators who have so far operated their plants purely with a view to covering their own needs. This is where we at bnNETZE see the most interesting area of application for the FLEXGRID ATP.

But further development of the ATP developed so far is needed. Automated access to the power exchanges and to the balancing energy market should be created via software module extensions. Furthermore, the good concepts concerning generation, load and price forecasting should be integrated into the ATP. In a next step, this requires significantly expanded personnel capacities in software development. After an estimated development time of three years, a mature product could be ready for commercial marketing. In parallel, energy suppliers and electricity traders from various European countries should be integrated into the project to reflect the specifics of the regional energy markets as well as possible. In addition, this could generate a multiplier effect for product marketing since these companies in turn have their own networks. This could significantly facilitate the market entry of the software without cost-intensive marketing, trade fair or sales activities.

**Transmission System Operator – HOPS**

HOPS is currently facing a rising number of installed renewable sources on both the distribution and transmission networks. Managing and balancing such a small energy system with a large proportion of renewable sources located in a geographically very challenging area is sometimes extremely demanding. For this reason, participation in projects such as FLEXGRID is relevant for HOPS. It is extremely important that HOPS initially connects and achieves better cooperation with the Croatian operator of the distribution system. It is necessary to analyze all the possibilities and advantages of using the platform. However, before introducing any innovations in the balancing capacity and energy market, such as using new algorithms or obtaining new licenses, HOPS must seek special approval from the company board and from the Croatian Regulatory Agency, which could allow them based on detailed analysis.

## 3.4 Further funding

One of the main mechanisms both for researchers and industrial companies to increase the TRL and achieve new products based on precious developments as in FLEXGRID are public fundings. In this context, both national and European programs are the crucial mechanism for achieving this.

More specifically, the new Horizon Europe program gives the opportunity for the consortium of FLEXGRID and new partners to continue the work developed and go beyond research action to go to the next level. The possibilities to continue with the work done in previous projects and integrate new tolls with the ATP developed is possible thanks to the modular-by -design and open science approach. Each toolkit may be customizable and integrable by other platforms so that their potential is used at its fullest potential and that it may be not only a valuable tool for commercial purposes, but also as an excellent starting point for further research and development.

Some examples of finding further fundings will be:

- Transfer the FLEXGRID background knowledge of 'ICTs for the energy sector' to new innovative project ideas such as energy behavior analytics, B2B/B2C flexibility markets, interaction between energy markets and networks' operation, socially aware web platforms for sustainable energy management solutions, etc.
- Use the FLEXGRID project's achievements for contribution to co-shape new market mechanisms in energy market and introduce new flexibility business models successfully into it by including standardization bodies and policy actors.

Additionally, there also exist private capitals that the different partners or the consortium as a whole can try to investigate to further develop the tools already finished at medium TRL. The main problem with the private investment is the risk and for achieving this is essential to present a specific plan for exploitation. The analysis carried out during the whole life of the project and specifically explained on D8.2 and this document makes possible to have the needed material for searching private investment. The cost benefit analysis carried out per KER (see annex for detailed descriptions) and the business model analysis give an overview of the potential not only of the ATP, modules and algorithms developed, but also about the future and novel flexibility markets. In the private context, specifically for FMCT toolkit, it would be to investigate how to apply it to real systems in Denmark, such as in Nordhavn (net-zero carbon emissions region in Copenhagen), on the island of Bornholm, and a number of different regions across the country. Additionally, some industrial partners will take advantage of the knowledge about advanced AC-OPF models and package in novel consulting products.

## 3.5 Strategic partnerships

Different agreements and partners are crucial for further development and possible commercialization of the achievements made on FLEXGRID Project.

We can differentiate the work done on the projects and the strategic partnership needed to evolve the products and the research work will be different depending on the product/achievement. Specific agreements should be needed to protect and further exploit the developments. For FLEXGRID *business partnership* is the most appropriated contract to be performed between multiple partners reaching specific agreements. They are composed of licensing and franchising IP agreements which can contain royalty clauses. The License agreements are contract by which the owner of the IP (licensor) allows a third party (licensee) to exploit certain IP assets License agreements. Specifically, for the research and ICT SW, the developers are the main owners of the products, and it will be their responsibility to define how to share them. Regarding the ATP during the project lifetime internally in the consortium the platform would be use with no restrictions; after the project's end, a licensing of use will be required. Regarding the research work linked with new enhanced algorithms for novel and current markets, the services will be open source available on FLEXGRID GitHub area for all partners to have access as well as any interested target audience. A README file (user guide) is also be available for an interested S/W developer to be able to run the algorithm on its own PC. For further commercial exploitation, when a new customer (aggregator) is interested in this service, then the FLEXGRID exploitation agreement will be followed.

Regarding the research partners (i.e. ICCS, DTU, UNIZG-FER and UCY) who developed the FLEXGRID intelligence and have integrated the software in the FLEXGRID ATP, there is a clear plan in how to collaborate in the future towards further enhancing the FLEXGRID services. First of all, it is important that each individual FLEXGRID service is developed by a single research partner, so that there is neither overhead nor misunderstanding in the intellectual property rights (see more on IPR issues in the chapter 4 below). Furthermore, all the potential research partnerships have been well identified. For example, UNIZG-FER and ICCS can collaboratively work on combining FST service #1 and #3 into a single service. UCY can collaborate with UNIZG-FER and ICCS by providing its AFAT service #4 (market forecasting service) to FST service #1 and #3 respectively. DTU can also collaborate with ICCS and UNIZG-FER towards providing the DTU's network-aware market clearing services (FMCT) for better modelling the distribution network and thus the accuracy of FST service calculations.

**Industrial partners showed a strong interest on the FLEXGRID solution:**

**NPC**

NPC will, in the initial stage, liaise with its mother company Nord Pool to assess the market potential offered by FLEXGRID's services from a market operator's point of view. After this initial assessment, a more thorough analysis will be conducted, potentially involving Nord Pool owners, to elaborate on more concrete initiatives involving potential partners outside the organization. Flexibility is one of several strategic pillars at Nord Pool. There might also be some potential for further collaboration with the FLEXGRID partner NODES. Although not being a shareholder at the company any longer, Nord Pool still has regular contact points with the company on flexibility market related issues.

From a marketplace operator's point of view, it is essential that potential market participants share a common understanding on the way a novel market works. In particular, the price setting methodology needs to be understood (and properly documented) for market participants to trade on the platform. Therefore, deeper engagement, both with prospective sellers and buyers is needed where they need to be educated regarding the clearing logic of the FMCT. A certain amount of transparency is also needed when it comes to the different algorithms proposed for the FMCT. This does not mean, however, that all the inner workings (e.g., the source code) of the algorithms need to be publicly exposed. The challenge in this respect is to be open enough to educate and create trust but at the same time to protect the IPR of the solution. FLEXGRID ATP can facilitate this challenge because it provides both user-friendly GUIs (i.e., frontend services), which are decoupled from FLEXGRID intelligence (i.e. backend services), which may be kept in restricted/closed access. A starting point for an evaluation could also be the public description of the EUPHEMIA algorithm[42] which provides a well-

[42] https://www.nordpoolgroup.com/globalassets/download-center/single-day-ahead-coupling/euphemia-public-description.pdf

enough description for most market participants while not revealing all the "bits and pieces" that make up the algorithm.

What may be needed at some stages are partnerships that secure a certain degree of standardization when it comes to algorithm use. Otherwise, market participants might be reluctant to join new markets, especially if different market clearing logics are implemented in different locations where they are active. Lessons could be learned from the All-NEMO committee, which is a joint body consisting of representatives from different power exchanges like Nord Pool with the aim of finding common solutions for maintenance and further development of the EUPHEMIA algorithm.

**NODES**

Energy and flexibility markets are currently confronted with vast amounts of data and as such data security, storage, and exchange mechanisms. The FLEXGRID approach may thus provide useful functions in combination with data hubs.

**ETRA**

In order to properly address the market in the future with the new ATP, ETRA is willing to establish partnerships with FLEXGRID partners involved in the product and algorithms development, thus ETRA guarantees that new functionalities and communication features are integrated in due form and comply with the high-quality standards that the market is demanding. Additionally, ETRA will add the development on its portfolio and use the experience in other projects (WISEDRID, CROSWOOD or X-FLEX) to integrate new functionalities to save the possible gaps to the current portfolio in terms of new DLFM markets. With this strategy it will be possible to offer the developments in upcoming projects and commercialized by the subsidiary companies of the Group. Also, to the industrial partners of the project interested on enhancing the platform and integrating it in their own application, ETRA is willing to establish specific partnerships to ensure the correct integration.

**bnNETZE**

bnNETZE is part of the largest German energy supplier network THUEGA with 100 companies via the holding badenova AG. There is a central energy trading with all market accesses as well as already with offers for flexibility marketing of third-party plants. As a partner for the further development of FLEXGRID ATP, badenova could provide important impetus and serve as a multiplier in Germany. However, numerous other energy suppliers and traders should be involved to achieve the broadest possible coverage of the energy markets in the EU.

# 4 Intellectual Property Right Management (ETRA)

## 4.1 Intellectual Property (IP) management

The “modular-by-design” strategy of FLEXGRID S/W architecture provided the flexibility to the consortium to achieve an efficient trade-off between the efficacy of the communication activities and the protection of Intellectual Property Rights (IPR). More specifically, the 1st version of the integrated FLEXGRID system prototype (delivered in M24, see Milestone #8) was unanimously agreed to be open source in order to facilitate the maximum possible impact to the targeted audiences and potential customer segments during and after the project’s lifetime. Indeed, the FLEXGRID GitHub area[43] includes comprehensive material (i.e source code, user manual for S/W installation, sample data to be used for FLEXGRID services’ validation, etc.) for each individual FLEXGRID service, so that every interested potential customer or researcher can reuse and experiment with FLEXGRID intelligence. On the other hand, certain S/W sub-modules of the platform (i.e., mainly intelligent research algorithms) are kept in closed/restricted access mode facilitating thus the maximum possible business exploitation in the future. Moreover, large-scale EU H2020 projects, which are closely affiliated with FLEXGRID consortium (i.e., WISEGRID, INVADE, CROSSBOW, X-FLEX) will also use FLEXGRID’s foreground knowledge to enhance the intelligence of their already existing tools. The Consortium and Exploitation Agreement, which was signed at the beginning of the FLEXGRID and was refined during the project’s lifetime explicitly set the limits between FLEXGRID’s background knowledge (both regarding industrial partners’ background and H2020 project tools) and FLEXGRID’s foreground knowledge to be further exploited after the project’s lifetime (see also the table below).

As already explained in chapter 3 above, there are four main FLEXGRID Key Exploitable Results (KERs), namely the: a) Automatic Trading Platform (ATP), b) Automatic Flexibility Aggregation Toolkit (AFAT), c) FlexSuppliers’ Toolkit (FST), and d) (FMCT). ATP includes all FLEXGRID frontend services developed by ETRA.

AFAT services were developed by UCY and ICCS. Each AFAT’s backend service can be offered on a standalone basis or as a bundle of services (together with frontend services or not). This provides the opportunity to UCY, ICCS and ETRA to seek for future business opportunities both in an individual as well as collaborative manner. The same rationale holds for FST services, which were developed by UNIZG-FER and ICCS. Finally, FMCT services were developed by DTU. The basic IPR strategy of all development partners is to have a basic version of the mathematical model and algorithmic solution integrated in the S/W platform and publicly available in the FLEXGRID GitHub area. More advanced versions are kept in closed access to protect the partners’ IPR. These advanced versions have been published in prestigious scientific journals (cf. chapter 6), so that it is straight-forward for a future customer to understand the potential of FLEXGRID’s intelligence. More technical details on how to integrate each FLEXGRID service in the targeted stakeholder’s business as well as an indicative (CBA) are provided in this report’s annex. The table below summarizes the IPR-related information for all FLEXGRID services:

[43] FLEXGRID GitHub repository link: FlexGrid · GitHub

Table 46 FLEXGRID final list of IPR

<table>
<tr><th>Development</th><th>Owner</th><th>Background IPR</th><th>Foreground IPR</th><th>Partnerships</th></tr>
<tr><td>Stacked revenue maximization</td><td>ICCS</td><td>Background knowledge based on SOCIALENERGY project and ICCS/NTUA IPR.</td><td rowspan="3">This service will be open source (FLEXGRID GitHub area) in order for all partners to have access as A README file (user guide) will also be available in order for an interested S/W developer to be able to run the algorithms in its own PC. For further commercial exploitation, when a new customer (aggregator) is interested in this service, then we will follow the FLEXGRID exploitation agreement.</td><td>For this service (UCS 2.3), ICCS will collaborate with ETRA and possibly with UNIZG, if the customer segment (ESP) is also interested in the other 2 FST services (i.e., UCS 2.1 & 2.2).</td></tr>
<tr><td>Manage B2C flexibility market</td><td>ICCS</td><td>Background knowledge based on SOCIALENERGY project and ICCS/NTUA IPR.</td><td rowspan="4">For this service (UCS 4.2), ICCS will collaborate with ETRA and possibly with UCY, if the customer segment (aggregator) is also interested in the other 3 AFAT services (i.e., UCS 4.1, 4.3 & 4.4).</td></tr>
<tr><td>Create a FlexOffer</td><td>ICCS</td><td>Background knowledge based on SOCIALENERGY project and ICCS/NTUA IPR.</td></tr>
<tr><td>Manage a FlexRequest</td><td>UCY</td><td>Background knowledge based on UCY's research and IPR.</td><td rowspan="4">This service will be open source (FLEXGRID GitHub area) in order for all partners to have access as A README file (user guide) will also be available in order for an interested S/W developer to be able to run the algorithms in its own PC. For further commercial exploitation, when a new customer (ESP) is interested in this service, then we will follow the FLEXGRID exploitation agreement.</td></tr>
<tr><td>Market Price Forecasting</td><td>UCY</td><td>Background knowledge based on UCY IPR.</td></tr>
<tr><td>Minimize ESP's OPEX</td><td>UNIZG</td><td>Background knowledge based on UNIZG-FER's research and previous projects.</td><td rowspan="2">For this service (UCS 2.1), UNIZG will collaborate with ETRA and possibly with ICCS, if the customer segment (ESP) is also interested in the other 2 FST services (i.e., UCS 2.2 & 2.3).</td></tr>
<tr><td>Minimize ESP's CAPEX</td><td>UNIZG</td><td>Background knowledge based on UNIZG-FER's research and previous projects.</td></tr>
<tr><td>Market clearing tool (Auction/Continuous)</td><td>DTU</td><td>Background knowledge based on DTU's OPF research and previous projects, FEVER, Euniversal.</td><td>This service will be open source (FLEXGRID GitHub area) in order for all partners to have access as A README file (user guide) will also be available in order for an interested S/W developer to be able to run the algorithms in its own PC. For further commercial exploitation, when a new customer (FMO) is interested in this service, then we will follow the FLEXGRID exploitation agreement.</td><td>For this service (UCS 1.1, 1.2 and 1.3), DTU will collaborate with ETRA if the customer segment (FMO) is interested on use the Market clearing algorithms withing the ATP</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| **Automatic Trading Platform (ATP)** | **ETRA** | Background knowledge based on WISEGRID project. | **Internally** in the consortium the platform would be use with **no restrictions** to prove all algorithms integrate in the ATP. **For further commercial use** the platform should need a **licensing: monthly fee or an exploitation agreement.** For another research works the ATP would be use with exploitation agreement specific for research work. | All partners involved in the algorithms developments and APIs to integrate them on the ATP will be involved and should take the decisions for further exploitation or commercialization of the whole platform (ETRA, ICCS, UCY, DTU and UNIZG). ETRA will lead it as the owner and developer of the ATP software |

## 4.2 Innovation and exploitation committee

The FLEXGRID Innovation and Exploitation Committee (InEC) has been responsible for managing innovation related to the project activities. Its role was to link the technical activities of the project with requirements and developments coming from the targeted business ecosystem, so as to streamline the "technology push" created in the project with current and anticipated "market pull". The InEC interacted closely with the Steering Committee (SC) and the Technical Management Team (TMT) and was responsible to:

i. identify knowledge generated within the project that is suitable for protection as well as to generate and exploit IPR from the knowledge that is generated within the project,
ii. regularly review the state-of-the-art in project-related activities on a global scale, regarding new scientific developments and recently generated IPR and provide input to the TMT,
iii. regularly review new regulatory and legal frameworks in the topics addressed by the project,
iv. review evolving market trends and provide inputs to the SC on market shares, forecasts and analyses,
v. identify opportunities for innovation (new product, service or process) to the SC and TMT by consolidating knowledge generated in the project with market data, partner business plans and regulatory framework,
vi. generate and update the dissemination and exploitation of results' plan, subject to validation from the SC.
vii. Organize exploitation workshops to share and gain interest from businesses.

The InEC consists of one person that had been appointed by each partner during the kick-off plenary meeting (Athens, October 2019) and is chaired by the WP8 leader (SIN). In a nutshell, the main target for InEC members was to bridge the gap between novel low-TRL scientific results (cf. research partners' work of ICCS, DTU, UCY, AIT and UNIZG-FER in WP3-WP5) and the real-life business applicability of FLEXGRID solutions (cf. industrial partners' work of NPC, NODES, HOPS, BNNETZE, BADENOVA, ETRA and SIN in WP6-WP8).

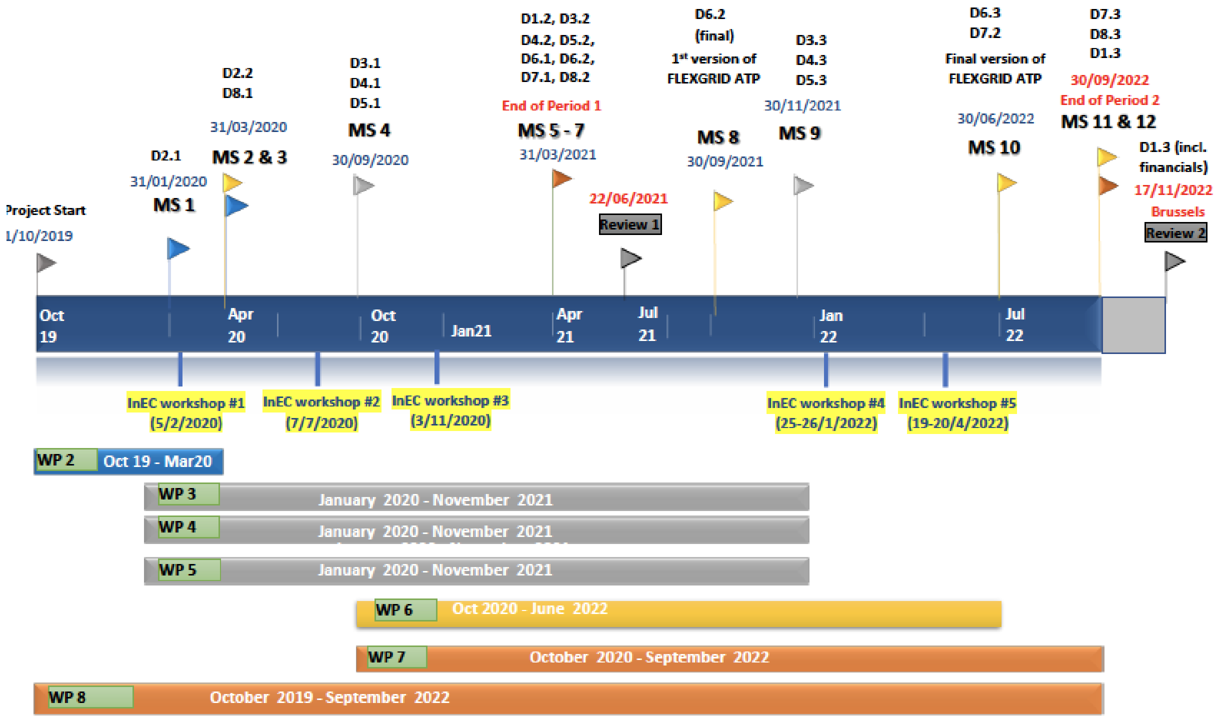


**Figure 49 Timeline of the most important FLEXGRID InEC meetings during the whole project's lifetime**

In the figure above, the timeline of the most important FLEXGRID InEC workshops is depicted (see yellow highlights). The first InEC workshop took place on 5/2/2020 (i.e. right after the delivery of D2.1 and accomplishment of MS1). Its main purpose was to reach a common agreement among all the consortium partners on the project's data management plan (cf. chapter 3 of D8.1), dissemination and communication plan (cf. chapter 4 of D8.1) and exploitation plan (cf. chapter 5 of D8.1). These plans have been slightly updated during the project's lifetime in order to follow up the ongoing progress and unexpected events such as the covid-19 crisis.

The second InEC workshop took place on 7/7/2020 (M10). Its main purpose was to agree on a common research methodology that also fits the respective business requirements of the four high-level use cases (HLUC) and the respective use case scenarios (UCS) that had been defined in WP2. More specifically, research partners presented the state-of-the-artwork (in terms of scientific excellence) and the respective FLEXGRID contribution points. On the other hand, industrial partners reviewed this research material (also documented in D3.1, D4.1 and D5.1) and their role was to guide the WP3-5 research teams towards taking into consideration the existing EU regulatory framework, markets and related innovative products and services.

After the accomplishment of MS4 (i.e., design documents and technical specifications for all FLEXGRID subsystems), the third InEC workshop took place on 3/11/2020 (M14). Its main purpose was to agree on the initial list of project's Key Exploitable Results (KERs) and adapt the somewhat abstract ideas of research work to real business problems. More specifically, the industrial partners presented their business cases, as follows: i) NPC presented their business interest on how the proposed DLFM can be integrated in existing transmission-level electricity markets, ii) NODES presented their business cases on how the proposed network-aware flexibility market clearing algorithms can be applied in local flexibility markets, iii) HOPS presented their business cases on how the distribution-level flexibility can be exploited by a TSO in order to deal with transmission network operation issues, iv) BNNETZE presented their business cases on how a DSO can exploit the distributed flexibility in order to lower its OPEX and postpone its grid reinforcement investments, v) ETRA presented their business interest on providing their S/W platform development expertise towards bringing closer the various smart grid stakeholders. The results of all these discussions were documented in D8.2 (M18).

During Period 2, two major workshops took place. The first one was a 2-day event on 25-26 January 2022 (M28). Its main purpose was for research partners to present the WP 3-5 results (documented in D3.3, D4.3 and D5.3) that fit with the ongoing business modelling work. As a result, industrial partners worked on the quantification of their business cases providing numerical results based on their real-life data and proving the feasibility and economic viability of the proposed FLEXGRID intelligence. The second workshop of this period was held on 19-20 April 2022 (M31). Its main purpose was to define and agree on an exploitation strategy for each individual FLEXGRID service and the platform as a whole. More specifically, for each FLEXGRID service, the responsible (development) partner compared the Business-As-Usual (BAU) solution with FLEXGRID solution and presented a detailed Cost-Benefit Analysis (CBA). The CBA includes the quantitative figures for the cost structure as well as the expected revenue streams. Special emphasis was put on clarifying the business attractiveness of each FLEXGRID service, or else why would it be economically beneficial for a FLEXGRID customer to purchase a FLEXGRID service. Finally, several scenarios have been documented regarding the profit margin of each FLEXGRID service/KER. These results are documented in this report (see annex).

# 5 Impact Analysis and Innovation Management

## 5.1 Impact Analysis of the FLEXGRID project

The FLEXGRID impact analysis methodology was presented in D8.2[44], where the focus was to put emphasis on creating a structure for translating the research work into corresponding project level impact and finally connecting these to the overall societal impact. The methodology will be used in this chapter to conduct a detailed analysis of FLEXGRID's research topics, where each of the research inputs with its KPIs will be mapped to the project KPIs under each work package (WP). The section discusses the KPIs defined as part of the grant agreement (DoA) and explained here for building the context for the reader to understand the various KPIs for the overall project and their relation to the FLEXGRID research threads and finally the impact of the project.

The overreaching KPIs are defined for the overall system and the benefits of flexibility towards a system while ensuring the costs are kept at the optimal levels. These are KPIs that are addressed by multiple research outcomes of the FLEXGRID project.

**Table 47 Overreaching KPIs for FLEXGRID Impact**

| **A. Overreaching KPIs** | |
|---|---|
| KPIs | Description |
| A.1 Increase network capacity at affordable cost | Increase the overall network capacity to handle an increase power flow while keep the costs of investment at optimal levels |
| A.2 Increased system flexibility at affordable cost | Increase system flexibility for all grid-players, while avoiding potential instability and blackouts. |

The specific KPIs are related to the functional objectives of the FLEXGRID research work and helps in defining the Research & Innovation activities and the impact towards the research community working on flexibility related topics. Following are the KPIs discussed in DoA and mentioned here for the readers convenience:

**Table 48 Specific KPIs for FLEXGRID Impact**

| **B. Specific KPIs** | |
|---|---|
| KPIs | Description |
| B.1 Increased RES and DER hosting capacity | Optimal investment to help increase RES and DER penetration in the network |
| B.2 Reduced energy curtailment of RES and DER | Reduce the cost of curtailment for RES and DER operators and owners |
| B.3 Power quality and quality of supply | Increase power quality by actively using flexibility for grid support |
| B.4 Extended asset lifetime | Increase asset lifetime by providing optimal dispatch strategies |

[44] D8.2: Intermediate Business models, dissemination, and exploitation of results

| | |
|---|---|
| B.5 Increased flexibility from energy players | Overall enhance the flexibility portfolio of flexibility providers |
| B.6 Improved competitiveness of the electricity market | Increase the market participation of flexibility actors and enhance flexibility market participation |
| B.7 Increased hosting capacity for EVs and other new loads | Increase grid capacity by scheduling flexibility at certain nodes for better power supply for EV charging and new loads |

There are several FLEXGRID KPIs defined in the DoA that were utilized for the early part of the research work, but the list was also expanded with additional research KPIs that are mentioned in the sections below. The starting list of the FLEXGRID KPIs included: *Renewable content increment, (Distributed) RES/FlexAssets' forecast accuracy, Measurement of the Merit Order Effect (MOE), Voltage deviation, Frequency deviation from nominal value after short-time period, Area control error over longer time period, Variation in power transfers over critical distribution/transmission corridors, Congestion alleviation, RES/FlexAsset dispatchability/flexibility rate, FlexAsset benefit-cost ratio, Balancing cost reduction, ESP's profit increase/optimization, Probabilistic System Adequacy Index (SAI) and Energy cost reduction for end users.* Many of the KPIs were compared with the state of the art in the early deliverables of WP3, WP4 and WP5 by conducting a through literature review. This has resulted in extending the list further and replacing some of the KPIs with the more recent research practices to present the latest outcome of the research results that are both relevant in the research domain but also can be beneficial for future projects and commercial R&D processes. The following sections summarize the research KPIs that were utilized for evaluation of the three main research threads:

- Automated flexibility aggregation
- Innovative Energy Storage Service (ESS) aware Business Models (BMs) for ESPs
- Optimal power flow and interaction between network operators and markets

The goal of the impact analysis work is to present the linkage between the FLEXGRID research KPIs to the specific and overreaching KPIs and the contributions to the overall impact of the project.

### 5.1.1 Automated flexibility aggregation

The FLEXGRID research work related to the Automated flexibility aggregation energy market development and management as a service work package KPI's are summarized in table below.

The FLEXGRID approach described in detail under D3.3[45] compared to the two benchmark cases. For the UCS_4.1, there are 2 benchmark scenarios defined in D3.3 for the comparison. Benchmark 1 where all FlexRequests are known a priori (before the time horizon). Benchmark 2 is a more conservative approach, where the aggregator decides for each Market Time Unit (MTU), thus limited its portfolio to adjustable assets, which can be seen as more conventional sources of flexibility. The portfolio of the aggregator is assumed to consist of 10 end-users, 7 households and 3 small enterprises, where each end-user contributes to the flexibility portfolio with 2-3 shiftable assets and 1-2 adjustable assets as per D3.3.

**Table 49: Deterministic approach for UCS_4.1**

| |
|---|
| An Aggregator efficiently responds to FlexRequests made by TSO/DSO/BRPs by optimally orchestrating its aggregated flexibility portfolio of end energy prosumers. (HLUC04_UCS01) deterministic approach.[46] |

[45] D3.3: Final Version of Distributed Flexibility Asset Markets, P2P Trading Models and Advanced Retail Market Mechanisms

[46] Scheduled operating pattern of Distributed Flexibility Assets (DFAs) is known. Independent aggregator and energy supplier are assumed to be 2 different market actors (i.e. the scheduled operating pattern of the portfolio is determined by the supplier of the FlexAssets and is then submitted to the independent aggregator).

| Classification | FLEXGRID KPI | KPI value | Comments |
|---|---|---|---|
| **Overreaching KPI:** *A.2 Increased system flexibility at affordable cost* **Specific KPIs:** *B.1 Increased RES and DER hosting capacity* *B.5 Increased flexibility from energy players* *B.6 Improved competitiveness of the electricity market* | Profit | **78 - 96%** compared to Benchmark 1 | Although the aggregator cannot increase the number of positive responses, in the proposed approach and in benchmark 1, due to limited available flexibility, the dispatch order is optimized leading to larger profits. |
| | | **6 - 35%** above Benchmark 2 | |
| | Profit (based on relaxed assets) | **56 – 86%** compared to benchmark 1 | Available flexibility of the portfolio is limited mainly due to two reasons. The first one involves the minimum and maximum operation of adjustable assets and the second one the maximum activation for each flexibility asset. To understand the effect of limited flexibility, the maximum activation of assets was relaxed. |
| | | **5 – 18%** above benchmark 2 | |

In the Stochastic approach of UCS_4.1, an economic dispatch problem for an aggregator's portfolio, where energy management decisions are made online and under uncertainty. In the table below are the key KPIs for the stochastic approach of UCS_4.1:

**Table 50: Stochastic Approach for UCS_4.1**

| An aggregator manages its portfolio of many distributed flexibility assets dealing with many sources of uncertainty. (HLUC04_UCS01) Stochastic approach.[47] | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:** *A.2 Increased system flexibility at affordable cost* **Specific KPIs:** *B.1 Increased RES and DER hosting capacity* *B.5 Increased flexibility from energy players* *B.6 Improved competitiveness of the electricity market* | Mean Absolute Error (MAE) | **3.1%** Training set **3.4%** Test set for 2000 dataset size | Aggregator's decisions are made in an online fashion and thus the MAE is reduced. This has a direct impact of aggregator's revenues (or else reduce penalties). The MAE increases with longer time horizons. The MAE is not significantly affected by performing more offline experiments. |
| | Sensitivity to portfolio's deviations (i.e., ratio of actual deviation value to the value used for training datasets) | Somewhat | Not particularly sensitive to non-stationarity of electricity market prices, but sensitive to the one of inflexible demand. |
| | Computational complexity (i.e., tractability) | yes | FLEXGRID solution allows the Neural Network to update the optimal dual variables in an online fashion upon receiving new information about the system's state. |

[47] The difference with the deterministic approach is that the scheduled operating pattern of FlexAssets is not known beforehand and the decision-making process is online under uncertainty. Aggregator and energy supplier are assumed to be 1 single market actor (i.e., the aggregator is also responsible for the imbalances compared to the day-ahead energy schedule).

| | | | |
|---|---|---|---|
| | | | The use of primal variables makes the problem intractable. |
| | Handling of big data | **2000** Dataset size | FLEXGRID solution can achieve a good trade-off between close-to-optimal results while handling huge amounts of data, very complex processes, and several uncertainty factors. |
| | average social cost | **~14%** less social cost | decrease in the aggregator's cost compared to the conservative benchmark (i.e., robust optimization solution that guarantees that all constraints are respected). |

In the UCS_4.2, a novel B2C flexibility market architecture is proposed where such B2C market is operated by an aggregator with various flexibility assets competing to become FlexSuppliers for the flexibility portfolio of the aggregator. Following are the key KPIs discussed in D3.3:

**Table 51: A novel B2C flexibility market UCS_4.2**

| An aggregator operates an ad-hoc B2C flexibility market with its end energy prosumers by employing advanced pricing models and auction-based mechanisms. (HLUC04_UCS02) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br>*B.2 Reduced energy curtailment of RES and DER*<br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness of the electricity market* | Aggregator's revenue | ~20% increase | Increased revenues due to the introduction of the proposed personalized pricing model |
| | Quantity of flexibility offered to the system | **~20-30%** increase | Increased flexibility quantity due to the extra motivation that is given to the highly flexible end users |
| | Algorithmic convergence/scalability | At least **2 orders** of magnitude | The proposed hybrid cloud computing solution can deal with a large number of FlexRequests, large number of FlexAssets with more complex models and more stringent real-time constraints |
| | Truthfulness guarantee | 0% loss of social welfare | FLEXGRID solution protects the B2C flexibility market from "inc-dec gaming" by incentivizing the end users to bid truthfully. |
| | Fairness | All grades of fairness can be applied | Each flexible end user is rewarded based on its personalized contribution and not based on the real-time price |
| | Competitiveness | Fully configurable by the aggregator | Easily adjustable trade-off between profits' maximization and end users' welfare |
| End user participates in a B2C flexibility market operated by an aggregator | | | |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility* | Aggregated end users' welfare (AUW) | **~1-4%** increase | Slight increase of AUW, which is important because flexibility quantity is increased without affecting end users' comfort levels |

| | | | |
|---|---|---|---|
| *at affordable cost*<br>**Specific KPIs:**<br>*B.2 Reduced energy curtailment of RES and DER*<br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness* | Individual end user's welfare | Depends on the degree of end user's flexibility | ~15-20% increase for highly flexible end users, while inflexible end users may experience a ~10-15% decrease |
| | Social welfare | **~15-25%** increase compared to RTP | VCG outcome (i.e., optimal) is achieved for the proposed B2C flexibility market. |
| | Privacy protection | Yes | End users do not have to reveal their utility functions, but just respond to the B2C flexibility market price signals |

In the UCS4.3 presented in detail under D3.2[48], a generic method for constructing aggregated FlexOffers that best represent the aggregator portfolio's actual flexibility costs, while accounting for uncertainty in future timeslots. Following are the important KPIs for the research work:

**Table 52: Aggregator maximize revenues UCS4.3**

| An aggregator maximizes its revenues by dynamically orchestrating its distributed flexibility assets (DFAs) from its end users to optimally participate in near-real-time energy markets. (HLUC04_UCS03) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br>*B.2 Reduced energy curtailment of RES and DER*<br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness* | Aggregator's profits | Guaranteed | The aggregator's profits are always positive. This is not trivial, since if the aggregator does not submit FlexOffers in the balancing market and follows its day-ahead market schedule, it obviously makes zero profit, and if the bidding method performed poorly (e.g., resulted in major imbalances or FlexAsset costs), the aggregator's profit could even be negative. |
| | Aggregator's imbalances | Profits are not affected by the balancing market price after a certain point | This means that the aggregator succeeds in minimizing imbalances, which in turn indicates that the proposed ML method achieves a very good capturing of the aggregator's flexibility cost, i.e., the FlexOffers made by the proposed ML method do not result in dispatch decisions that the aggregator cannot eventually follow. |
| | Accuracy of machine learning algorithms (MAE) | **27-29%** | Relatively high but satisfactory given the fact that the objective is to minimize the aggregator's imbalances. |

[48] D3.2: Intermediate Version of Distributed Flexibility Asset Markets and Advanced Retail Market Mechanisms

### 5.1.2 Innovative ESS aware BMs for ESPs

The research work on the innovative Energy Storage Services (ESSs) aware Business Model (BMs) for ESPs is categorized under the HLUC #2. Where ESP is defined as an actor with participation in various markets and its interaction with DSOs/TSOs and BRPs. The research work focuses on different UCS and assessment of various KPIs for each UCS. FLEXGRID's WP4 contribution includes a PV generation forecasting and Market Price forecasting to ESPs/aggregators. In the D4.3[49] for the UCS4.4, a detail mathematical modelling with various parameters discussed for forecasting services of ESPs/aggregators by aggregating their end-users' PV generation and in addition perform market price forecasting for various electricity markets in Europe. Following are the KPIs for the advanced forecasting services:

**Table 53: Production and Market price forecasting UCS4.4**

| Advanced forecasting services to predict market prices and FlexAssets' state and curves (UCS 4.4) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost:*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.2 Reduced energy curtailment of RES and DER*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness* | Market price forecasting<br>Mean Absolute Error (MAE) - Finnish Market | Negative prices: **13.30 (€/MWh)**<br>High prices: **18.89 (€/MWh)**<br>Normal prices: **10.69 (€/MWh)** | The market price forecasting compared for Finnish market with very volatile and negatives prices affecting the MAE. |
| | Market price forecasting<br>Mean Absolute Error (MAE) - German Market | Negative prices: **18.26 (€/MWh)**<br>High prices: **13.76 (€/MWh)**<br>Normal prices: **7.26 (€/MWh)** | The algorithm cannot forecast negative or peak market prices because they do not occur as often. On the contrary, in the case of normal market prices the algorithm generates much better results. |
| | Solar PV forecasting<br>Mean absolute percentage error (MAPE) | 4.70% | ESPs/aggregators will be able to increase their profits by making informed market decisions and minimizing errors and deviation from the declared position. |
| | Solar PV forecasting<br>Normalized root means square error (nRMSE) | 9% with Data quality routines (DQRs) | |

[49] D4.3: Final Version of Advanced Energy Service Providers' and Renewable Energy Service Providers' Business Models

As part of the research work of FLEXGRID, an ESP is defined as a profit-oriented entity that has commercial contracts with different types of flexibility asset owners. For UCS 2.1, a non-network aware scenario is used, where the location of a flexibility assets (i.e Battery Storage Unit (BSU)) is not considered in research work of D4.3. There are several markets considered for the OPEX minimization of the problem, these markets are DA-EM operated by the MO, DA-DLFM operated by an FMO, IDM operated by a MO and the real-time balancing markets operated by the TSO. The FLEXGRID novel energy market architecture are taken into account for ESPs participation in various markets to minimize their OPEX using the scheduling algorithm in UCS 2.1. These market architectures are i) Reactive and ii) Proactive DLFMs. To analyze the KPIs for the use-case, the following are the assumptions taken from D4.3:

- CAPEX not considered for OPEX optimization UCS 2.1
- One battery storage unit observed
  - 5 MWh,
  - Charging / Discharging power: 5 MW
- Observed markets: intraday (ID), day-ahead (DA), balancing market (BM), x-Distributed Level Flexibility Market (DLFM) architecture
- DA & ID prices: CROPEX
- BM prices according to Croatian regulations
- X-DLFM prices – manually generated
- Daily operation observed

**Table 54: ESP OPEX minimization KPIs for UCS2.1**

| ESP minimizes its OPEX by optimally scheduling the end user consumption, production of RES and storage assets (UCS 2.1) at uncertainty budget of 10 (an average conservative position of an ESP) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.2 Reduced energy curtailment of RES and DER*<br><br>*B.4 Extended asset lifetime*<br><br>*B.5 Increased flexibility from energy players* | ESP's End-profit (€) | NO DLFM: **400 €**<br>R-DLFM: **1200 €**<br>P-DLFM: **1300 €** | In no DLFM case ID, DA and BM are considered. While P-DLFM case exhibits higher profit than R-DLFM case, but R-DLFM easier to integrate into the existing power market structure |
| | Utilization of the flexibility services (MWh) | **NO DLFM:** N/A<br>**R-DLFM:**<br>Flex-up **19 MWh**<br>Flex-down **11 MWh**<br>**P-DLFM:**<br>Flex-up **39 MWh**<br>Flex-down **22 MWh** | P-DLFM incentivizes arbitrage in the highest amount. Market design proposed as part of the FLEXGRID project may increase ESP's profit without higher battery degradation, in fact – the battery degradation may even lower |
| | Computational effort (seconds (s)) | **2.88 s** per day | Machine configuration: Intel(R) Core (TM) i7-10510U CPU @ 1.80 GHz 2.30 GHz, 16 GB RAM Windows 11 |

As part of the research for D4.3, to optimize CAPEX, the ESP needs to conduct optimal investments in RES and FlexAssets, both in terms of siting and sizing. As part of the research work the following considerations are made for the respective KPIs under UCS 2.2:

- Various electricity market segments (DA, IDM, Balancing, DLFM etc.)
- Network topology and constraints or DSO zone approach
- Detailed study of various battery types (their characteristics such as charging/discharging efficiency etc.)
- RES generation forecasts
- Market price forecasts

With a 5% operational expenditure (OPEX) reduction, the optimal siting and sizing algorithm ensures the optimal investment strategy. Following are the respective KPIs for UCS 2.2:

**Table 55: ESPs CAPEX optimization KPIs for UCS 2.2**

| ESP minimizes its CAPEX by co-optimizing distributed renewable energy and storage investment decisions (UCS 2.2 – ESP-DSO-TSO coordination framework) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.2 Reduced energy curtailment of RES and DER*<br><br>*B.4 Extended asset lifetime*<br><br>*B.5 Increased flexibility from energy players* | Optimal trade-off between ESP's, DSO's and TSO's gains | ESPs **15% ROI**<br><br>Vs<br><br>TSOs **4.3% cost reduction** | ESP achieves the anticipated rate of return of its investments (e.g. 15%), while the electricity cost for DN users declines compared to the case without DER investments (e.g. 5.5%). The TSO benefits from the DER investments, since expensive TN-level electricity production is replaced in the generation mix by low-cost RES (e.g. 4.3% cost reduction). |
| | Impact of ESP's minimum profit constraint | Somewhat | The greater the ESP's profit constraint, the less DER investments should take place for all market actors (i.e., ESP, DSO and TSO) to realize gains. |
| | Impact of co-optimizing RES and storage investments | **~5-10%** less investment budget is needed to satisfy the same ESP's minimum profit constraint | Co-optimizing RES and storage investments, the ESP achieves 15% profit by installing 5.5% less RES capacity compared to the case in which the ESP installs only RES capacity. |
| | Impact of bi-level modeling | ESP's profit constraint is respected | The impact of DER investments on energy market price is taken into consideration avoiding thus over-investments that hamper the ESP's role |

| | | | |
|---|---|---|---|
| | Computational efficiency | Algorithm converges after a finite number of iterations | Proposed decomposition method reaches an optimal solution within finite number of iterations |

For UCS 2.3 the FLEXGRID FlexSupplier Toolkit (FST) can be used by the ESP user to place optimal bids in the four different market segments. The ESP can use both the online and offline mode of operation for the stacked revenue maximization algorithm. Both modes of operation are explained in detail as part of the D4.2 research work. Following are the KPIs related to UCS 2.3:

**Table 56: ESPs profit maximization with several markets' participation KPIs for UCS 2.3**

| ESP's profit maximization by co-optimizing its participation in several energy and local flexibility markets (UCS 2.3) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:** *A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:** *B.1 Increased RES and DER hosting capacity*<br><br>*B.2 Reduced energy curtailment of RES and DER*<br><br>*B.4 Extended asset lifetime*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness of the electricity market* | ESP's expected stacked revenues | **~20-25%** more revenues compared to adding individual revenues for providing services to TSO or DSO<br><br>**~50%** more revenues compared to sequential market participation strategy | FLEXGRID solution for ESP's co-optimized market participation achieves super-linear gains for the participation in day-ahead energy, reserve, DLFM and balancing energy markets. |
| | Impact of BSU's **location** | Variable impact | When a BSU is close to a RES plant at the edge of the grid, the ESP tries to maximize its revenues from DLFM. When a BSU is close to the TSO-DSO coupling point, ESP tries to maximize its revenues from day-ahead energy market. |
| | Impact of **competing price offers** | Maximum revenue | When there is much competition in the DLFM, the ESP tries to maximize its revenues from DLFM. |
| | Impact of **BSU's size** | Optimal investment | ESP tries to avoid under- or over- BSU investment scenarios. |

In UCS 2.4 research work shared in D4.3, the ESP considered as a Microgrid Operator (MGO) in an Energy Island (that is a microgrid with weak connection to the main land) or rural energy communities that gradually decides the optimal mix of its RES and flexibility assets' sizing, siting and operation, respects the physical distribution network constraints in high RES penetration contexts, and is able to bid strategically in the existing day-ahead energy market. Following are the KPIs and key results from the WP4 work:

**Table 57: ESP Market and Network aware bidding KPIs for UCS_2.4**

| Market-aware and network-aware bidding policies to optimally manage a virtual FlexAsset's portfolio of an ESP (UCS 2.4) | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.2 Reduced energy curtailment of RES and DER*<br><br>*B.4 Extended asset lifetime*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness of the electricity market* | ESP's expected revenues | **~20%** more revenues compared to the "price-taker" (market-unaware) bidding solution<br><br>Guaranteed revenues compared to the network-unaware solution | ESP is able to anticipate the electricity market's reaction to its decisions. A Stackelberg Game is formulated in which the ESP is the *Leader,* and the electricity market is the *Follower*. |
| | Impact of heterogeneous FlexAssets' **siting** | Significant Impact | The mix of renewable generators, storage units and shiftable loads can have a significant impact on ESP's revenues. |
| | Impact of heterogeneous FlexAssets' **sizing** | Variable Impact | ESP needs to find an optimal mix of renewable generators, storage units and shiftable loads to avoid under- or over-investment scenarios. |
| | Impact of **spatial-temporal arbitrage** | Increase in Revenues | ESP can increase its revenues by exploiting the fact that its FlexAssets reside in multiple distribution networks |

UCS 2.6, proposes storage (capacity and power) to be leased for an agreed period of time. An ESP can create new business cases and adjust its financial portfolio accordingly. Instead of buying energy storage systems, the ESP would have the opportunity to lease exactly the required capacity and power. Large FlexAsset owners could benefit from leasing agreements with several market stakeholders without the need to participate in the electricity markets themselves. The use-case is proposed as a novel approach for minimizing the costs of business operation for an ESP and therefore there are no KPIs evaluated for UCS 2.6.

### 5.1.3 Optimal power flow and interaction between network operators and markets

The research work on OPF and the interaction between network operators and Business Model (BMs) for FMOs is categorized under HLUC #1. The FMO is defined as an actor operating an innovative network-aware local flexibility markets and interacting with FlexBuyers (DSOs) and FlexSuppliers (aggregators, retailers, and prosumers). The research work focused on the development of two market clearing algorithms (continuous and auction-based), which were adapted to each of the three use cases evaluated using specific KPIs. The business-as-usual scenario used considers that there is no DLFM implemented.

The WP5 work focusing on HLUC #1, has three main UCS, where UCS 1.1 focuses on a distribution network aware flexibility market, clearing energy bids. The main objective is for the FMO user to clear a Distributed Level Energy Market (DLEM), with offers from various ESPs. The developed algorithms ensure that the resulting flows are feasible for the network.

The following are the key results of the KPIs analyzed under UCS 1.1 using the continuous clearing algorithm.

**Table 58: Continuous Clearing DLEM DN aware flexibility market KPIs for UCS-1.1**

| Continuous Clearing DN aware flexibility market UCS_1.1 | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br><br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.3 Power quality and quality of supply*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness of the electricity market*<br><br>*B.7 Increased hosting capacity for EVs and other new loads* | Total surplus of participants (Social Welfare) | KPI results depending on the scenario*:<br>- Ref: **0,543 €/h**<br>- midRES: **3,59 €/h**<br>- highRES: **6,72 €/h**<br>- lowLiq: **0,373 €/h**<br>- highLoad: **5,037 €/h**<br>* In the BAU case the social welfare is negative in all the scenarios | The social welfare increases with network aware market clearing. Therefore, the market participants are benefited. |
| | DSO cost reduction | Sufficient liquidity cases - **33% reduction**[1].<br>Low liquidity case – **28% reduction**[1]<br>High load case – **80% reduction**[1].<br>[1.] compared to the BaU scenario | The DSO is able to purchase flexibility ensuring that it won't cause network constraints, and on top of that the cost of the flexibility is reduced. |
| | Energy not served ($E^{ENS}$) | **0 MWh/h**[2]<br>2. Versus - BaU highLoad 0,636 MWh/h | The network aware algorithm is able to clear the market without causing new congestions. Except for the low Liquidity scenario, where there is not enough flexibility available. |
| | Energy curtailed ($E^{Curt}$) | **0 MWh/h**[3]<br>[3.] Versus – BaU Ref 0,059 MWh/h; midRES 0,468 MWh/h; highRES 0,878 MWH/h; lowLiquidity 0,01 | The network aware algorithm is able to clear the market without causing new congestions. |
| | Cost of energy not served | **0 €/h**[4]<br>[4.] Versus - BaU highLoad 127.1€/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |
| | Cost of curtailment | **0 €/h**[5]<br>[5.] Versus – BaU Ref 3,54€/h; midRES 28,08€/h; highRES 52,68€/h; lowLiquidity 0,6€/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |

In the same UCS as above but considering the problem of an FMO that wants to clear a network aware flexibility market through auctions to manage congestions in the distribution network. The following are the KPIs results for the Auction based market clearing UCS_1.1:

**Table 59: Auction based DLEM KPIs for UCS_1.1**

| Auction-based DN aware flexibility market UCS_1.1 | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br><br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.3 Power quality and quality of supply*<br><br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness of the electricity market*<br>*B.7 Increased hosting capacity for EVs and other new loads* | Total surplus of participants (Social Welfare) | KPI results depending on the scenario*:<br>- Ref: **0,875 €/h**<br>- midRES: **5,284 €/h**<br>- highRES: **10,498 €/h**<br>- lowLiq: **0,7 €/h**<br>- highLoad: **8,512 €/h**<br>* In the BaU case the social welfare is negative in all the scenarios | The use of Auction-based market clearing mechanisms improve the social welfare of the market participants, when compared to the BaU scenario but also the Continuous Clearing Market. |
| | DSO cost reduction | Sufficient liquidity cases - **33% reduction**[1] .<br>Low liquidity case – **28% reduction**[1]<br>High load case – **80% reduction**[1]**.**<br>[1.] compared to the BaU scenario. | The use of Auction-based market clearing mechanisms reduce the procurement costs for DSOs, when compared to the BaU. When compared to the Continuous Clearing Market the behavior of both is the same.<br>The optimization algorithm can optimize for different objectives, in this analysis it maximized social welfare. |
| | Energy not served ($E^{ENS}$) | **0 MWh/h**[2]<br>[2.] Versus - BaU highLoad 0,636 MWh/h | The network aware algorithm is able to clear the market without causing new congestions. |
| | Energy curtailed ($E^{Curt}$) | **0 MWh/h**[3]<br>[3.] Versus – BaU Ref 0,059 MWh/h; midRES 0,468 MWh/h; highRES 0,878 MWH/h; lowLiquidity 0,01 | The network aware algorithm is able to clear the market without causing new congestions. |
| | Cost of energy not served | **0 €/h**[4]<br>[4]. Versus - BaU highLoad 127.1€/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |
| | Cost of curtailment | **0 €/h**[5] | The implementation Network aware DLFMs has the potential to reduce |

| | | | |
|---|---|---|---|
| | | 5. Versus – BaU Ref 3,54€/h; midRES 28,08€/h; highRES 52,68 €/h; lowLiquidity 0,6€/h | DSOs operational costs by avoiding new internal congestions. |

For UCS-1.2 and UCS 1.3, the focus is on market-based congestion management and voltage control in distribution networks using output from AC-OPF model calculations. In UCS 1.2, a FMO clears an active power reserve market and in UCS-1.3 a FMO clears a reactive power reserve market. D5.3 explains in detail the model chosen for getting the FlexRequest from the DSOs and the FlexOffers from the ESPs while respecting network constraints. The following tables present the KPIs related to the DLFM for UCS 1.2 and UCS 1.3. First the continuous clearing results are presented:

**Table 60: Continuous clearing DLFM KPIs part of the UCS_1.2 & UCS_1.3**

| Continuous Clearing Algorithm for DLFM UCS_1.2 & UCS_1.3 | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br><br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.3 Power quality and quality of supply*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness of the electricity market*<br><br>*B.7 Increased hosting capacity for EVs and other new loads* | Total surplus of participants (Social Welfare) | KPI results depending on the scenario*:<br>- Ref: **2,10 €/h**<br>- midRES: **5,32 €/h**<br>- highRES: **8,94 €/h**<br>- lowLiq: **1,09 €/h**<br>- highLoad: **7,31 €/h**<br>* In the BaU case the social welfare is negative in all the scenarios | The social welfare in the market increases with network aware market clearing. Therefore, the market participants as a whole are benefited. |
| | DSO cost reduction | Ref: **257,9%** increase<br>midRES: **77,6%** increase<br>highRES: **55,6%** increase<br>lowLiq: **52,3%** increase<br>highLoad: **55,6%** increase<br>compared to the BaU scenario | The DSO is able to purchase flexibility ensuring that it won't cause new network constraints, but in the case of power reserves (P & Q) the cost increases. |
| | Energy not served<br>[$E^{ENS}$ and $Q^{ENS}$] | **0 kW/h ; 0 kVar/h²**<br>2. Versus - BaU Ref 0,02 kW/h and 0,07 kVar/h; midRES 0,01 kW/h and 0,11 kVar/h; highRES 0,01 kW/h and 0,17 kVar/h; highLoad 0,67 kW/h and 0,37 kVar/h. | The network aware algorithm is able to clear the market without causing new congestions. |
| | Energy curtailed ($E^{Curt}$) | Low liquidity case:<br>**0,01 kW/h; 0,23kVar/h³**<br>Rest of the scenarios:<br>**0 kW/h ; 0 kVar/h³**<br>3. Versus – Versus - BaU Ref 0,1 kW/h and 0,25 kVar/h; midRES 0,48 kW/h and 0,31 kVar/h; highRES 0,89 kW/h and 0,51 kVar/h; highLoad 0,03 kW/h and 0,14 kVar/h. | The network aware algorithm is able to clear the market without causing new congestions. Except for the low liquidity scenario, where there is not enough flexibility available to avoid congestions. |

| | | | |
|---|---|---|---|
| | Cost of energy not served | Low liquidity case: **0,16 €/h**[4] Rest of the scenarios: **0 €/h**[4] [4.] Versus - BaU Ref 0,66 €/h; midRES 0,45 €/h; highRES 0,45 €/h; highLoad 27,27 €/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |
| | Cost of curtailment | Low liquidity case: **0,41 €/h**[5] Rest of the scenarios: **0 €/h**[5] [5.] Versus – BaU Ref 4,10€/h; midRES 19,64€/h; highRES 36,49€/h; highLoad 1,03€/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |

Similarly, to UCS 1.1, the UCS 1.2 and UCS 1.3 are also evaluated using a case of an FMO clearing an auction-based network aware market. Following are the KPIs for auction-based clearing for both UCS 1.2 & UCS 1.3:

**Table 61: Auction based DLFM clearing KPIs for UCS 1.2 & UCS 1.3**

| Auction-based Algorithm for DLFM UCS_1.2 & UCS_1.3 | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:** *A.1 Increased network capacity at affordable cost* *A.2 Increased system flexibility at affordable cost* **Specific KPIs:** *B.1 Increased RES and DER hosting capacity* *B.3 Power quality and quality of supply* *B.5 Increased flexibility from energy players* *B.6 Improved competitiveness of* | Total surplus of participants (Social Welfare) | KPI results depending on the scenario*: - Ref: **2,10 €/h** - midRES: **5,32 €/h** - highRES: **8,94 €/h** - lowLiq: **1,09 €/h** - highLoad: **7,31 €/h** * In the BaU case the social welfare is negative in all the scenarios | The use of Auction-based market clearing mechanisms improve the social welfare of the market participants. |
| | DSO cost reduction | Ref: **213,9%** increase midRES: **51,5%** increase highRES: **43,6%** increase lowLiq: **52,3%** increase highLoad: **45%** increase 1. compared to the BaU scenario | The use of Auction-based market clearing mechanisms reduce the procurement costs for DSOs, when compared to both BaU, but also the continuous clearing one. The optimization algorithm can optimize for different objectives, in this analysis it minimizes procurement costs. |

| | | | |
|---|---|---|---|
| *the electricity market*<br>*B.7 Increased hosting capacity for EVs and other new loads* | Energy not served ($E^{ENS}$) | **0 kW/h; 0 kVar/h**[2]<br>2. Versus - BaU Ref 0,02 kW/h and 0,07 kVar/h; midRES 0,01 kW/h and 0,11 kVar/h; highRES 0,01 kW/h and 0,17 kVar/h; highLoad 0,67 kW/h and 0,37 kVar/h. | The network aware algorithm is able to clear the market without causing new congestions. Except for the lowLiquidity scenario, where there is not enough flexibility available. |
| | Energy curtailed ($E^{Curt}$) | Low liquidity case:<br>**0,01 kW/h; 0,23kVar/h**[3]<br>Rest of the scenarios:<br>**0 kW/h; 0 kVar/h**[3]<br>3. Versus – Versus - BaU Ref 0,1 kW/h and 0,25 kVar/h; midRES 0,48 kW/h and 0,31 kVar/h; highRES 0,89 kW/h and 0,51 kVar/h; highLoad 0,03 kW/h and 0,14 kVar/h. | The network aware algorithm is able to clear the market without causing new congestions. Except for the low liquidity scenario, where there is not enough flexibility available to avoid congestions. |
| | Cost of energy not served | Low liquidity case:<br>**0,16 €/h**[5]<br>Rest of the scenarios:<br>**0 €/h**[4]<br>2. Versus - BaU Ref 0,66 €/h; midRES 0,45 €/h; highRES 0,45 €/h; highLoad 27,27 €/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |
| | Cost of curtailment | Low liquidity case:<br>**0,41 €/h**[5]<br>Rest of the scenarios:<br>**0 €/h**[5]<br>5. Versus – BaU Ref 4,10€/h; midRES 19,64€/h; highRES 36,49€/h; highLoad 1,03€/h | The implementation Network aware DLFMs has the potential to reduce DSOs operational costs by avoiding new internal congestions. |

There is no use case attached to the FlexRequest research work under WP5. However, the creation of a FlexRequest is a prerequisite for a functioning DLFM market and therefore it is an important research outcome of the FLEXGRID project. The results of the case study discussed using the various scenarios Basic (10% DSM flexibility), Slow (7.5% DSM flexibility), Medium (15% DSM flexibility) and Fast (30% DSM flexibility) explained in more detail with assumptions in D5.3. In the following table there are the key KPIs for the research presented in D5.3:

**Table 62: Investment and Operation results with VOLL 1500 €/MWh and 3000 €/MWh**

| Classification | FLEXGRID KPI | KPI value | Comments |
|---|---|---|---|
| Investment & Operation Results assuming Value of Lost Load (VOLL) – **1500 €/MWh** | | | |
| **Overreaching KPI:** | Loss of Load<br>(MWh) | Basic: **514.61 MWh** and Invest in **#1-line** segment<br>FLEXGRID: **449.96 MWh** | The results show that compared to the different scenarios of investment in the |

<table>
<tr><td rowspan="2">A.1 Increased network capacity at affordable cost<br><br>A.2 Increased system flexibility at affordable cost<br><br>Specific KPIs:<br>B.1 Increased RES and DER hosting capacity<br><br>B.3 Power quality and quality of supply<br><br>B.5 Increased flexibility from energy players<br>B.6 Improved competitiveness of the electricity market<br>B.7 Increased hosting capacity for EVs and other new loads</td><td>And Investment in no. of lines (#)</td><td>Slow: 373.87 MWh and Invest in #2-line segments<br>FLEXGRID: 184.52 MWh<br>Medium: 0 MWh* and invest in #4-line segments<br>FLEXGRID: 0 MWh*<br>*All demand met<br>Fast: 213.29 MWh and Invest in #3-line segments<br>FLEXGRID: 0 MWh*<br>*All demand met</td><td>grid and VOLL, the FLEXGRID approach of creation of a Flexrequest results in significant decrease in the VOLL and hence the overall system costs for the network operator can be lower by enabling DSM participation</td></tr>
<tr><td>Net benefit (BAU-FLEXGRID) in €</td><td>Basic: 92,332 €<br>Slow: 540,948 €<br>Medium: 9,748 €<br>Fast: 323, 510 €</td><td>It is evident that use of FLEXGRID DSM flexibility with lower investments in line segments results in more overall benefit for the network operator</td></tr>
<tr><td colspan="4">Investment & Operation Results assuming Value of Lost Load (VOLL) – 3000 €/MWh</td></tr>
<tr><td>Overreaching KPI:<br>A.1 Increased network capacity at affordable cost<br><br>A.2 Increased system flexibility at affordable cost<br><br>Specific KPIs:<br>B.1 Increased RES and DER hosting capacity</td><td>Loss of Load<br>(MWh)<br>And Investment in no. of lines (#)</td><td>Basic: 68.99 MWh and Invest in #2-line segment<br>FLEXGRID: 454.56 MWh<br>Slow: 0 MWh and Invest in #3-line segments<br>FLEXGRID: 185.69 MWh<br>Medium: 0 MWh* and invest in #4-line segments<br>FLEXGRID: 0 MWh*<br>*All demand met<br>Fast: 0 MWh* and invest in #5-line segments<br>FLEXGRID: 0 MWh*<br>*All demand met</td><td>The results show that for higher VOLL (3000 €/MWh), DSM services are less significant in comparison to BAU approach. System operator intents to increase network capacity more than higher incentivize DSM providers, besides DSM services also covers all load in the system</td></tr>
</table>

| | | | |
|---|---|---|---|
| *B.3 Power quality and quality of supply*<br><br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness of the electricity market*<br>*B.7 Increased hosting capacity for EVs and other new loads* | Net benefit (BAU-FLEXGRID) in € | Basic: **-1,157,228 €**<br>Slow: **-553,505 €**<br>Medium: **+9,748 €**<br>Fast: **+15,934 €** | In case of BAU approach covers more investment in lines the DSM flexibility is less attractive even with higher VOLL. |

The FLEXGRID research work on the DLFM architectures is analyzed by comparing the different x-DLFMs architectures: (i) Reactive (R-DLFM), ii) Proactive (P-DLFM), and iii) Interactive (I-DLFM) against the no-DFLM case, where there is no market for procuring flexibility at the DN level, and constraints of local DN are not considered for market clearing. There is no particular UCS attached to this work presented in detail under D5.3. The following are the relevant KPIs for the comparison of x-DLFM architectures:

**Table 63 x-DLFM architecture comparison KPIs**

| Classification | FLEXGRID KPI | KPI value | Comments |
|---|---|---|---|
| x-DLFM comparison cases at VOLL 1000 €/MWh and Curtailment cost 133 €/MWh | | | |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br><br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br>*B.5 Increased flexibility from energy players*<br>*B.6 Improved competitiveness of the electricity market* | **NO-DLFM**<br>**vs**<br>**R-DLFM (low flexibility scenario)**<br>Flexibility costs (€) | **0% RES**<br>NO-DLFM: **12000 € vs** R-DLFM: **8000 €**<br>**150% RES**<br>No-DLFM: **28000 € vs 20000 €**<br>**300% RES**<br>No-DLFM: **58000 € vs** R-DLFM**: 50000€** | In the No-DLFM case, For the 0% RES DSO needs to curtail load for avoiding congestion and undervoltage issues. For the 150% is where flexibility costs start to increase and are significantly higher with very high-RES penetration. In the R-DFLM, The FMO can minimize the flexibility cost making use of the flexibility assets that participate in the DLFM. Thus, curtailing load or generation is not the only option for the FMO for securing the |
| | **NO-DLFM**<br>**vs**<br>**R-DLFM (Medium flexibility scenario)**<br>Flexibility costs (€) | **0% RES**<br>NO-DLFM: **12000 € vs** R-DLFM: **5000 €**<br>**150% RES**<br>No-DLFM: **28000 € vs 17000 €**<br>**300% RES**<br>No-DLFM: **58000 € vs** R-DLFM**: 46000€** | |

| | | | |
|---|---|---|---|
| | **NO-DLFM**<br><br>**vs**<br><br>**R-DLFM (High flexibility scenario)**<br><br>Flexibility costs (€) | **0% RES**<br><br>NO-DLFM: **12000 € vs** R-DLFM: **3000 €**<br><br>**150% RES**<br><br>No-DLFM: **28000 € vs 15000 €**<br><br>**300% RES**<br><br>No-DLFM: **58000 € vs** R-DLFM**: 42000€** | DN operation as it is the case in the No-DLFM. |
| Comparison of P-DLFM and I-DLFM | | | |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br><br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br><br>*B.5 Increased flexibility from energy players*<br><br>*B.6 Improved competitiveness of the electricity market* | Ratio of Distribution Network level profits between P-DLFM and I-DLFM (%) | **Low Flex Scenario**<br><br>0% RES: **68%**<br><br>150% RES: **86%**<br><br>300% RES: **87%**<br><br>**Medium Flex Scenario**<br><br>0% RES: **96%**<br><br>150% RES: **98%**<br><br>300% RES: **99%**<br><br>**High Flex Scenario**<br><br>0% RES: **65%**<br><br>150% RES: **93%**<br><br>300% RES: **95%** | For the low flexibility scenario, the DN level profits are much lower in P-DLFM then in I-DLFM. For the medium flexibility scenario, the gap is closing since the zero marginal cost RE generators are far cheaper then thermal unit. In high-RES scenario, the difference increase again because of underutilized flexibility units from the FMO since their use is not financially useful for FMO |

## 5.2 Contribution of the FLEXGRID KPIs to the resulting impact

The FLEXIGRID research work contributes significantly to the flexibility market, processes, ICT tools, market architectures and many more aspects related to the overall electricity markets. This section discusses the project impact that is generated based on the ***A. Overreaching, B. Specific and C. FLEXGRID project KPIs*** mentioned in the section above. The goal of this section is to discuss the impact as described in the DoA, the contribution of the various research threads, and the corresponding results of the FLEXGRID WP3, WP4 and WP5 work.

The project impacts are presented considering the latest EC framework program, Horizon Europe. The inspiration to further map the project impacts to the wider and societal level is done based on the Key Impact Pathways (KIPs) defined by the EC for the Horizon Europe Framework (2021-2027)[50].

[50] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

### 5.2.1 Advanced modelling tools

There are various tools developed as well as tested in simulations and the results for the overall FLEXGRID project are expected to contribute to "*increase the knowledge on how to design of price structure and magnitude in order to be able to finance e.g., infrastructure and research and innovation*". In the following, some of the impact points related to the contribution of the research work for advanced modelling tools are described.

- **Impact on Enhancement of modelling tools and price structure for the grid operators (DSOs and TSOs)**

FLEXGRID's research work has contributed a great deal to the operations of grid operators. In particular the UCS 1.1 where the continuous and auction-based market clearing with network aware modelling tools helps achieving significant cost reductions for DSOs. Several KPIs are analyzed in the WP5 research work presented above. The continuous and auction based DLEM clearing KPIs described in Table 58 and Table 59 show the benefits of DSO cost reduction of up to 80% (compared to BaU scenario), while at the same time ensuring a high overall social welfare. Similarly, the DLFM clearing under the UCS 1.2 and UCS 1.3 show the benefit for DSOs to have lower costs by ensuring it can procure flexibility with network aware algorithms and at the same time not violating any network constraints. However, in case of the power reserves (active and reactive power) the cost increases. This is where further research needs to be conducted to ensure the appropriate power reserves actions are chosen for DSO to procure flexibility in a network aware market. The results of the FLEXGRID research work are presented in Table 60 and Table 61, where the benefits for DSOs are observed by looking at the Energy Not Served and Cost of curtailment especially in the high-RES scenarios. For the TSO, there is a special case analyzed in the UCS 2.2, where an ESPs minimizes its CAPEX by co-optimizing distributed RE and storage investment while ensuring cost reductions for TSOs. The results in Table 55 show that TSOs benefits from the DER investment, since expensive electricity at the TSO level is replaced by the generation mix of low-cost RES, resulting in 4.3% cost reduction. These results have a direct impact in both the DSO and TSO business across Europe and help in creating more resilient grid operations for the European society.

- **Impact on modelling tools and price structure for ESPs business models**

The role of an ESP has been defined and discussed in D8.2 where the several market roles and service providers are termed. In section 2, the business ecosystem depicted the role of the ESP in a flexibility value chain, where in the project ESPs and aggregator terms are used interchangeably. However, the research work under HLUC 2, is primarily focusing on the operation and business models of ESPs. ESPs' OPEX and CAPEX optimization results described in Table 54 and Table 55 highlight the benefits that FLEXGRID WP4 work has contributed to ESP business across Europe. The ESPs' profit is analyzed in both UCS 2.1 and UCS 2.2 by looking at today's market (No-DLFM, compatible with current market regulatory practices) and future DLFM architectures (R-DLFM and P-DLFM). This creates a valuable outcome for ESPs who are looking for new business cases under changing regulatory conditions for flexibility markets in Europe. By utilizing advanced models created in the FLEXGRID project, ESPs are estimated to make around 400 € profit in today's market condition (No-DLFM case) and the profits increase as the regulatory changes appear in Europe with new market architectures, such as R-DLFM (1200 € profit) and P-DLFM (1300 €) becoming dominant in the European energy market. ESPs, by minimizing their CAPEX for investment decisions can achieve 15% Return on Investment (ROI) by optimally planning investments in a BSU using the FLEXGRID modelling tools. A detailed analysis is presented for such optimal investment in D4.3 and some additional KPI results are highlighted in Table 55 above.

Considering an ESP as an aggregator or an independent aggregator. The FLEXGRID work under the HLUC 4 have made a considerable contribution to the role of aggregators and the novel services that aggregators can offer using FLEXGRID tools. UCS 4.2 modelling results shown in Table 51 show an estimated 20% increase in aggregators' revenues and a 20 – 30% increase in flexibility portfolio. This also increases the aggregated end user's welfare by up to 4%. The B2C flexibility market contributes to the impact for enabling fair flexibility provisioning from end-users. The novel work of penalizing the inaccurate end-user profiles contribute to increase in revenues for aggregators in Europe, while ensuring the delivery of flexibility to the market happens in more fair manner. UCS 4.3 further increases the business viability of an aggregator, where the results in Table 52 show that the aggregator can achieve guaranteed profits (except in some cases when only DA market schedule is followed). This work can be taken further by commercial actors and help in achieving a great deal of competitiveness for the aggregator business in Europe.

- **Impact on price structure on the interaction between markets and smart grid operation**

The electricity market liberalization in the EU and the various energy packages focusing on bringing the citizen to center of the European Energy landscape have brought the need of better interaction between markets and grid operation. The FLEXGRID project brings this closer to realization by proposing various new tools, algorithms, market architectures and clearing processes that help improving the interaction between markets and electricity grid operation. Following are some of the sub-impact points that discuss the FLEXGRID contribution towards efficient interaction between market and grid operation:

- *Impact on market clearing*

The work on the DLEM and DLFM under the WP5 of FLEXGRID contributes a great deal to the network aware and non-network aware market clearing state-of-the-art. HLUC 1 for both continuous and auction-based markets shows the benefits for Social Welfare, where the results for the various scenarios shown in Table 58 and Table 59 demonstrate that the social welfare increases with network aware market clearing, particularly with auction-based algorithms. Therefore, market participants as a whole benefit from this novel FLEXGRID approach of market clearing.

- *Impact on market power mitigation*

The FLEXGRID platform contributes to the better management of market power mitigation in case of the grid operators (DSOs or TSOs) needing grid upgrades. The FLEXGRID work in the HLUC 2 shows the benefits that can result for the grid operator by finding an optimum for the ESPs to provide flexibility using the FlexAssets placed in different nodes of the grid. While the grid operator can avoid congestion and voltage issues using the flexibility provided by the ESPs assets. HLUC 1 further supports the market clearing and with network aware clearing the grid constraints are also taken into the account. Hence, the overall system keeps the costs at minimal level and that contributes to the lower costs for the end-consumers.

- *Impact on scaling up existing local flexibility management platforms*

The FLEXGRID ATP platform is a unique tool, and its various features are described in deliverable D6.3[51]. The platform prototype showcases various features and the interoperable design that can contribute to improvements and further development of existing flexibility platforms in Europe. Section 2 describes the various business models through which such a platform can be integrated, operated or utilized stand-alone with the existing local flexibility management platforms. The FLEXGRID ATP's modular by design approach helps in making flexibility management platforms easier to be utilized with existing legacy system.

- *Impact on facilitating communication among market/grid actors*

The FLEXGRID project test-cases are evaluated under the work of WP7. The deliverable D7.3 highlights the contribution of the project towards setting up pilot site where flexibility assets, DSO network and the ATP platform communicates for optimal orchestration of flexibility request, market clearing and

[51] D6.3: Final version of FLEXGRID S/W prototype

flexibility activation. The figure below shows the communication between several actors their technical systems and FlexAssets (Battery storage, PV, EV charging etc.) done for demonstrating FLEXGRID services in the bnNEtze pilot in Germany.

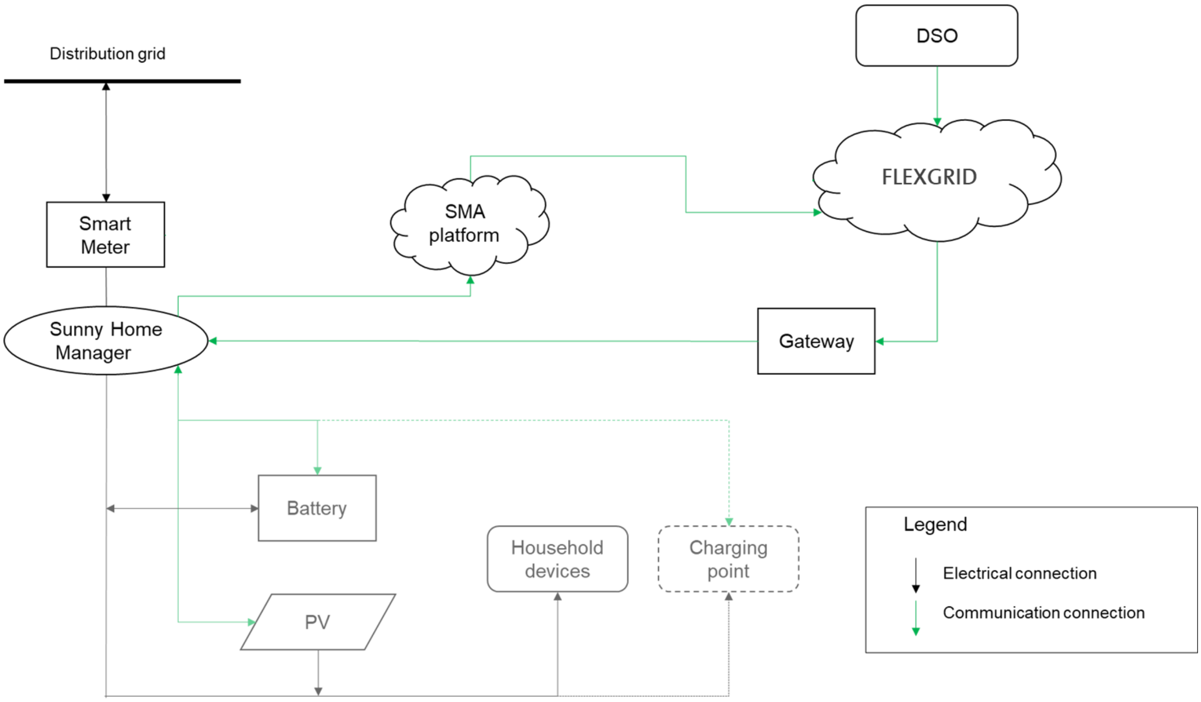


**Figure 50 Communication plan setup for bnNETZE pilot (from D7.3)**

### 5.2.2 Enhance the accuracy

The FLEXGRID project has contributed significantly to the improvement of various tools and processes around flexibility markets. Particularly, this involves improvement in market clearing processes, forecasting services for both production and market prices. This section highlights the project's contribution for enhancing the accuracy of the tools addressing the work program accuracy mentioned on "*the prediction of electricity production from variable renewables and better qualify and quantify associated issues and remedies*."

- **Impact of production and energy market forecasting**

The FLEXGRID ATP hosts the services related to the solar PV production forecasting and the energy market price forecasting. These services are developed and tested in the pilot site of the University of Cyprus (UCY). The production forecasting tool can be utilized by various stakeholders for their service delivery towards the customer and can also contribute to the optimal operation of the grid. Following are the two sub impact points describing FLEXGRID's contribution towards this impact:

- *Contribution to grid operation*

The results of the research work under WP5 for creating a FlexRequest by a grid operator are shown in Table 62. Where the loss of load is observed for the various investment and operational aspects related to the grid. The FLEXGRID approach shows significant decrease in the VOLL and hence the overall grid costs can be lower by utilizing the DSM using the FlexRequest generated by FLEXGRID ATP. Various scenarios are discussed for reinforcement of the grid considering the low and high cost of VOLL. This contributes further to the business models for the grid operators to consider the optimal investment planned for the grid and the different nodes where the DSM could be more beneficial. Similarly, the work for the novel market architectures presented in D5.3, where the different x-DLFM architectures have been discussed. This research work shows the need of such market architectures for reducing the flexibility costs in case of low, medium, and high-RES penetration. The results of these cases for various x-DLFM architectures are described in Table 63.

- *Optimizing ESPs portfolio*

UCS 2.3 describes the benefit for an ESP, where an ESP tries to do profit maximization by optimally allocating flexibility in multiple markets. The results shown for UCS 2.3 in Table 56 show that an ESP can expect 20-25% higher revenues compared to adding individual revenues for providing services only to grid operators (DSOs and TSOs). The ESP can expect 50% more revenues compared to sequential market participation. This optimization work from the FLEXGRID WP4 research clearly shows the potential of enhancing the accuracy of the profit maximization algorithms and contributes to the ESP's new business cases.

Another example of optimally managing the portfolio for an ESP is described in UCS 2.4. Where the ESP conducts market aware and network aware bidding to ensure the portfolio is maximized for the profits. The results of UCS 2.4 in Table 57 show the expected revenue to increase by up to 20% for ESPs. This is due to the method used in FLEXGRID for the modelling of such an ESP case where the electricity market reaction can be anticipated. This is a unique research outcome from the FLEXGRID project that can be taken further under research to investigate the accuracy of the algorithm under different market conditions across Europe.

### 5.2.3 Additional Impacts

- **Peak Load forecasting for DSOs**

The business case for the DSO described in section 2, highlights the important of forecasting peak load in a distribution network area for a single DSO. It is common in different European countries that a DSO must pay a grid usage fee for the highest physical peak load in its grid over a one-year period. In other countries such as Sweeden the regulation penalizes DSOs for exceeding the agreed capacity with the TSO. To minimize the cost for the DSO, a load forecasting algorithm has been developed in the FLEXGRID project. This work was not defined under any use-case scenario and the detailed modelling approach is described in D7.3 where two attempts are made for generating the load forecast for the bnNETZE grid. This forecasting attempt was evaluated with several forecast performance indication methods, but to keep the assessment process consistent between all forecasting algorithms, RMSE was the chosen accuracy indicator. The results from the first attempt were already strong despite being a fairly simple model. Following table summarizes the results of the forecasting algorithm:

**Table 64 Peak Load Forecasting algorithm for DSO**

| Peak load forecasting for the DSOs | | | |
|---|---|---|---|
| Classification | FLEXGRID KPI | KPI value | Comments |
| **Overreaching KPI:**<br>*A.1 Increased network capacity at affordable cost*<br>*A.2 Increased system flexibility at affordable cost*<br><br>**Specific KPIs:**<br>*B.1 Increased RES and DER hosting capacity*<br>*B.3 Power quality and quality of supply*<br>*B.5 Increased flexibility from energy players* | Root Mean Squared Error (RMSE) attempt 1 | **8.1%** | With only two input variables- load data provided in kilowatt (kW) and the associated quarter hour time stamp- the RMSE was already 8.1% |
| | Root Mean Squared Error (RMSE) attempt 2 | **5.1%** | To improve the forecast the residual load profile was further divided into its main constituent parts: consumption and generation from different sources, which resulted in a |

| | | | |
|---|---|---|---|
| *B.6 Improved competitiveness of the electricity market* | | | remarkable improvement of 3 % |

This research work of developing a load forecasting algorithm for a DSO result in direct impact for a DSO to reduce their operational costs. The test conducted as part of WP7 activities for the bnNETZE pilot show the relevant peaks with a capacity of at least 140 MW. Peaks that occurred during the test period were all below 140 MW. The highest forecast peak was 124 MW on 29/08/2022. The forecasts were tested in under many different weather conditions and the results described in D7.3, show the maximum peak was successfully recorded and the corresponding flexibility from the prosumer and the battery storage was utilized to lower this forecasted peak. The testing needs to be carried out for longer period to showcase the full impact of the work, however the results received so far are satisfactory for the DSO and the testing will continue beyond the FLEXGRID project.

- **Impact towards overcoming barriers and obstacles related to regulatory frameworks**

The FLEXGRID research presented in D5.3 on the introduction of x-DLFMs presents solutions for integrating DLFMs in the existing European market design. This provides the regulatory changes required to make DLFM integration into the existing markets. The suggestions on the design, modelling and performance evaluation of the three x-DLFM architectures, FLEXGRID puts emphasis on the trade-off between: i) social welfare maximization (or else market efficiency), ii) the level of compatibility of the proposed architecture with the existing markets' architecture (i.e., day ahead, balance), and iii) their efficiency for various energy sector stakeholders (e.g., ESPs, FSPs, market/system operators, etc.). Thee three architectures (R-DLFM, I-DLFM and P-DLFM) described in D5.3. Where the R-DLFM, acts reactively to the existing energy markets and in this way sacrifices efficiency for compatibility. The second one (P-DLFM) acts proactively to the existing energy market. The third architecture (I-DFLM) is framed within existing markets in D5.3 but offers the maximum possible smart grid efficiency by allowing market participants to facilitate the transmission or the distribution network at the same time, independently of their location.

## 5.3 FLEXGRID contribution towards impact on the broader society

The FLEXGRID impact analysis methodology was introduced in D8.2[52], where the focus was to detail the research findings into corresponding project-level impacts and then describe these contributions towards broader societal level impacts. In this section the FLEXGRID impact on broader scale is described using the Quintuple Helix model defined in D8.2, together with the Horizon Europe (HE) approach to track impact of projects[53].

The FLEXGRID contribution for the broader impact is well aligned within the following three impact areas of HE:

1. Scientific Impact
    a. Creating high-quality new knowledge
    b. Strengthening human capital in R&I
    c. Fostering diffusion of knowledge and Open Science
2. Societal Impact
    a. Addressing EU policy priorities & global challenges through R&I
    b. Delivering benefits & impact via R&I missions
    c. Strengthening the uptake of R&I in society
3. Economic Impact
    a. Generating innovation-based growth
    b. Creating more and better jobs

[52] D8.2: Intermediate Business models, dissemination, and exploitation of results
[53] Horizon EU presentation. Link: ec_rtd_he-investing-to-shape-our-future_0.pdf (europa.eu)

c. Leveraging investments in R&I

The sections below highlight the broad impact by combining the HE impacts areas, and the Quintuple helix segments for describing the impact beyond the project specific objectives and impact areas described above.

### 5.3.1 Academia

FLEXGRID contributes to the broader European academic sector in electricity and energy markets discipline by developing novel algorithms on advance modelling tools and providing open-source educational materials for universities and academic institutions. The project has disseminated the academic outputs thorough handbooks for academic professionals, and project presentations on scientific subjects related to FLEXGRID. These presentations are available to the public through the project open-source channels (such as project website, Github repository and social medial channels). The FLEXGRID contribution strengthens the research efforts and advance European academic competitiveness by delivering publications in important international conferences and scientific journals with high impact factors (described in section 6). Finally, academic partners intend to utilize the project's designs, algorithms, techniques, and other open results in new Ph.D. topics, advanced specialized courses for graduate students and increase overall contribution to the European academic advancement in Electricity Markets after the project ends.

### 5.3.2 Civil Society

Flexibility from energy sources is still a very novel topic for most societal actors. FLEXGRID dissemination work has not only been focused on academic papers (usually limited to the academic world), but industry workshops have also been developed to show the innovations developed during the project, and a public demo day event has been organized to raise awareness around energy flexibility. Furthermore, continuous dissemination activities have contributed a great deal to the understanding of the flexibility initiatives in Europe by civil society. For this, various social media platform have provided updates on FLEXGRID's research work (e.g Facebook, Twitter, and LinkedIn accounts), and educational as well as tutorial-type videos on the FLEXGRID's YouTube channel.

### 5.3.3 Government Regulators and Policy makers

FLEXGRID research work and KERs are the outcomes of the collaboration between academia and the industrial partners of the consortium. The work has been shared by many stakeholders including the national regulators and flexibility communities in Europe. For this a workshop where the Norwegian Regulator (NVE[54]/RME) together with a focused community on standardizing flexibility initiatives (FlexCommunity[55]) participated. FLEXGRID contribution to the Bridge working groups have also contributed a great deal for policy makers to know the challenges surrounding the flexibility markets in Europe and contribute to informed policy making in Europe. Some of the findings build on top of previous H2020 project results to show the main barriers in regulation and highlight new areas where required regulations are missing (e.g., new network codes for flexibility markets, the novel DLFM architectures etc.), and serve as overall guideline for policy strategy and investment plans (such as the EU Green Deal, and its Fit-for-55 package) towards a more resilient, fair, and sustainable power system.

### 5.3.4 Industry

FLEXGRID has from the very beginning involved both industrial and academic partners to align the interests and goals during the development of the project. This joint effort has allowed to study the feasibility and business potential of innovative solutions for the industrial partners' challenges. The

[54] https://www.nve.no/english/
[55] https://flex-community.eu/

learnings from the process can be used by the different industrial partners to guide their R&D strategy and re-focus or strengthen their business models and value propositions. Furthermore, FLEXGRID developed services, if brought to higher TRL levels, can actively contribute to create new jobs in the European energy industry, and offer innovative services that will be needed during, and after, the energy transition.

### 5.3.5 Environment

The research developed along the project and the tools created during the project have the potential to support the energy transition and therefore help in achieving decarbonization objectives of Europe. Furthermore, the different roles and use-cases in FLEXGRID contributes to raising awareness of the role of end users in the energy transition and promoting the consecution of SDG goals such as: *11. Sustainable cities and communities*, *12. Responsible production and consumption*, and *7. Affordable clean energy.* All these innovations have the potential to benefit the environment through more rational and efficient use of energy.

# 6 Report on communication activities and dissemination of project results

According to the FLEXGRID's dissemination and communication plan that was described in chapter 4 of D8.1, FLEXGRID dissemination and communication activities are presented in seven (7) main categories, namely:

- Academia-oriented publications and events
- Organization and participation at major international events
- Industry-oriented communication activities of FLEXGRID services and intelligence to interested stakeholders
- Open access FLEXGRID reports, data and software
- Training activities and academic dissemination
- Cooperation and mutual dissemination activities with other related EU projects
- Other general public dissemination actions

## 6.1 Academia-oriented publications and events

Regarding academia-oriented publications and events, there are three main sub-categories, namely: a) international journal papers, b) international conference papers, and c) organization of scientific FLEXGRID special sessions and/or workshops at international conferences and related special issues in scientific journals. More details per dissemination item are provided below:

**ICCS led WP3-related contributions, UNIZG-FER led WP4-related contributions and DTU led WP5-related dissemination activities of this category. The initial target was 14 journal papers and 18 conference papers. FLEXGRID achievement was at least 18 journal papers (a few more are currently under review process) and 8 conference papers. This deviation is related with the pandemic crisis restrictions and the respective consortium's strategy to shift to journal publications that did not require physical attendance.**

### 6.1.1 International journal papers

**J1** – G. Tsaousoglou, K. Steriotis, N. Efthymiopoulos, P. Makris and E. Varvarigos, "Truthful, Practical and Privacy-Aware Demand Response in the Smart Grid via a Distributed and Optimal Mechanism," IEEE Transactions on Smart Grid, vol. 11, no. 4, pp. 3119-3130, July 2020, doi: 10.1109/TSG.2020.2965221.

Available online: https://ieeexplore.ieee.org/document/8954657

**This paper was part of FLEXGRID's WP3 research work and dealt with UCS 4.2 (i.e. "Manage a B2C flexibility market"). Part of these research results have been integrated in FLEXGRID AFAT. It already has more than 1,000 full text views and more than 25 citations. The impact factor of this prestigious scientific journal is 8.96.**

**J2** – K. Steriotis, K. Smpoukis, N. Efthymiopoulos, G. Tsaousoglou, P. Makris, E. Varvarigos, "Strategic and Network-Aware Bidding Policy for Electric Utilities through the Optimal Orchestration of a Virtual and Heterogeneous Flexibility Assets' Portfolio", Elsevier Electric Power Systems Research (EPSR) Journal, vol. 184, July 2020. Available online: https://www.sciencedirect.com/science/article/abs/pii/S0378779620301085

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.4 (i.e. "ESP's network-aware bidding policies to make optimal use of its FlexAssets taking into account physical network constraints"). Part of these research results have been integrated in FLEXGRID FST. It already has more than 20 citations. The impact factor of this high-quality scientific journal is 4.25.**

**J3** – K. Smpoukis, K. Steriotis, N. Efthymiopoulos, G. Tsaousoglou, P. Makris and E. Varvarigos, "Network and Market-Aware Bidding to Maximize Local RES Usage and Minimize Cost in Energy Islands with Weak Grid Connections", MDPI Energies, Special Issue on "Integration of Electric Vehicles and Battery Storage Systems", vol. 13 (16), 4043, August 2020, Available online: https://doi.org/10.3390/en13164043

**This paper was part of FLEXGRID's WP4 research work, dealt with UCS 2.4 and was similar to the previous paper. The main difference is that this paper emphasizes on a remote microgrid placed in a rural area focusing on the BNNETZE's business case. It already has more than 1,000 full text views. The impact factor of this journal is 3.**

**J4** – M. Miletić, H. Pandžić, *"Energy Storage Integration in European Markets"*, Springer Current Sustainable Renewable Energy Rep 7, 160–164, December 2020, doi: 10.1007/s40518-020-00156-2, Available online: https://doi.org/10.1007/s40518-020-00156-2

**This survey paper analyzes various ways that energy storage assets can be integrated in EU markets towards optimal flexibility exploitation. It already has more than 280 full text views.**

**J5** – Pandžić, K.; Pavić, I.; Andročec, I.; Pandžić, H., "Optimal Battery Storage Participation in European Energy and Reserves Markets", Energies 2020, 13, 6629. Available online: https://doi.org/10.3390/en13246629

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.3 (i.e. "Maximize ESP's stacked revenues"). Part of these research results have been integrated in FLEXGRID FST. It already has more than 2,200 full text views and more than 10 citations. The impact factor of this journal is 3.**

**J6** – K. Pandžić, K. Bruninx and H. Pandžić, "Managing Risks Faced by Strategic Battery Storage in Joint Energy-Reserve Markets," in *IEEE Transactions on Power Systems*, vol. 36, no. 5, pp. 4355-4365, Sept. 2021, doi: 10.1109/TPWRS.2021.3058936. Available online: https://ieeexplore.ieee.org/document/9353227

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.2 (i.e. "Minimize ESP's OPEX"). Part of these research results have been integrated in FLEXGRID FST. It already has more than 520 full text views and 5 citations. The impact factor of this prestigious journal is 6.67.**

**J7** – L. Bobo, A. Venzke, S. Chatzivasileiadis, "Second-Order Cone Relaxations of the Optimal Power Flow for Active Distribution Grids: Comparison of Methods", in *International Journal of Electrical Power and Energy* Systems, vol. 127, 106625, 2021. doi: 10.1016/j.ijepes.2020.106625. Available online: https://linkinghub.elsevier.com/retrieve/pii/S0142061520341703

**This paper was part of FLEXGRID's WP5 work and set the foundations for the AC-OPF algorithms for the market clearing of the flexibility markets in the distribution grids. Along with the paper, we have also made publicly available the code we have developed (https://github.com/LucienBobo/SOCP_OPF_Nick2017), which has been used by FLEXGRID partners, and can also be openly used by the wider research community. This paper already has 12 citations. The impact factor of this high-quality journal is 4.63.**

**J8** – A. Khaksary, G. Tsaousoglou, P. Makris, K. Steriotis, N. Efthymiopoulos, E. Varvarigos, "Planning of Electric Vehicle Charging Stations with Smart Charging Capabilities and Quality of Service Requirements", Elsevier Sustainable Cities and Society, March 2021, https://doi.org/10.1016/j.scs.2021.102872. Available online: https://www.sciencedirect.com/science/article/pii/S2210670721001621?via%3Dihub

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.2 (i.e. "Minimize ESP's CAPEX"). It already has more than 20 citations. The impact factor of this journal is 8.53.**

**J9** – M. Vidan, F. D'Andreagiovanni and H. Pandžić, *"Individual Thermal Generator and Battery Storage Bidding Strategies Based on Robust Optimization"*, IEEE Access, vol. 9, pp. 66829-66838, 2021, doi: 10.1109/ACCESS.2021.3076872. Available online: https://ieeexplore.ieee.org/document/9420055

**This paper was part of FLEXGRID WP4 research work and dealt with UCS 2.3 ("i.e. Maximize ESP's revenues by co-optimizing its participation in several markets"). It already has more than 300 full-text views. The impact factor of this high-quality journal is 3.37.**

**J10** – G. Tsaousoglou, K. Mitropoulou, K. Steriotis, N. G. Paterakis, P. Pinson and E. Varvarigos, "Managing Distributed Flexibility Under Uncertainty by Combining Deep Learning With Duality," in *IEEE Transactions on Sustainable Energy*, vol. 12, no. 4, pp. 2195-2204, Oct. 2021, doi: 10.1109/TSTE.2021.3086846. Available online: https://ieeexplore.ieee.org/document/9447957

**This paper was part of FLEXGRID's WP3 research work and dealt with UCS 4.1 (i.e. "Manage a FlexRequest"). It already has more than 500 full-text views and 5 citations. The impact factor of this prestigious journal is 7.92.**

**J11** – G. Tsaousoglou, I. Sartzetakis, P. Makris, N. Efthymiopoulos, E. Varvarigos and N. G. Paterakis, "Flexibility Aggregation and of Temporally Coupled Resources in Real Time Balancing Markets Using Machine Learning," IEEE Transactions on Industrial Informatics, December 2021. Available online: https://ieeexplore.ieee.org/document/9633146

**This paper was part of FLEXGRID's WP3 research work and dealt with UCS 4.3 (i.e. "Create a FlexOffer"). Part of these research results have been integrated in FLEXGRID AFAT. It already has more than 200 full-text views. The impact factor of this prestigious journal is 10.21.**

**J12** – K. Steriotis, K. Sepetanc, K. Smpoukis, N. Efthymiopoulos, P. Makris, E. Varvarigos, H. Pandzic, "Stacked Revenues Maximization of Distributed Battery Storage Units via Emerging Flexibility Markets", I*EEE Transactions on Sustainable Energy*, vol. 13, no. 1, pp. 464-478, Jan. 2022. Available online: https://ieeexplore.ieee.org/document/9557813

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.3 (i.e. "Maximize ESP's stacked revenues"). Part of these research results have been integrated in FLEXGRID FST. It already has more than 400 full-text views. The impact factor of this prestigious journal is 7.92.**

**J13** – G. Tsaousoglou, P. Soumplis, N. Efthymiopoulos, K. Steriotis, A. Kretsis, P. Makris, P. Kokkinos, E. Varvarigos, "Demand Response as a Service: Clearing Multiple Distribution-Level Markets," *IEEE Transactions on Cloud Computing*, vol. 10, no. 1, pp. 82-96, 1 Jan.-March 2022, doi: 10.1109/TCC.2021.3117598, Available online: https://ieeexplore.ieee.org/document/9557809.

**This paper was part of FLEXGRID's WP3 research work and dealt with UCS 4.2 (i.e. "Manage a B2C Flexibility Market"). Part of these research results have been integrated in FLEXGRID AFAT. It already has more than 250 full-text views. The impact factor of this prestigious journal is 5.94.**

**J14** – N. Efthymiopoulos, P. Makris, G. Tsaousoglou, K. Steriotis, V. Lacort, R. Gehrcke, M. Bagherpour, G. Milzer, B. Pellerin, F. Farrukh, M. Thoma, T. Tadin, M. I. Baka, C. Papadimitriou, A. Kyprianou, G. Georghiou, H. Pandzic, D. Badanjak, S. Chatzivasileiadis, E. M. Prat, M. Calin, T. Esterl, E. Varvarigos, "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", Open Research Europe Journal, October 2021, Available online: https://open-research-europe.ec.europa.eu/articles/1-128/v1.

**This is a position paper that reflects the collaborative work among all FLEXGRID partners in WP2 and WP6. Open Research Europe is a new initiative taken by the EC in order to promote open peer review scientific publications and collaboration among related EC-funded projects.**

**J15** – G. Tsaousoglou, N. Efthymiopoulos, P. Makris, E. Varvarigos, "Multi-stage Energy Management of Coordinated Smart Buildings: A Multiagent Markov Decision Process Approach", in *IEEE Transactions on Smart Grid,* doi: 10.1109/TSG.2022.3162915., April 2022, Available online: https://ieeexplore.ieee.org/abstract/document/9744105

**This paper was part of FLEXGRID's WP3 research work dealing with the advanced management and scheduling of distributed flexibility assets. It is related with UCS 4.1 (i.e. "Manage a FlexRequest"). It already has more than 350 full-text views. The impact factor of this prestigious journal is 8.96.**

**J16** – L. Herre, P. Pinson, S. Chatzivasileiadis, "Reliability-aware probabilistic reserve procurement", Elsevier Electric Power Systems Research, Vol. 212, Nov. 2022, Available online: https://www.sciencedirect.com/science/article/pii/S0378779622005193

**This paper was part of FLEXGRID's WP5 research work and dealt with UCS 1.2 and 1.3 ("Clearing of a novel distribution-level flexibility market taking into account distribution grid constraints"). This paper's ideas have also been presented at PSCC 2022 conference in June 2022. The impact factor of this high-quality scientific journal is 4.25.**

**J17** – K. Steriotis, P. Makris, G. Tsaousoglou, N. Efthymiopoulos, E. Varvarigos, "Co-Optimization of Distributed Renewable Energy and Storage Investment Decisions in a TSO-DSO Coordination Framework", IEEE Transactions on Smart Grids, under review, April 2022. Available online: https://www.techrxiv.org/articles/preprint/Co-optimization_of_Distributed_Renewable_Energy_and_Storage_Investment_Decisions_in_a_TSO-DSO_Coordination_Framework/19298513

**This paper was part of FLEXGRID's WP4 research work and dealt with UCS 2.2 (i.e. "Minimize ESP's CAPEX"). Part of these research results have been integrated in FLEXGRID FST. The "techrxiv" version of the paper already has more than 350 full-text views. The impact factor of this prestigious journal is 8.96. The paper has been conditionally accepted and is expected to be officially published within the next few months.**

**J18** – D. Badanjak, H. Pandzic, "Distribution-Level Flexibility Markets – A Review of Trends, Research Projects, Key Stakeholders and Open Questions", Energies 14(20), 6622, September 2022. Available online: https://www.mdpi.com/1996-1073/14/20/6622/htm

**This paper was part of FLEXGRID's WP5 research work surveying the research field related with distribution level flexibility markets.**

### 6.1.2 International conference papers

**C1** – K. Seklos, G. Tsaousoglou, K. Steriotis, N. Efthymiopoulos, P. Makris and E. Varvarigos, "Designing a Distribution Level Flexibility Market using Mechanism Design and Optimal Power Flow," International Conference on Smart Energy Systems and Technologies (SEST), Istanbul, Turkey, 2020, pp. 1-6, doi: 10.1109/SEST48500.2020.9203564. Available online: https://ieeexplore.ieee.org/document/9203564

**This paper was part of FLEXGRID's WP5 research work focusing on the truthfulness property for the pricing mechanism of the proposed DLFM. It already has more than 370 full-text views and 9 citations. More than 40 persons have attended this paper's presentation.**

**C2** – N. Efthymiopoulos, K. Steriotis, P. Makris, G. Tsaousoglou, K. Seklos, K. Smpoukis, M. Efthymiopoulou, D. J. Vergados, E. Varvarigos, "FLEXGRID: Development and Comparison of Distribution Network Flexibility Market Architectures", CIRED 2021, 26th International Conference and Exhibition on Electricity Distribution, pp. 2984-2988, Geneva, Switzerland, 20-23 September 2021, Available online: https://ieeexplore.ieee.org/document/9692345.

**This paper was part of FLEXGRID's WP5 research work and is related with the ways that the proposed x-DLFMs can be integrated in the existing energy market architectures and respective EU regulatory framework. It already has more than 20 full-text views. More than 20 persons have attended this paper's presentation.**

**C3** – E. Prat, L. Herre, J. Kazempour, S. Chatzivasileiadis, "Design of a Continuous Local Flexibility Market with Network Constraints", IEEE PowerTech, Madrid, Spain, June 2021. Available online: https://ieeexplore.ieee.org/abstract/document/9494978

**This paper was part of FLEXGRID's WP5 research work and dealt with UCS 1.2 and 1.3 ("Clearing of a novel distribution-level flexibility market taking into account distribution grid constraints"). Part of this work has been integrated in FLEXGRID FMCT. The paper already has more than 170 full-text views. More than 50 persons have attended this paper's presentation.**

**C4** – B. Pellerin, F. Farrukh, I. Ilieva, P. Makris, E. Varvarigos, N. Efthymiopoulos, M. Calin, M. Thoma, "Integrated ICT Tools to Support Flexibility Management in Future Distribution Networks", CIRED 2021, 26th International Conference and Exhibition on Electricity Distribution, pp. 3060-3064, Geneva, Switzerland, 20-23 September 2021, Available online: https://ieeexplore.ieee.org/document/9692856

**This paper discusses ICT tools designed to assist network operators, flexibility suppliers and market operators, and make the flexibility markets both efficient and attractive. It already has more than 10 full-text views. More than 30 persons have attended this paper's presentation.**

**C5** – L. Herre, P. Pinson, S. Chatzivasileiadis, "Reliability-Aware Probabilistic Reserve Procurement", PSCC, Porto, Portugal, June 2022. Available online: https://arxiv.org/abs/2110.11445

**This paper was part of FLEXGRID's WP5 research work and dealt with UCS 1.2 and 1.3 ("Clearing of a novel distribution-level flexibility market taking into account distribution grid constraints"). The paper has been presented in person at PSCC in Porto. An extended version of this paper has also been part of a Special Issue of Electric Power Systems Research (EPSR).**

**C6** – F. Farrukh, B. Pellerin, "Business ecosystem of local flexibility platforms with corresponding business models in a digital energy system ", IEEE ENERGYCON 2022, Riga, Latvia Available online: https://ieeexplore.ieee.org/document/9830297

**This paper was part of FLEXGRID's WP8 work, and describes ICT tools developed to facilitate the operations of these stakeholders. The focus is on specific features and the value propositions**

**delivered to different actors in the business ecosystem. In addition, the paper brings an overview of the business models associated with these innovative ICT tools and corresponding business cases for important actors of flexibility markets. Conclusively, the paper gives an overview of key aspects that should be considered in the development of efficient and resilient energy systems with flexible energy resources. More than 20 persons attended this paper's presentation.**

**C7** – D. Badanjak, H. Pandžić, "Interaction between the Distribution System Operator and the Battery Storage Operator for Flexibility Procurement Services", ICNERA 2022, Shanghai, China 27-29 June 2022. Available online: https://ieeexplore.ieee.org/document/9880954

**This paper was part of FLEXGRID's WP4 work, and dealt primarily with the UCS 2.2 - CAPEX minimization. The paper discussed battery investment problem and interaction between profit-oriented battery storage operator and respective distribution system operator. The paper is accepted and it will be presented at ICNERA 2022.**

**C8** – P .Plana Ollé, B. Pellerin, O. H. Skonnord, S. Ø. Ottesen, "A Business Case for Flexibility Market Operators Using Algorithms for Improved Market Efficiency", EEM 2022, Ljubljana, Slovenia 13-15 September 2022.

**This paper was part of FLEXGRID's WP8 work, and analyzed the business case for a flexibility market operator to implement a network aware local flexibility market. The paper does a business case analysis of an FMO operating a continuous clearing network aware local flexibility market, and also considers the implications and challenges for the FMO business model to implement network aware clearing algorithms.**

### 6.1.3 Organization of special sessions and/or workshops at international conferences and special issues in scientific journals

**SS1** – MDPI Energies, Special Issue on "Integration of Electric Vehicles and Battery Storage Systems, organized by Prof. Hrvoje Pandzic (UNIZG-FER), https://www.mdpi.com/journal/energies/special_issues/EV_battery_storage

**This special issue was focused on both the stationary batteries and the mobile batteries in electric vehicles. Both should be used to provide flexibility and balancing services to the power systems. The topics covered in this Special Issue coincide with the FLEXGRID's WP3 and WP4 research efforts. A total of 10 scientific papers written by authors from more than 9 countries around the globe have been accepted to this Special Session disseminating thus the FLEXGRID knowledge in an efficient way.**

**SS2** – 5th International Conference on Smart Energy Systems and Technologies (SEST 2022), Eindhoven, Netherlands, 5-7 September 2022, https://www.sest2022.org/, Special Session entitled "Efficient interaction between energy markets and grid management systems under high RES penetration scenarios" organized by FLEXGRID consortium, https://www.sest2022.org/downloadables/SEST2022_Booklet.pdf (see pp. 48-49)

This Special Session was organized by FLEXGRID consortium and chaired by ICCS (Dr. Georgios Tsaousoglou) on September 6th 2022. Members of the consortium presented FLEXGRID results to a targeted audience from both academia and industry. ETRA (Elena Leal Lorente) demonstrated FLEXGRID Automated Trading Platform (ATP) explaining how the various mathematical models and algorithms have been integrated in the S/W platform and how can the respective FLEXGRID services be exploited in the future. SIN (Farhan Farrukh) elaborated on FLEXGRID business modeling and value propositions analyzing the potential impact on future flexibility initiatives in Europe. AIT (Filip Pröstl Andrén) demonstrated FLEXGRID validation results from the real-life testing sites (i.e. BNNETZE in Germany, UCY in Cyprus) as well as the laboratory validation results (TRL 4) that took place in AIT's premises in Austria. Another industrial presentation from HOPS (Matea Pavić) took place emphasizing on a TSO's business case regarding a TSO's long-term economic analysis by using DN-level flexibility through a Distribution Level Flexibility Market. Finally, ICCS (Konstantinos Steriotis) presented a highly novel idea and respective scientific results regarding a coordinated ESP-DSO-TSO decision making scheme towards finding the optimal equilibrium point for co-optimized DER and storage investments at the DN level. More than 40 persons attended the special session, while fruitful discussions and f2f meetings for future research collaborations took place after the session's end.

## 6.2 Event organization, presentations and participation in major international venues

**SIN led this type of dissemination and communication activities in collaboration with ETRA. SIN specializes in stakeholder engagement actions by organizing international events, supported by their NCE Smart Energy Markets cluster, in which many stakeholders attend and exchange ideas on new energy market developments and novel business models. Moreover, ETRA led DEMO-related communication activities by demonstrating the FLEXGRID S/W platform's functionalities. The initial target was 6 international events. FLEXGRID achievement was 9 international events described below.**

**E1** – ETRA/ICCS presentations in the digital event "Sustainable Places 2020" organized by the EC (https://www.sustainableplaces.eu/). ETRA organized a workshop entitled "Sustainable Digital Tools for All Energy Actors" on 29/10/2020 https://www.sustainableplaces.eu/home/sp20-workshops-events/sustainable-digital-tools-for-all-energy-actors/

Sustainable places is a digital workshop to present ICT tools in H2020 projects moderated by the project coordinator of X-FLEX (ETRA). The objective of this workshop was to present the ICT tools developed in various H2020 projects such as X-FLEX, HOLISDER, FLEXCOOP, SYNERGY and FLEXGRID. Each project has presented the digital tools developed in order to provide ICT services and functionalities to the different actors of the energy value chain, which will make them more sustainable and efficient. FLEXGRID project has presented the actual and future developments to introduce new tools to manage the interaction between the different energy actors. The presentation was made by Dr. Prodromos Makris and the title was: "*Integrating Advanced Intelligence in Existing Digital Tools of Energy Market Stakeholders*". More information and video can also be found here: http://xflexproject.eu/successful-workshop-for-all-energy-actors/ . With 740 Post Views on the webpage and 47 visualizations on youtube channel so far.

**E2** – SIN presented the FLEXGRID strategies and developments at the digital event: "World Energy Storage Day (WESD) Global Conference & Expo 2020" organised by the India Energy Storage Alliance (IESA) on 22/09/2020. https://energystorageday.org/event/conference-program/

The IESA is an industry organisation that represents Indian actors in the energy storage sector from across the value chain. They organise the World Energy Storage Day (WESD) Global Conference & Expo 2020, a global event with speakers from industry, academia, and policy. Bryan Pellerin (SIN) participated with a presentation and panel discussion on stationary storage. Bryan presented the strategies adopted by the FLEXGRID project, and the opportunities for industry stakeholders, especially storage providers, that are being tested in research and innovation. Over 5,000 participants were registered for the event, from 70 different countries.

**E3** – SIN presented the FLEXGRID H2020 project and the work that is being carried out for redispatch 2.0 with a group of young professionals working in areas of Flexibility for the Energy sector. The group is an invite based professional group of Energy flexibility professionals in Europe. The event was held with the group members on Date: 21.01.2021, https://www.linkedin.com/groups/12475050/

Flexibility for energy and mobility circularity leaders: A LinkedIn community of Young professionals looking to accelerate the advent of a more circular economy via renewable energies, storage, and sustainable mobility by developing flexibility capabilities. Farhan Farrukh (SIN) participated in the session organised to discuss the FLEXGRID project and what is the story of redispatch 2.0. The group consists of individuals from various disciplines with interest in learning and developing careers in the Flexibility for energy sector.

**E4** – SIN presented the FLEXGRID H2020 project and the various tools, services and use-cases developed for different stakeholders involved in the project. Finally, the survey of FLEXGRID was shared for gathering additional inputs. InnoEnergy is a Knowledge Innovation Community (KIC) supported by European Institute of Technology (EIT). CommUnity by InnoEnergy is a digital platform gathering Master students in Energy topics, PhD researchers, Entrepreneurs, and energy professionals. The event was organised by one of the student volunteer groups of CommUnity by InnoEnergy on Horizon 2020 projects where FLEXGRID H2020 project introductory presentation was conducted on Date: 22.02.2021, https://community.innoenergy.com/events/48985

The FLEXGRID H2020 project was shared with the different members of the CommUnity by InnoEnergy. A group focused on creating sustainable energy related events and sharing of new developments in the energy sector of Europe. The CommUnity is organised in several locations across Europe, where this particular event was organised by Stockholm Community and Farhan Farrukh (SIN) presented the general overview of the FLEXGRID H2020 project to students, PhDs and some young professionals working in the energy sector in Europe.

**E5** – SIN participated in the symposium organized on the diverse research themes together with the Nordic Edge 2021 (https://nordicedge.org/expo/) in the city of Stavanger, Norway. The FLEXGRID business modelling and impact analysis work was presented in the University of Stavanger (UiS) symposium (https://indico.uis.no/event/14/) under the session organized by European Bauhaus Nordic representatives.

Nordic Edge is one of the leading events in the Nordics where several Industrial, academic and public stakeholders gathered from across the Nordic region. In 2021, the Nordic Edge also organised a parallel symposium to discuss the latest results and impacts of research activities on the Nordic initiatives in smart cities, cleaner mobility and better way of living a sustainable life. FLEXGRID presented the topic "Business models in energy flexibility and impact assessment for the future of sustainable smart cities". From Smart Innovation Norway, Farhan Farrukh and Bryan Pellerin presented the topic showcasing the step by step process that FLEXGRID used for developing the business cases, the value proposition and the intermediate business models, while ensuring that the impact analysis methodology is closely followed to achieve maximum value for the project research results. The presentation was around 30 minutes with a discussion session followed up with European Bauhaus representatives in Nordics (https://europa.eu/new-european-bauhaus/index_en) and the other H2020 projects. The discussion mainly highlighted the need for translating the research results into impact and FLEXGRID impact methodology was appreciated by the other fellow researchers taking part in the discussion.

**E6** – FLEXGRID was represented at the ENLIT 2021 conference in Milan, Italy on 01/12/2021 by partners SIN, DTU, UCY and ICCS. The project had a booth in EU projects' zone where it networked with other projects and industry representatives, and presented its concepts and results to stakeholders in a presentation and one panel session (https://www.enlit-europe.com/post-event-report-2021).

ENLIT Europe is one of the largest events in energy and has the mission to drive the energy transition. The event was the only one of the international conferences in Europe that held physically in 2021 where FLEXGRID was able to exchange ideas with industrial stakeholders. The project was present in the EU projects' zone, where partners SIN, DTU, UCY and ICCS were represented. Here, the project received attention from participants in other EU projects, many of which deal with similar challenges as FLEXGRID. Furthermore, the booth was located beside the Energy Markets' zone. This provided exposure to industry stakeholders active in this domain, including EPEX spot, Grid Singularity, as well as technology providers who develop ICT solutions for market and grid management. Finally, SIN presented findings from WP8 on "Value created from novel flexibility markets, models and algorithms''. This included a panel discussion on "grid edge and new technologies to help elevate the grid" where they were joined by industry speakers from Gridspertise, Stedin and RTE. The audience for these presentations was approximately 100 people, while the conference had over 10,000 attendees from 145 countries.

**E7** – FLEXGRID was represented at the ETIP SNET webinars in the context of presenting the High Level Use Cases for the ETIP SNET 2022-2025 R&I implementation Plan. ETRA presented some lessons learned from the project related to HLUC 9 - Flexibility provision by Building, Districts and Industrial Processes. Recording available (in the following weeks) https://ec.europa.eu/info/events/etip-snet-webinars-high-level-use-cases-2022-may-12_en

ETRA presented some of the lessons learned related to "Elaborate energy models and validate economic benefits", "Improved flexibility assessment and forecast" and "Integration of heterogeneous flexibility in one platform" The event was followed by 30 experts on flexibility and future R&I initiatives. The presentation was focused on showing the next steps to be done in relation to the flexibility and markets, following the main topics discussed in the FLEXGRID context:

- Need of appropriate FlexContracts with end-users
- Coordination between suppliers and indement aggregators
- The attractive prices of flexibility may overcome some dilemmas

- The interrelation between CAPEX and OPEX
- How the forecast should be improve considering extreme prices (positive and negative)

**E8** – FLEXGRID was represented at the 45th Jubilee International Convention on Information, Communication and Electronic Technology held in Opatija, Croatia 23.-27.05.2022. M. Pavić from HOPS together with Prof. H. Pandžić and D. Badanjak from UNIZG-FER presented FLEXGRID project.

HOPS and UNIZG-FER presented the FLEXGRID project at the seminar session "Green Transition of the Power Systems" held on the 23th of May 2022 as part of the Convention. The interested audience had the opportunity to listen about the FLEXGRID project in general, the most important goals and milestones accomplished so far. Moreover, HOPS and UNIZG-FER explained in great detail their tasks and contributions to the project.

**E9** – FLEXGRID was represented by SIN at a prediction workshop on 7th of June 2022, "Digital workshop: Forecasting in Energy". In addition, Spyros Theocharidis and Stylianos Loizidis from UCY, Paul Zehetbauer from AIT presented research cases from the FLEXGRID project.

SIN, AIT and UCY presented the FLEXGRID project at the digital workshop session "Forecasting in Energy" held on the 7th of June 2022 as part advanced forecasting research exchanging experiences. The interested participants had the opportunity to listen about the FLEXGRID project in general, the most important achievements and milestones accomplished so far and in detail on content related to predictions/forecasting techniques in the FLEXGRID project. Performances and challenges related to forecasting in commercial products and in high quality research were compared. SIN, UCY and AIT also discussed challenges and experiences with the industry partner present and with researchers from the INTHYDRO project, a Norwegian Chinese research collaboration research project. For more details and material: https://smartinnovationnorway.com/nyheter/bringing-together-stakeholders-to-increase-collaboration-exploitation-of-energy-forecasting-products/

## 6.3 Industry-oriented communication activities of FLEXGRID services and intelligence to interested stakeholders

**NODES and NPC** engaged in B2B meetings with targeted industrial stakeholders, who could be interested to operate on a FLEXGRID marketplace in their geographical region in the future or are interested in using any of the novel FLEXGRID services. **NODES/NPC** tried to attract the stakeholders, who would like to participate in flexibility marketplaces in order to educate them on the features of the platform and persuade them to participate and extend their business through it.

**SIN** led the organization of industrial workshop(s)/DEMO days and webinars.

**SIN & ETRA** led communication activities to regulators/policy makers.

**BNNETZE** led communication activities to public authorities exploiting its experience/network from Thuega group and respective public municipality affiliations.

**ETRA** led communication activities to grassroots community organizations such as RESCOOPs and smart energy communities, which want to be front-runners in Europe's green energy transition era.

The initial target was to have 11 events to targeted industrial companies. Below, FLEXGRID achievements are clustered in 10 industrial communication (IC) activities. Some of them refer to more than one activity like IC1 (from NODES), IC2 (from NPC), IC3 (from SIN), IC4 (from bnNETZE) and IC6 (from HOPS). So, in total, the industrial communication activities have been far more than the target that was initially set.

**IC1 - NODES** – Communication of FLEXGRID topics and ideas to stakeholders in other pilot projects to raise awareness of challenges and topics addressed and sensibilize for future results. Results of increased interest are the advanced OPF algorithms for grid state analysis as well as grid-aware market clearing approaches. Furthermore, topics of major interest within FLEXGRID are new tools implemented to facilitate the commercialization of flexibility to market agents as well as analyses of the flexibility potential and comparison of flexibility prices with spot prices.

NODES has communicated FLEXGRID objectives to a broad audience and triggered discussions as follows:

- The publication of the DNV-GL article sponsored by NODES "Market-based redispatch in the distribution grid-Why it works?" October 2020 has been published on the NODES website, social media and other project´s websites (https://nodesmarket.com/download/why-it-works-market-based-redispatch/). The article has triggered extensive discussions about pros and cons of market-based redispatch and the risk of strategic bidding within SmartEn task force of prevention of Increase-Decrease bidding and was followed up by a Montel podcast about the subject in January 2021. Before the publication, FLEXGRID results were discussed as a possible project to allow for a comparison of flexibility prices with the spot price, however under simplified conditions. It is worth noting that "ESP's truthful bidding" research problem is investigated within WP5, while results have already been published in prestigious IEEE Transactions on Smart Grids (cf. J1 mentioned above).
- Presentation of the FLEXGRID project and objectives, in particular the tests including the German market, TSO/DSO coordination and the impact of redispatch 2.0 on the German market as a whole to Danske Commodities.
- Publication and sharing of FLEXGRID results and outcomes such as articles, surveys and deliverables on the NODES website, social media and stakeholders participating in other pilot projects with NODES being the market platform operator

- Presentation of FLEXGRID research objectives in NODES´s white paper as well as to various forums in Germany, including SynErgie/Kopernikus projects.
- Presentation of FLEXGRID research objectives and possible interaction with the H2020 project EUniversal to identify potential for knowledge exchange.

**IC2 - NPC** – Customer and stakeholder engagement through regular capacity building workshops, both in the framework of quarterly power market courses and through targeted B2B sessions with interested stakeholders.

NPC regularly used the reoccurring "Physical and Financial Power Markets" courses, organized by NPC's mother company Nord Pool as an arena to disseminate the FLEXGRID research and services to industrial stakeholders. These courses were usually attended by individuals involved in power market operations who represent a very relevant target group for FLEXGRID. https://www.nordpoolgroup.com/en/services/nord-pool-academy/ThePhysicalandFinancialPowerMarkets/

NPC organized frequent B2B meetings with industry stakeholders, both with a European but also a wider international scope, where increased need for flexibility and market-based solutions in the energy domain is a prominent topic. Flexibility in energy markets being one of the strategic pillars of NPC's mother company Nord Pool, we capitalize on the FLEXGRID intelligence to raise awareness and present business cases for participating in flexibility markets to its business partners.

**IC3 - SIN** – A survey organized and shared with various organizations representing broad overview of energy market perspectives from different countries in Europe. There was a total of 9 respondents representing 6 European countries with diverse stakeholder profiles.

The survey was created by SIN as part of gathering inputs from actual market players working in the areas of interest for the FLEXGRID project and supporting the work done in D8.2. There were 3 Energy Service Providers (ESPs) / Aggregators reached from 3 different countries in Europe, providing their perspectives on FLEXGRID innovations and how it facilitates the future of flexibility markets in Europe. There was 1 Distribution System Operator (DSO) and 1 retailer participated from Germany. In addition, the commercial and research actors from the consortium partner organizations also participated to provide feedback and assessment on the business and market value of FLEXGRID innovation. The survey will also facilitate the organisation of future workshops and events, where participants of the survey who have shown interest to be part of FLEXGRID future activities will be invited as external stakeholders for future activities. More information about the stakeholder survey can be found here: https://flexgridh2020.typeform.com/to/BrFrw8Ax

**IC4 - bnNETZE** – The results of the project have been presented within the 'Thuega-Group' - the widest network of utilities in Germany with around 100 member companies.

bnNETZE (and also BADENOVA) is part of 'Thuega-Group' (https://www.thuega.de/). It is one of the major players in this network as it has also the role to coordinate all small utilities collecting their shares in a separate company called KOM9. BADENOVA is the coordinator and speaker of this large group of small utilities. Apart from this group, there are three other major utilities operating in regions around Frankfurt, Hannover, and Leipzig. Within Thuega, there is a department responsible for innovation and research. On a regularly basis, online conferences for interested member utilities are organized to keep them on track regarding new topics. bnNETZE has been presenting the results of the FLEXGRID project in the context of such a conference. Special focus of the communication activities has been put on the software platform developed and its functionality as well as on additional benefits from the project like forecast algorithms and economic analyses of flexibility marketing.

**IC5 - NPC** – Regular stakeholder discussions with customers looking for alternative ways to operate their power systems by increasing the use of distributed flexibility resources.

NPC is regularly contacted by stakeholders around the world to present their view on the future development of organized power markets. A re-occurring theme of these discussions is the increased dissemination of VRE and dispatchable demand on lower grid levels. During these consulting projects, NPC regularly drew on the experiences gained in the FLEXGRID project, when it comes to finding new ways to capitalize on these new developments.

**IC6 - HOPS** – HOPS had several meetings with the first aggregator in Croatia - KOER Ltd.

KOER (https://koer.mykajabi.com/ ) is a technology company that developed the infrastructure of the first Croatian virtual power plant, and thus became the first Croatian aggregator - a new participant in the electricity market that is the link between the electricity market and end users who are part of the virtual power plant. During the establishment of the entire process, HOPS used the knowledge and experience gained by participating in the FLEXGRID project. KOER offers HOPS, with which it has a signed agreement, ancillary services geared at optimizing the managing and balancing of the electric power system. The balancing is achieved in such a way that at the request of the operator the energy consumption of end-users, who are part of the virtual power plant, is reduced.

**IC7 - HOPS** – HOPS had a joint meeting with several parties (Voltalis, DR4EU, EIHP, HERA) about large-scale aggregation of small consumers sharing examples and experiences.

HOPS participated in a joint meeting to discuss flexibility in the distribution network, where issues relevant to the topic of the FLEXGRID project were mentioned. The meeting participants were: 1. Voltalis - French company who had an aggregation platform and their in-house technology covers all aspects of Demand Response, including smart devices in participant buildings, dedicated Home Energy Management Systems for participants, and a central control room connected to power markets; 2. DR4EU - European association of companies involved in Demand Response in more than 20 countries in Europe; 3. Energy institute HRVOJE POŽAR - an institution owned by the Republic of Croatia whose activity includes the implementation of scientific research in the field of energy, the provision of professional support to public authorities, and advisory services in the domestic and international markets; 4. HERA - Croatian Energy Regulatory Agency; 5. HOPS. Some of the subjects presented on the meeting were: large-scale aggregation of small consumers - the example of Voltalis, the need for flexibility in the Croatian electricity, DR participation in the wholesale market. HOPS presented projects with the topic of flexibility in the distribution network in which it participates, including FLEXGRID.

**IC8 - HOPS** – HOPS presented its work on FLEXGRID project on Croatian conference organized by Croatian CIGRE society (15th HRO CIGRE conference - November 2021)

HOPS presented its work on FLEXGRID project on business-professional conference on electric power industry in Croatia organized by Croatian CIGRE society (15th HRO CIGRE conference). The conference participants were from various energy companies from Croatia as Hrvatska elektroprivreda (HEP Group) - national energy company, KONČAR - Croatian electrical, transport and energy company, HERA - Croatian Energy Regulatory Agency, HEP Operator distribucijskog sustava (HEP ODS), DALEKOVOD and others. HOPS (Z. Luburić) presented results from WP5 techno-economic analysis.

**IC9 - SIN** - Industrial event called "Energy flexibility: from customer to market", in which several energy companies from Norway exchanged ideas on the development of flexibility markets and related standardization efforts in the EU area:https://smartinnovationnorway.com/en/kurs-og-arrangementer/flexibility-from-customer-to-market/ The event took place on 20/9/2022 at 12:00-15:30 CET.

The goal of this industrial event was to share experiences related to flexibility markets, business models for aggregators and flexibility as a resource. The latest market developments were discussed to share knowledge and approaches to enter the market. The event focused on use cases, challenges and opportunities related to flexibility as a commercial product and highlighted required research such as the one performed within FLEXGRID project. A special session was dedicated to standardization and policies related to flexibility markets, both from FlexSupply and FlexDemand sides led by FLEXGRID Coordinator (Dr. Prodromos Makris). Flex-Community (https://flex-community.eu/) members attended the panel discussions together with Norwegian regulator, managers of FSP companies as well as NODES. Special focus was put on how standardization efforts can help towards scalability, interoperability and replicability of the various existing flexibility market solutions. More than 20 persons attended physically and more than 40 persons joined remotely.

**IC10 - SIN** - Industrial event called "Final FLEXGRID Hybrid DEMO Day event", in which the most important FLEXGRID results were demonstrated https://flexgrid-project.eu/hybrid_demo_day.html The event took place on 26/9/2022 at 09:00-12:30 CET.

This was the final FLEXGRID DEMO day event, in which more than one hundred (100) individuals participated from: i) research institutes, ii) industries, iii) SMEs, iv) other project coordinators/partners, v) EC representative, vi) PhD/MSc students etc.

This event's agenda can be summarized as follows:

- A keynote speech by NPC (Europe's leading electricity market operator)
- Energy flexibility and vision of NODES marketplace (Norway's leading flexibility market operator)
- A live demo & pitch of the novel Flexibility trading platform and corresponding services
    - Automatic Trading Platform (ATP) for Flexibility Market actors (DEMO by ETRA)
    - FLEXGRID Automated Flexibility Aggregation Toolkit (AFAT) for aggregator companies (DEMO by ICCS)
    - FlexSupplier's Toolkit (FST) for Energy Service Providers (ESPs) (DEMO by UNIZG-FER)
    - Flexibility Market Clearing Toolkit (FMCT) for grid operators (DEMO by DTU)

- Panel discussions around energy flexibility algorithms, market architectures, and technological tools
- Licensing opportunities and business deals for acquiring such services
- Networking and collaboration with leading EU energy actors

## 6.4 Open Access FLEXGRID reports, data and software

**ICCS** led this activity being responsible for periodically updating the FLEXGRID's website with new dissemination and communication material. The target set in the DoA was 19 open access deliverables, 4 open access datasets, 2 open access S/W prototypes and user manuals and 5 S/W toolkits' DEMO videos. All these milestones have been accomplished as detailed below.

Regarding the open access FLEXGRID reports, data and software, there are three main sub-categories, namely: a) public FLEXGRID reports and deliverables, b) open access datasets, and c) open access FLEXGRID software and user manuals.

Regarding (a), all FLEXGRID deliverables (together with all other dissemination material like scientific papers) are made public in the project's website (see the "Downloads" tab here: https://flexgrid-project.eu/deliverables.html), so as everyone may have access and download the respective material.

Regarding (b), each FLEXGRID subsystem provides open datasets to be used mainly for research purposes. For more details about the structure and contents of these datasets, please see the Data Management Plan – DMP in D8.1 (M6). These datasets were made publicly available after the end of the first S/W integration phase (M27) in the FLEXGRID GitHub area (https://github.com/FlexGrid). The project's GitHub area consists of several repositories. More specifically, once a new UCS algorithm was tested, validated and its performance was evaluated via exhaustive simulations, a new repository was created, in which there is a readme file explaining the algorithms' operation as well as the exact datasets that have been used. The source code of the algorithm is also provided so that any interested researcher can replicate the simulation, reproduce the results and possibly elaborate on them.

Finally, regarding (c), the consortium's strategy was to have a basic version of S/W prototypes fully accessible to anyone interested in understanding the basics about the whole system's operation and experiment with the innovative functionalities and respective services of FLEXGRID ATP. In particular, a comprehensive user manual has been available for every subsystem and the system as a whole in order for everyone to be able to start experimenting with the platform's functionalities. This material was made publicly available at the end of the S/W integration process (M34). This was done in order to further disseminate the project's results (i.e. FLEXGRID foreground knowledge). However, the final version of S/W prototypes will be kept in "closed/restricted access" in order to boost the commercial exploitation activities of the FLEXGRID beneficiaries and protect the respective IPR (see more details in chapter 4 above about the FLEXGRID IPR management). Example links from GitHub area:

https://github.com/FlexGrid/FST-service-3-stacked-revenues-maximization (FST service #3)

https://github.com/FlexGrid/AFAT-service-2-manage-b2c-flexibility-market (AFAT service #2)

https://github.com/FlexGrid/AFAT-service-3-flex-offer-creation (AFAT service #3)

## 6.5 Training activities and academic dissemination

**DTU** led this activity exploiting its large and international academic portfolio and its experience in organizing summer/winter schools and other types of research brainstorming workshops and training activities. All other academic partners (i.e. UNIZG-FER, ICCS, UCY, AIT) contributed, too.

**TA1** – Dr. Prodromos Makris (ICCS) presented FLEXGRID functionalities in the context of academic lectures at the University of the Aegean, School of Engineering, Department of Information and Communication Systems Engineering. Three lectures took place in December 2019, December 2020 and December 2021 in the MSc program and two dedicated DEMO lab workshops in the BSc program (January 2021 and January 2022).

Dr. Prodromos Makris was invited to present FLEXGRID project's functionalities in the context of the MSc program entitled: "Internet of Things: Intelligent Environments in next generation networks" (https://msc.icsd.aegean.gr/en/iot/). The MSc academic course is called "Modern Networks and IoT Interfacing", the title of the presentation was "IoT for Smart Energy Networks" and the target audience was 12, 14 and 11 students in the academic years 2019-2020, 2020-2021 and 2021-2022 respectively. Moreover, Dr. Makris gave two explicit lectures and organized two DEMO lab workshops for the BSc course entitled "Sensor Networks" (https://www.icsd.aegean.gr/pps_lessons_en.php?lesson_id=321-9405) in which more than 150 BSc students had the opportunity to learn about the FLEXGRID-related advancements in the smart grid and energy efficiency sector and have a hands-on experience with FLEXGRID S/W platform functionalities.

**TA2** – NPC presented extracts of the FLEXGRID project during the ERRA online course on "Introduction to Regulation of Flexibility in the Power Grid" on 8 March 2021.

NPC was invited as a speaker at a conference, organized by the *Electricity Regulators Regional Association*. The aim of the training course was to present current and prospective flexibility solutions in the power grid. As part of NPC's lecture and training activity, local flexibility markets were presented as a possible means to increase the amount of flexibility in the electricity markets. FLEXGRID was mentioned as a project that NPC is involved in and making contributions on market design and business case related tasks. More information can be found here: https://erranet.org/kick-off-online-training-on-flexibility-in-the-power-grid/

**TA3** – NPC presented the main concept of the FLEXGRID project during the Nord Pool standard introductory power market course "The Physical and Financial Power Markets" on 4 March 2021.

NPC presented FLEXGRID during this in-house Nord Pool standard course. The subject was new kind of marketplaces with a special focus on local flexibility markets.

https://www.nordpoolgroup.com/services/nord-pool-academy/thephysicalandfinancialpowermarkets2/

**TA4** – HOPS presented FLEXGRID project and its main concept and goals to the students from University Zagreb - Department of Energy and Power Systems during the Summer school in HOPS.

HOPS presented the main concept of the FLEXGRID project during the 2 weeks of summer school for students from University of Zagreb (2nd year of bachelor programme) in HOPS. Students gained the first experiences about the importance of flexibility in transmission and distribution system and learned about energy and balancing market.

## 6.6 Cooperation and mutual dissemination activities with other related EU projects

FLEXGRID consortium had mutual dissemination activities, collaboration and knowledge/ideas' exchange with several H2020 "sister" projects in which several FLEXGRID partners are also participating. Project coordination and technical management team has also got in contact with other project coordinators, too.

**RP1** – ICCS presented the FLEXGRID project during the "H2020 Low TRL Smart Grids and Storage Projects Clustering workshop" that was organized by EC's Innovation and Networks Executive Agency (INEA) on 03-04 December 2020.

FLEXGRID project presented and shared its major business models and its technical objectives through a presentation, which mentioned: its concept, its impact, and its main achievements. Through this event, FLEXGRID was influenced by ideas and concepts of other projects in the same domain. They acted as useful feedback that enhanced FLEXGRID's innovation and testified its importance. This event was organized by INEA (the Innovation and Networks Executive Agency) and was the perfect opportunity for synergies to take place between projects and the facilitation of experiences sharing, which could lead to new project ideas. Dr. Nikolaos Efthymiopoulos represented FLEXGRID project. More details about the participating projects: https://interplan-project.eu/wp-content/uploads/2020/12/20201203-Agenda.pdf

**RP2** – ICCS presented the FLEXGRID project during the "BRIDGE General Assembly 2021" that was organized by EC and BRIDGE project 02-04 March 2021.

ICCS (coordinator) participated in BRIDGE General Assembly 2021 (https://www.h2020-bridge.eu/2021-bridge-general-assembly-takes-place-on-march-2nd-3rd-and-4th/). On March 2nd 2021, FLEXGRID concepts and expected results were presented in Plenary 2 session together with other new BRIDGE projects. ICCS team has also participated in two BRIDGE working groups (WGs), namely: i) Regulation WG, and ii) Data Management WG. During the Regulation WG session that took place on March 3rd, FLEXGRID exchanged ideas and shared knowledge regarding two tracks, namely: i) Flexibility Markets (Track 4), and ii) Flexibility Mechanisms - dynamic tariffs (Track 3). During Data

Management WG session that took place on March 3rd, ICCS was informed about the BRIDGE energy data exchange architecture, the energy data space and other types of reference architectures that are used in other related H2020 projects. ICCS aims at following up the next action points associated with these specific BRIDGE WGs and possibly contribute to the above-mentioned tracks with novel ideas, results, and policy-related recommendations. More info can be found here: https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/news/bridge-general-assembly-march-2021-conclusions-next-steps

**RP3** – ICCS participated in the writing of the BRIDGE report entitled "Interoperability of flexibility assets" by cooperating with other related H2020 projects. Published in Q1 2022. FLEXGRID partners have also actively participated in BRIDGE "BRIDGE General Assembly 2022" event that was held on 22-24 March 2022.

FLEXGRID contributed by defining the new business role of a Flexibility Market Operator (FMO) and how the business role of other flexibility market stakeholders (e.g. FlexBuyers and FleSuppliers) should be adapted in order for an efficient flexibility market operation to be realized. In particular, it contributed to the Generic Business Process (GBP #1) entitled "Flexibility for System Operator through open market". FLEXGRID also received important feedback from other related H2020 projects such as InterConnect, Merlon, Accept, EU-Sys-Flex, Osmose, OneNet, etc regarding the possible integration of the proposed DLFM in the existing energy market architecture.

**RP4** – FLEXGRID actively participates in the FlexCommunity (https://flex-community.eu/) forum which is composed of many ongoing EU projects (e.g. FlexiGrid, edgeFLEX, FEVER, GIFT, Platone, BD4OPEM, etc.) related to flexibility in smart grids and interaction with social sciences. Kick off of the community was on 2nd of February 2022. Dr. Nikolaos Efthymiopoulos represented FLEXGRID on behalf of ICCS.

The purpose of the FlexCommunity is to tackle all obstacles preventing a comprehensive roll-out of flexibility applications. More specifically, FlexCommunity strives the following purposes:

- Targeted and efficient networking between stakeholders and projects
- Knowledge exchange and mutual learning
- Align the terminology and communication efforts
- Strengthen the cooperation in developing and implementing advanced organizational structures and business models including energy communities
- Push for adapted standardization and regulation
- Better understanding of the similarities and differences of the technical approaches

FLEXGRID facilitates these purposes by providing knowledge relevant with flexibility aggregation and trading through its active participation in FlexGroup #2 entitled "Flexibility market and organizational design". Finally, FLEXGRID disseminates in this community its novel architectures relevant with distribution level flexibility markets.

**RP5** – **H2020 PARITY project**: ICCS/NTUA team had a physical meeting with HYPERTECH energy labs (https://www.ht-energylabs.com/), which is an SME offering ICT solutions for the future smart grid. The meeting took place in ICCS premises (Athens) on 14th July 2020. FLEXGRID Project Coordinator exchanged research ideas with the H2020 PARITY (https://parity-h2020.eu/) technical coordination team and discussed about future project proposals.

**RP6** – **H2020 WISEGRID, CROSSBOW and X-FLEX projects**: ETRA, being responsible for FLEXGRID ATP S/W integration as well as integration with other S/W platforms, coordinated the technical discussions on how FLEXGRID algorithmic results can be used as input to or be shared with the above-mentioned S/W platforms developed by ETRA, too. The same strategy was followed with H2020 SOCIALENERGY project coordinated by ICCS, while this "know-how" will be used as part of FLEXGRID future exploitation activities (cf. chapter 3 above).

## 6.7 Other general public dissemination actions

**Web portal:**

The FLEXGRID's public web site (https://flexgrid-project.eu/) is up and running from the very early stages of the project (M2). ICCS has developed this web portal and is also the administrator. The material that is uploaded in this web site is continuously updated and will continue even after the project's lifetime. In the "download" tab, all public deliverables are available together with all scientific publications. The "News" tab is continuously updated with new material, too. Moreover, there is a sidebar on the right hand side of the portal that presents in a user-friendly manner all updated feeds from FLEXGRID twitter account. In particular, when a new 'tweet' is posted on the project's twitter account, then this is automatically posted on the project's web portal, too.

**YouTube channel:**

FLEXGRID YouTube channel (https://www.youtube.com/channel/UCEpdrFhiltkGTi7dmNL--yg) contains several DEMO videos from the S/W platform as well as the individual S/W toolkits and services. These DEMO videos were used in every new communication activity and public events (including the final DEMO day event on 26/9/2022) of the consortium and will be exploited even after the project's lifetime. The project's official promo video has already gained much interest (>500 full views).

**Social Media:**

FLEXGRID maintains project accounts on the most popular social media sites such as:

- Twitter (https://twitter.com/FlexgridP),
- Facebook (https://www.facebook.com/flexgridh2020) and
- Linkedin (https://www.linkedin.com/company/flexgrid-h2020-project/)

Via the above-mentioned social media accounts, FLEXGRID disseminates news about the project's most important accomplishments.

## 6.8 Actions taken to mitigate covid-19 crisis effects on dissemination/communication activities

Specific targets provided in the initial dissemination and communication plan (M6) have been achieved with mixed success, notably due to the impact of the COVID-19 pandemic on the organisation of physical events. For example, more journals paper publications than expected have been produced, while publications at physical conferences and workshops have not been as numerous as originally planned. The presentation of project achievements in events has largely moved to a digital format (or hybrid format after Q1 2022). FLEXGRID partners have therefore not had the same opportunity to meet with their networks as was planned before the outbreak of the pandemic, thus limiting the effectiveness of some of the communication and dissemination activities compared to physical events. However, the consortium faced this challenge during Period 2 by focusing on the organisation of very targeted and concise digital events tailored to highly relevant stakeholders and covering very specific topics of interest. In this way, FLEXGRID managed to communicate the project's results to targeted industrial and commercial audiences, too.

# 7 Conclusions

The core work conducted during WP8 consisted of market analysis, business modelling, exploitation planning, communication and dissemination. To do so, this deliverable has relied on the research, piloting and integration work done in other WPs, starting with the guidelines set in WP2 by defining the use cases, followed by the results of the research packages WP3, WP4 and WP5. Finally, the implementation experiences from WP6 and WP7 have been relevant inputs for the business modelling task, and the exploitation and business plan work. The work carried out in this deliverable concludes the FLEXGRID work under WP8 by presenting the final version of FLEXGRID's business models, FLEXGRID's ATP exploitation plan, the overall impact analysis of the project and the communication & dissemination activities done as per the plans set in the beginning of the project.

Building on top on the intermediate results from D8.2, this deliverable has worked to refine the envisioned business models of FLEXGRID' services, and the exploitation plan of the ATP. To have a better understanding of the potential viability of the business models defined, a more concrete business case analysis was conducted, and during the process technical, regulatory, and business model challenges have raised which might lead the way to further research on the correspondent topics. The following list present the key take-aways of each of the proposed business models analyzed:

- FLEXGRID services for FMOs – Network aware market clearing algorithms have a significant impact on the business model of an FMO. Challenges such as liability over network constraints, data acquisition and observability of the grid, need to be overcome prior to have a solid business model.
- FLEXGRID services for DSOs and TSOs - This business model has proven to be one of the more promising; however, it is heavily dependent on the flexibility needs of the system operator (particularly for the DSO) where flexibility costs could jeopardize FLEXGRID/FMO business model.
- FLEXGRID services for ESPs and CPOs - Assets specialized to provide services to the grid are usually not in the need of optimization tools, since they can maximize their revenue by providing the service they are specialized at. The main hinderer of additional revenue streams by using optimization services in this case could be the impossibility to stack revenues due to market design.

Overall, the business case analysis exercise has shown the potential (and need) of innovative solutions such as the ones developed by FLEXGRID. However multiple barriers have been identified that will need to be removed if these innovative business models are expected to flourish. Up until this point the regulatory framework has been kept out of the equation to present relevant business insights; however, as already mentioned in D8.2 it continues to be a major factor in the feasibility of new flexibility services used in the flexibility domain. After the publication of the Clean Energy Package in 2019 the process started to create new network codes and regulations more suited for the new paradigm shift within the power system. Recently ACER has started the consultation process to create the guidelines for Demand Response, which should start to set solid pillars to create a distributed flexibility economy and the FLEXGRID analyzed business cases can be taken further in analysis by commercial actors. However, some of the business cases presented in this deliverable show the benefit for a German DSO to have an accurate load forecasting and procuring flexibility to reduce its costs for upstream network operator. Similarly for a TSO in Croatia, the business case show results to have lower costs by procuring flexibility from the distribution network and additional benefits to the BSPs in the market with such flexibility procurement possibilities.

The exploitation work for lower TRL tools have proven to be difficult although some of the outcomes have shown promising outcomes for Industrial actors. Some of the novel methods of market clearing

(Network aware vs non-network aware) have shown promises but needs further exploration to be part of a business strategy of an FMO. The peak load forecasting work for DSOs have already shown promising results and the bnNETZE pilot will continue to test beyond the project. Some of the other works have also received great importance from academic point of view and therefore the exploitation will need further advancement in the TRL of such outcomes of the project. The CBA has been preformed for the three main services of the FLEXGRID ATP, during the calculation of the revenue streams and pricing of the services significant assumptions were needed to be made due to the lack of commercial data available for open research. This presents the challenge that the FLEXGRID innovative services and their correspondent business models face towards commercialization. However, for the scope of a lower TRL project the project demonstrated several pathways towards commercialization and therefore can be beneficial for the project partners, external stakeholders and future research projects to take into account when using the FLEXGRID tools in future.

The project Impact have been delivered with various contributions by different research threads of the project and all the key results are summarized in this deliverable. The contribution of research tasks has been crucial in expanding the knowledge on several aspects related to energy flexibility eco-system such as: forecasting (load, generation, and market price), optimization techniques for asset aggregation and market participation, and developing new algorithms for improved market clearing of local markets. The outcomes of the research work have opened new promising threads that will need to be further developed in coming projects to reach a more mature TRL. The developed impact analysis goes one step further and shows the work developed during the project, not only within the project boundaries, but from an overreaching impact in societal perspective. Where the project results are mapped to the specific impact that project have contributed towards the Advanced modelling tools and the benefits in lower costs for grid operators such as DSOs and TSOs. Also, the work on CAPEX and OPEX optimization for ESPs have been significant in generating new methods for optimizing profits for an ESP operating in a European electricity market. The impact of aggregator profits by considering various costs and novel method of B2C aggregation toolkit is highlighted with potential increase in aggregated social welfare for end-users. The market clearing process and the novel DLFM architecture pave the way for further research on the flexibility initiatives and market regulations in Europe. The impact work highlights the broader contribution to society and the overall impact in the end of the project and corresponding impact generated for the next 3 to 7 years after the project lifetime.

To conclude, WP8 work on dissemination and communication of FLEXGRID foreground knowledge has been developed throughout the whole FLEXGRID project, starting with the dissemination and data management plans. The project has published a high number of journal and conference papers with high impact factor, held several events focusing on industrial actors and training courses for energy professionals. The work has created a common repository for all the open-source material, events, presentations, Github repository on the project website and social media channels in connection with FLEXGRID work.

# Annex

## CBA for AFAT services

Being part of the FLEXGRID ATP, the FLEXGRID Automated Flexibility Aggregation Toolkit (AFAT) consists of three service offerings, namely:

AFAT service #1 (Manage a FlexRequest)
AFAT service # 2 (Manage a B2C flexibility market)
AFAT service #3 (Dynamic FlexOffer creation)

Following a modular-by-design approach, each of the AFAT services can be exploited as a standalone service or a combination (e.g., service #1 together with service #3, or service #2 together with service #3, or all three services together).

**AFAT service #1 (Manage a FlexRequest)**

The AFAT service 1 includes a SaaS module regarding the implementation of an algorithm targeted for an aggregator company (i.e., FLEXGRID customer), whose aim is to manage a FlexRequest by appropriately orchestrating the aggregator's flexibility portfolio. It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The independent aggregator will be able to upload its portfolio/datasets (offline[56]). A portfolio comprises of two types of FlexAssets, i.e., adjustable assets and shiftable assets. The data/information contained in the datasets (excel files) for each type of asset are listed below:

Adjustable Assets:

- Scheduled operating pattern
- Power/Wattage of Assets
- Minimum acceptable operation for each Market Time Unit (MTU)
- Maximum acceptable operation for each MTU
- Cost of upwards flexibility for each MTU
- Cost of downwards flexibility for each MTU
- Required activation notice
- Maximum total flexibility activation

Shiftable Assets:

- Operation pattern
- Scheduled start time
- Minimum start time
- Maximum/latest start time
- Required activation notice
- Cost function

With the information regarding the flexibility portfolio and FlexRequests as input from the market, the independent aggregator user will be able to utilize the service in order to decide if a FlexRequest is accepted and thus orchestrate its portfolio to satisfy the accepted FlexRequests. The following KPIs can be utilized to evaluate the impact of the service:

- Aggregator's revenues and profit

[56] The portfolios/datasets are stored in appropriate excel files. Uploading the excel files requires contact with the service provider (i.e. FLEXGRID ATP administrator).

- Aggregated user's revenues/Aggregator's cost
- Quantity of flexibility accepted by the market

The OPEX and required human capital for one projected year are shown in Figure 51. For UCY to offer the AFAT service #1, a total OPEX of 28.100 € for the 1st year of market uptake (Cloud/H/W equipment and fees) and 6.7 Person Months will be required to serve an initial client volume of up to 8 independent aggregators until the end of the year.

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Recurring Costs** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| Payroll | | €1,500.00 | €1,500.00 | €1,500.00 | €900.00 | €1,200.00 | €1,800.00 | €1,500.00 | €1,500.00 | €2,400.00 | €1,800.00 | €1,800.00 | €2,700.00 | €20,100.00 |
| Apartment | | | | | | | | | | | | | | 0 |
| Office | | | | | | | | | | | | | | 0 |
| Finance cost | | | | | | | | | | | | | | 0 |
| Legal services | | | | | | | | | | | | | | 0 |
| Travel expenses | | | | | | | | | | | | | | 0 |
| Marketing | | | | | | | | | | | | | | 0 |
| Hardware/equipment | | €0.00 | €0.00 | €2,000.00 | €0.00 | €0.00 | €2,000.00 | €0.00 | €0.00 | €2,000.00 | €0.00 | €0.00 | €2,000.00 | 8000 |
| Other? | | | | | | | | | | | | | | |
| **Total** | | €1,500.00 | €1,500.00 | €3,500.00 | €900.00 | €1,200.00 | €3,800.00 | €1,500.00 | €1,500.00 | €4,400.00 | €1,800.00 | €1,800.00 | €4,700.00 | €28,100.00 |
| **Person Months (PMs)** | **PM Cost** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total PM** |
| Integration developer | €3,000.00 | 0 | 0 | 0.1 | 0 | 0 | 0.2 | 0 | 0 | 0.3 | 0 | 0 | 0.3 | 0.9 |
| Product developer (software) | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Product developer (UIX/GUI) | €3,000.00 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Syst Administrator | | | | | | | | | | | | | | 0 |
| Energy Engineer/Consultant | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 2.9 |
| Data scientist | | | | | | | | | | | | | | 0 |
| Account Mngt / PM | | | | | | | | | | | | | | 0 |
| Content Manager (Marketing) | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Financial Qtr | | | | | | | | | | | | | | 0 |
| Salesmen/women | | | | | | | | | | | | | | 0 |
| COO | | | | | | | | | | | | | | 0 |
| Other? | | | | | | | | | | | | | | 0 |
| **Total PM** | | 0.5 | 0.5 | 0.5 | 0.3 | 0.4 | 0.6 | 0.5 | 0.5 | 0.8 | 0.6 | 0.6 | 0.9 | 6.7 |

**Figure 51: Costs (OPEX) for one year for AFAT service #1 (Manage a FlexRequest)**

The independent aggregator is a new market role, which will allow distributed flexible assets (cf. flexibility portfolio) to enter the wholesale market and more specifically, the flexibility market. Independent aggregators are now emerging in Europe, while local flexibility markets are being tried out for aggregated flexibility portfolio in real-life pilots.

The aggregator is responsible to respond to FlexRequests from the market and manage the flexibility of its portfolio in a manner that respects the day-ahead schedule of the flexibility assets and deviating from the schedule only when flexibility is activated due to a FlexRequest. The AFAT service #1 gives the aggregator access to a useful software tool, which allows the process of safely deciding the response to a FlexRequest, positive or negative, and provides the schedule of the assets in the portfolio in order to activate the required flexibility in case of a positive response. Such a software service is necessary to qualify and participate in electricity markets. As both actor and business cases involved in this service are currently being explored, no Business-As-Usual (BAU) models are suitable for a representative comparison.

FlexContracts between the independent aggregator and the end-users participating in the portfolio determine the cost of flexibility activation, which is the main cost for the independent aggregator. The revenue of the independent aggregator comes from the rewards of the FlexRequests.

In order to estimate the profit of the independent aggregator, both the cost of flexibility activation and rewards of the FlexRequests need to be considered. As the flexibility portfolio is expected to be comprised mainly of consumption assets, the direction of flexibility more suitable for consumption assets is upwards, meaning reduction of consumption. Prices for upward regulation are a reasonable assumption for the estimation of the rewards of FlexRequests, while the compensation to the end users for utilizing their flexible assets is assumed to be a bit higher than the day-ahead price. The average difference between these two prices is assumed to be 150 €/MWh. An aggregator with a flexibility portfolio of 1 MW (in capacity) is assumed to activate flexibility of about 20 MWh per month. This leads to a profit of 3.000 €/month. The fee for the AFAT service #1 is dependent on both the size/capacity of the portfolio and the total number of participating FlexAssets in the portfolio. For the purpose of this cost benefit analysis (CBA), a fixed monthly fee of 1.200 € is assumed for an aggregator with a portfolio size of 1 MW and 100 flexibility assets (i.e.,the average flexibility capacity of each FlexAsset is assumed to be 10 KW). This means that the expected net profit of the aggregator is 1.800 €/month. For this business case to be sustainable for the independent aggregator, an activation of at least 8 MWh of flexible energy per month is required.

The expected revenue stream of AFAT service #1 with a projection of a year is shown in *Figure 52*.

| | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
| Number of Aggregators | 1 | 1 | 1 | 3 | 3 | 3 | 6 | 6 | 6 | 8 | 8 | 8 | |
| Revenue | €1,200.00 | €1,200.00 | €1,200.00 | €3,600.00 | €3,600.00 | €3,600.00 | €7,200.00 | €7,200.00 | €7,200.00 | €9,600.00 | €9,600.00 | €9,600.00 | €64,800.00 |

*Figure 52: Revenue streams for one year for AFAT service #1*

**AFAT service #2 (Manage a B2C flexibility market)**

The AFAT service #2 offering includes a SaaS module regarding the implementation of a set of retail (or else behavioral real-time) pricing algorithms on demand[57] for the energy aggregator/retailer company (i.e., FLEXGRID customer). It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The aggregator customer will be able to upload its datasets (offline) onto the FLEXGRID database[58]. More specifically, the aggregator user will be able to fill in a well-explained Excel template, which contains all required FlexContract data from its portfolio. This template can be found in the FLEXGRID GitHub area[59]. It contains the following data:

- Historical energy consumption data (1-hour) for each end user's smart energy meter (cf. *"desired consumption"* Excel sheet).
- Baseload energy consumption data (1-hour) for each end user, which represents the inflexible energy consumption.
- Curtailable load data (1-hour) for each end user, which equals to (i) minus (ii).
- Shiftable load data (1-hour). For example, each end user may have one or more shiftable devices. For each user's set of shiftable devices, there is a start/end time and the deadline until which the devices can be operated.
- FlexOffer data for each end user. The FlexOffer is a 5-step curve of price/quantity pairs for each 1-hour timeslot.

After the above-mentioned "FlexContract" data have been successfully stored/updated in the FLEXGRID central database, the aggregator user will be able to use ATP GUI to perform calculations and produce results based on the aggregator user's inputs in ATP (GUI)[60]. By running several retail pricings schemes, the aggregator user will be able to evaluate the impact that new FlexContracts (with its end users) would have on the following KPIs:

- Aggregator's revenues
- Aggregated end users' welfare
- Quantity of aggregated flexibility offered to the system
- Individual end user's welfare

The operating expenses (OPEX) and required human capital for one projected year are shown in the figure below. For ICCS to offer the AFAT service #2, a total OPEX of 57,000 euros for the 1st year of market uptake (including travel and Cloud/H/W equipment and fees) and 9.5 Person Months will be

[57] In FLEXGRID, we assume an offline AFAT service #2, which means executing exhaustively "what-if business scenarios" by using historical data.

[58] Alternatively, the aggregator/retailer user will be able to send the complete xls file to the FLEXGRID admin and then the latter will be able to easily update the FlexContract data inside the FLEXGRID central database.

[59] FLEXGRID's Github - https://github.com/FLEXGRID/AFAT-service-2-manage-b2c-flexibility-market.

[60] More details about indicative inputs and outputs and respective demonstrations of AFAT service 2 will be provided in FLEXGRID D6.3.

required to serve an initial client volume of up to 5 aggregators/retailers (or else 5,000 flexible end users) until the end of the year.

Now, the critical question is: Why would it be beneficial for an aggregator's business to purchase FLEXGRID AFAT service #2? We assume the Business-As-Usual (BAU) case, in which the aggregator/retailer applies a classic Real Time Pricing (RTP with γ=0). In this case, all end users pay the same real-time price (€/kWh) in a given timeslot. Of course, this price changes every hour according to the dynamic system's need for flexibility (cf. FlexRequest in the case of an aggregator or else the cost of purchasing energy from the wholesale market in the case of a retailer). FLEXGRID AFAT service #2 proposes a behavioral RTP (B-RTP) scheme, in which each end user receives a personalized real-time price according to its individual flexibility contribution in the B2C flexibility market operated by the aggregator/retailer. Based on the scientific paper[61] results published by ICCS research team[62], we have the following case study example:

Assuming 10 end users, who pay an average of 100 €/month for their energy consumption to their retailer.The retailer company would receive 1000 €/month from these 10 end users. If a fully personalized B-RTP scheme is followed by the retailer (γ=1) every time that a FlexRequest is published, then the electricity bills can be reduced by ~15% (cf. the medium flexibility case). In other words, this means that the retailer would lose ~150 €/month[63] and the end users would pay 150 €/month less as a reward for providing their flexibility.

Then, the company should make a business decision about the percentage of its profits/cost reduction that would keep for its own interest, while the residual would be spent for providing a discount to its end users. This is not a trivial decision-making process because if the company keeps all the flexibility profits for itself, it will maximize its short-term revenues, but it may jeopardize the long-term ones given the competition with other rival companies. For example, if the company keeps the whole FLEXGRID gain (i.e., 100%) for its own, then the additional profits (or else cost reduction) for the company would be ~15% higher. If the company decides to distribute the whole FLEXGRID gain to its end users, then the electricity bills of the latter would be decreased by ~15% on average. In this case, the company's competitiveness would be increased because the end users would be much happier (i.e., would pay less while their comfort levels are not affected).

For the sake of this CBA, let us now assume that the company follows a 50%-50% allocation policy. This means that the half of the profits go to the company itself and the other half for rewarding the end users. In other words, if we assume that in the BAU scenario, the retailer has a profit margin of 20% (i.e., 200 €/month for the 10 end users), then in the FLEXGRID scenario, the additional profit would be 7.5% (i.e., 75 €/month for the 10 end users). So, for 1,000 flexible end users, the company would make 7,500 €/month excessive profit. In this case, the company would need to pay a total of 2,500 €/month for FLEXGRID AFAT service #2, so the net company's profits would be 5,000 €/month for adopting the FLEXGRID solution. On the other hand, for less than 350 flexible end users, there will not be a business case for this FLEXGRID solution.

Regarding the expected FLEXGRID revenue streams and based on the case study analysis described above, we assume a fixed monthly license per aggregator/retailer customer, which equals to 2,500 €[64]. More specifically, we assume that we will have 1 aggregator/retailer customer in the first 3

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[61] K. Steriotis et al., "A Novel Behavioral Real Time Pricing Scheme for the Active Energy Consumers' Participation in Emerging Flexibility Markets", Elsevier Sustainable Energy, Grids and Networks (SEGAN) Journal, vol. 16, pp. 14-27, Dec 2018, https://www.sciencedirect.com/science/article/pii/S2352467718300201.

[62]Link - https://www.sciencedirect.com/science/article/pii/S2352467718300201)

[63] We assume that the FlexRequest price is at least 15% greater than the retail price in order to be economically beneficial for the aggregator/retailer to operate the proposed B2C flexibility market. If we assume that the aggregator/retailer purchases electricity from the wholesale market, then the corresponding cost reduction for the company would be ~15%.

[64] An upper bound constraint for the number of what-if simulation scenario executions per month may be applied to ensure that server overloading (and thus customer quality of service degradation) is avoided.

months, 2 customers in the subsequent 3 months, while we expect that this number will rise to 5 customers by the end of the year (cf. 12,500 € in December)[65]. Conclusively, we expect a total of 80,000 € revenues, so the expected profits will then be 80,000 minus 57,000 €, which equals to 23,000 € net profit at the end of the year (or else ~29% profit margin for our FLEXGRID solution).

It should be noted that a pay-as-you-go revenue model could also be followed. In this case, each aggregator/retailer customer will pay according to the size of its portfolio (i.e., number of flexible end users)[66]. As shown in Figure 55 below, we assume that the aggregator/retailer company should pay 2.5 €/month for each flexible end user that belongs to its flexibility portfolio. Based on this, we consider a total 1,000 flexible end users (i.e., sum of end users that belong to whichever aggregator/retail company) during the first 3 months, a total of 2,000 end users for the next 3 months, ending up with an expected number of 5,000 end users until the end of Year 1. The expected net profit for FLEXGRID business is identical with the numbers mentioned above.

Finally, a third revenue model option would be that each FLEXGRID customer would be able to pay for each individual simulation scenario execution (or else a pay-as-you-go model according to the number of simulations executed via the FLEXGRID ATP). This option is expected to be more appealing for large FLEXGRID customers with a large flexibility portfolio, who may want to exploit FLEXGRID intelligence in an offline mode[67], test it via exhaustive simulations and then decide to go on with a more tightly coupled business relationship with FLEXGRID.

| | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXPENSES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| | | | | | | | | | | | | | |
| Payroll | 1300 | 1300 | 1300 | 2300 | 2300 | 2300 | 4500 | 4500 | 5000 | 5400 | 5400 | 5400 | **41000** |
| Apartment | | | | | | | | | | | | | **0** |
| Office | | | | | | | | | | | | | **0** |
| Finance cost | | | | | | | | | | | | | **0** |
| Legal services | | | | | | | | | | | | | **0** |
| Travel expenses | 500 | 500 | 500 | 500 | 500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1500 | **10000** |
| Marketing | | | | | | | | | | | | | **0** |
| Hardware/equipment | 0 | 0 | 0 | 0 | 0 | 3000 | 0 | 0 | 0 | 0 | 0 | 3000 | **6000** |
| **Total** | **1800** | **1800** | **1800** | **2800** | **2800** | **6300** | **5500** | **5500** | **6000** | **6400** | **6400** | **9900** | **57000** |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Integration developer | 0,1 | 0,1 | 0,1 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,5 | 0,5 | 0,5 | **3,9** |
| Product developer (software) | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | **2,7** |
| Product developer (UIX/GUI) | | | | | | | | | | | | | **0** |
| Syst Administrator | | | | | | | | | | | | | **0** |
| Energy Engineer/Consultant | 0,1 | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,4 | 0,4 | 0,4 | **2,9** |
| Data scientist | | | | | | | | | | | | | **0** |
| Account Mngt / PM | | | | | | | | | | | | | **0** |
| Content Manager (Marketing) | | | | | | | | | | | | | **0** |
| Financial Qtr | | | | | | | | | | | | | **0** |
| Salesmen/women | | | | | | | | | | | | | **0** |
| COO | | | | | | | | | | | | | **0** |
| **Total** | **0,3** | **0,3** | **0,3** | **0,5** | **0,7** | **0,7** | **1** | **1** | **1,1** | **1,2** | **1,2** | **1,2** | **9,5** |

***Figure 53: Costs (OPEX) for one year for AFAT service 2 (Manage a B2C flexibility market)***

[65] We could continue the current 1-year projections to several more years (e.g. 3 or 5 five years). However, the purpose of this business plan work is to show the financial trend regarding the potential increase in the profit margin curve if FLEXGRID can reach out increasingly more aggregator/retailer customers in the future.

[66] The number of FlexAssets increases the computational complexity of FLEXGRID solution and should also be taken into consideration.

[67] If an online mode, an ICT infrastructure is required to communicate with each individual FlexAsset in real-time (i.e. monitor/control). The associated ICT infrastructure costs have not been considered in FLEXGRID's draft business plan. In other words, we assume that the FLEXGRID customer has an already installed and functional "DR-ready" ICT infrastructure.

| | One Year Projection | | | | | | | | | | | | | Monthly license fee per aggregator customer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REVENUES (Europe) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| AFAT service 1 | | | | | | | | | | | | | | |
| AFAT service 2 | 2500 | 2500 | 2500 | 5000 | 5000 | 5000 | 7500 | 7500 | 10000 | 10000 | 10000 | 12500 | **80000** | 2500 |
| AFAT service 3 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **TOTAL** | **2500** | **2500** | **2500** | **5000** | **5000** | **5000** | **7500** | **7500** | **10000** | **10000** | **10000** | **12500** | **80000** | |

***Figure 54: Revenue streams for one year for AFAT service #2 (Monthly license fee revenue model)***

| | One Year Projection | | | | | | | | | | | | | Monthly pay-as-you-go fee per flexible end user (euros/month) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REVENUES (Europe) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| AFAT service 1 | | | | | | | | | | | | | | |
| AFAT service 2 | 2500 | 2500 | 2500 | 5000 | 5000 | 5000 | 7500 | 7500 | 10000 | 10000 | 10000 | 12500 | **80000** | 2,5 |
| AFAT service 3 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| **TOTAL** | **2500** | **2500** | **2500** | **5000** | **5000** | **5000** | **7500** | **7500** | **10000** | **10000** | **10000** | **12500** | **80000** | |

**Figure 55: Revenue streams for one year for AFAT service #2 (Pay-as-you-go monthly fee per end user)**

### AFAT service #3 (aggregated FlexOffer creation)

This AFAT service #3 offering includes a SaaS module regarding the implementation of an aggregated FlexOffer creation algorithm in an automated and dynamic manner for the energy aggregator company (i.e., FLEXGRID customer). It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The aggregator customer will be able to upload the required datasets offline[68] to the FLEXGRID database[69] and the AFAT will be able to perform calculations and produce results, based on the aggregator user's inputs (i.e., scenario) in ATP (GUI). More specifically, the aggregator user will be able to fill in a well-explained Excel template, which contains all required individual FlexOffer data from its portfolio.

After the above-mentioned "individual FlexOffer" data have been successfully stored/updated in the FLEXGRID central database, the aggregator user will be able to use ATP GUI to perform calculations and produce results, based on the aggregator user's inputs in ATP (GUI)[70]. The results are:

- One aggregated FlexOffer curve for up-reserve (quantity offered vs. time at a given price)
- One aggregated FlexOffer curve for down-reserve (quantity offered vs. time at a given price)
- One aggregated FlexOffer curve for up-reserve (quantity offered vs. price at a given timeslot)
- One aggregated FlexOffer curve for down-reserve (quantity offered vs. price at a given timeslot)
- Expected revenues (in euros) for the selected scenario (if FlexOffer is accepted)

The operating expenses (OPEX) and required human capital for one projected year are shown in the *Figure 56* below. For ICCS to offer the AFAT service #3, a total OPEX of 56,900 € for the 1st year of market uptake (including travel and Cloud/H/W equipment and fees) and 9.1 Person Months will be required to serve an initial client volume of up to 5 aggregators until the end of the year.

[68] Datasets required by the aggregator: For each individual FlexAsset, there is: i) one FlexOffer curve for up-reserve (quantity vs. price) for a given timeslot, ii) one FlexOffer for down-reserve (quantity vs. price for a given timeslot), and iii) location id. We assume that each FlexOffer curve includes 5 steps (i.e. 5 quantity/price pairs for each 1-hour timeslot. FLEXGRID algorithm can also support different number of steps (e.g. 10 steps), different time granularity (e.g. 15-minute timeslots) and balancing energy offers for providing near-real-time flexibility to the system operator.

[69] Alternatively, the aggregator user will be able to send the complete xls file to the FLEXGRID admin and then the latter will be able to easily update the FlexOffer data inside the FLEXGRID central database.

[70] More details about indicative inputs and outputs and respective demonstrations of AFAT service 2 will be provided in FLEXGRID D6.3.

Now, the critical question is: Why would it be beneficial for an aggregator business to purchase FLEXGRID AFAT service #3? We assume the Business-As-Usual (BAU) case, in which the aggregator aggregates the individual FlexOffers in a simplistic way by only summing them up and producing an aggregated FlexOffer curve. This means that the uncertainty of future timeslots is not taken into consideration and thus a rather static FlexOffer approach (i.e., fixed quantity and price tuples for the future timeslots) is followed. FLEXGRID AFAT service #3 proposes a ML-based algorithmic solution to address the problem of capturing the dynamic flexibility cost of a portfolio of FlexAssets within a price/quantity offer, because the FlexAssets' costs and constraints exhibit inter-temporal independencies. This miscalculation of aggregated flexibility cost can incur large imbalances for the aggregator and thus considerably reduce its expected revenues (or even destroy its business when unexpected balancing energy market price spikes occur). FLEXGRID solution aims at minimizing the aggregator's imbalance costs and thus maximizing its expected revenues/profits. Based on the scientific paper[71] results published by ICCS research team we have the following case study example:

Let us assume that an aggregator represents a portfolio of 100 flexible loads of 1 MW total capacity, which are categorized in: i) thermostatically controlled loads (i.e., HVACs, water heaters, boilers, heat pumps, etc.), and ii) Electric Vehicles (EVs). We also assume that the aggregator is a BRP of itself and thus should pay for any real-time imbalances with respect to its day-ahead energy dispatch schedule. We first showed that the accuracy of the tested ML algorithms is suitable for dynamic decision making to promptly acquire an efficient aggregated FlexOffer decision in near-real-time. Regarding the aggregator's profits, we show that whichever the imbalance price is, the aggregator's profit is always positive. This is not trivial, because if the aggregator does not submit any FlexOffers in the near-real-time TSO's balancing market and follows its day-ahead schedule, it obviously makes zero profit and if the bidding method performs poorly (e.g. resulting in major imbalances or FlexAsset costs), there is a high probability that the aggregator's profit could even be negative, because it will have to pay for the unavoidable imbalances that will occur in its portfolio (e.g. an EV/shiftable load may need to be served at a later timeslot).

We also show that the aggregator's profits are not affected by the imbalance price after a certain point, and this means that the aggregator succeeds in minimizing imbalances, which in turn indicates that the proposed ML-based method achieves a very good capturing of the aggregator's flexibility cost, i.e., the FlexOffers made by the proposed ML method do not result in dispatch decisions that the aggregator cannot eventually follow in the near-real-time balancing market operated by the TSO. The real-life business case/problem for the aggregator company is how to deal with the imbalance price spikes that tend to be continuously increasing within the last few years, while this situation is expected to be a reality because of the future high-RES penetration scenarios. ENTSO-e has recently consulted on this imbalance price spike issue[72]. In Greece, the Greek TSO confronted this issue during the last years[73]. More specifically, there were many timeslots within just one week (i.e., early Dec. 2020), when price spikes were 30-50 times higher than the average wholesale energy market price. Similar situations have happened many times in other EU countries, too. The price spike drivers are usually related with real energy shortage issues (cf. scarcity pricing concept[74]) but are also often inter-related with market manipulation phenomena.

In any case, the aggregator's business faces a business risk with very high potential impact and with relatively high probability. One solution would be to bid in a much more conservative manner, but that would mean that its profits would be considerably reduced. On the other hand, if its bid is not

[71] G. Tsaousoglou, et al., "Flexibility Aggregation and of Temporally Coupled Resources in Real Time Balancing Markets Using Machine Learning," IEEE Transactions on Industrial Informatics, December 2021, https://ieeexplore.ieee.org/document/9633146

[72] https://consultations.entsoe.eu/markets/proposal-for-amendment-of-pricing-methodology/supporting_documents/210602_Pricing%20Methodology%20Amendment%20Proposal.pdf

[73] https://www.eca-uk.com/2021/01/28/price-spikes-in-greeces-new-electricity-market-a-genuine-concern/

[74] G. Tsaousoglou, K. Petsinis, **P. Makris,** I. Skoteinos, N. Efthymiopoulos, E. Varvarigos, "A Shortage Pricing Mechanism for Capacity Remuneration and Simulation of Its Hypothetical Implementation in the Greek Balancing Market", Elsevier Utilities Policy, vol. 71, 101226, August 2021, https://doi.org/10.1016/j.jup.2021.101226

conservative, the risk of paying very high balancing energy penalties would directly endanger its business. Another solution would be to use a commercial optimization tool, but this would not satisfy the real-time requirements of this business case, because (for example) a stochastic optimization model would need to run many scenarios before a good approximation is achieved and this would entail a heavy computational task that cannot be solved in a few minutes. FLEXGRID solution aims at hedging the aggregator's business risks and thus guaranteeing its business case viability.

A fixed monthly license fee per aggregator customer may be applied for AFAT service #3 offering. However, this fee largely depends on many real-life business parameters (type of FlexAssets, diversity of FlexAssets' portfolio, imbalance market prices, up-to-date regulatory framework in a specific EU member state, etc.). As a conservative estimation, for simplicity reasons and for the sake of this CBA, we assume a 2,500 € monthly fee for a 1 MW FlexAsset portfolio of 100 FlexAssets.

We assume that we will have 1 aggregator customer in the first 3 months, 2 customers in the subsequent 3 months, while we expect that this number will rise to 5 customers by the end of the year[75]. Conclusively, we expect a total of 80,000 € revenues and 56,900 € OPEX so the expected profits at the end of the year would be ~23,000 € (or else ~29% profit margin).

It should be noted that a pay-as-you-go revenue model could also be followed. In this case, each aggregator customer would be able to pay only when it needs the AFAT service #3 offering and thus do not pay anything in time periods (i.e., even days) that it does not expect any major imbalances in the TSO's balancing market. Another pay-as-you-go option would be to charge the FLEXGRID service according to the number of FlexAssets that belong to a given aggregator company's portfolio. This also makes sense from a technical perspective, too, because the large number of FlexAssets increases the computational cost of the proposed FLEXGRID solution. Finally, a third revenue model option would be that each FLEXGRID customer would be able to pay for each individual simulation scenario execution (or else a pay-as-you-go model according to the number of simulations executed via the FLEXGRID ATP).

[75] We could continue the current 1-year projections to several more years (e.g. 3 or 5 five years). However, the purpose of this business plan work is to show the financial trend regarding the potential increase in the profit margin curve if FLEXGRID can reach out increasingly more aggregator customers in the future.

| | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EXPENSES (Europe) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
| | | | | | | | | | | | | | |
| Payroll | 1800 | 1800 | 1800 | 2700 | 2700 | 2700 | 4000 | 4000 | 4000 | 5000 | 5000 | 5400 | **40900** |
| Apartment | | | | | | | | | | | | | **0** |
| Office | | | | | | | | | | | | | **0** |
| Finance cost | | | | | | | | | | | | | **0** |
| Legal services | | | | | | | | | | | | | **0** |
| Travel expenses | 500 | 500 | 500 | 500 | 500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1500 | **10000** |
| Marketing | | | | | | | | | | | | | **0** |
| Hardware/equipment | 0 | 0 | 0 | 0 | 0 | 3000 | 0 | 0 | 0 | 0 | 0 | 3000 | **6000** |
| **Total** | **2300** | **2300** | **2300** | **3200** | **3200** | **6700** | **5000** | **5000** | **5000** | **6000** | **6000** | **9900** | **56900** |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Integration developer | | | | | | | | | | | | | **0** |
| Product developer (software) | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | **1,8** |
| Product developer (UIX/GUI) | | | | | | | | | | | | | **0** |
| Syst Administrator | | | | | | | | | | | | | **0** |
| Energy Engineer/Consultant | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | **1,2** |
| Data scientist | 0,2 | 0,2 | 0,2 | 0,4 | 0,4 | 0,4 | 0,6 | 0,6 | 0,6 | 0,8 | 0,8 | 0,9 | **6,1** |
| Account Mngt / PM | | | | | | | | | | | | | **0** |
| Content Manager (Marketing) | | | | | | | | | | | | | **0** |
| Financial Qtr | | | | | | | | | | | | | **0** |
| Salesmen/women | | | | | | | | | | | | | **0** |
| COO | | | | | | | | | | | | | **0** |
| **Total** | **0,4** | **0,4** | **0,4** | **0,6** | **0,6** | **0,6** | **0,9** | **0,9** | **0,9** | **1,1** | **1,1** | **1,2** | **9,1** |

***Figure 56: Costs (OPEX) for one year for AFAT service #3 (aggregated FlexOffer creation)***

| | One Year Projection | | | | | | | | | | | | | Monthly license fee per aggregator customer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| **AFAT service 1** | | | | | | | | | | | | | | |
| **AFAT service 2** | | | | | | | | | | | | | | |
| **AFAT service 3** | 2500 | 2500 | 2500 | 5000 | 5000 | 5000 | 7500 | 7500 | 10000 | 10000 | 10000 | 12500 | **80000** | 2500 |
| | | | | | | | | | | | | | | |
| **TOTAL** | **2500** | **2500** | **2500** | **5000** | **5000** | **5000** | **7500** | **7500** | **10000** | **10000** | **10000** | **12500** | **80000** | |

***Figure 57: Revenue streams for one year for AFAT service #3 (aggregated FlexOffer creation)***

## AFAT service offering as a whole

In the following, Figure **58** and Figure **59** the aggregated costs and benefits for all three AFAT services are presented. More specifically, both costs and revenues per AFAT service have been aggregated to produce the financial figures for the AFAT service offering. Extra fixed costs have been added that are related with all three AFAT services such as office rent, legal services, accounting services and marketing services. It should also be noted that personnel costs related with system administration and AFAT GUI functionalities have also been added and will be provided by ETRA.

After making all the required calculations, the total expected OPEX for AFAT service offering as a whole is 158,800 €, while the expected work effort is expected to be 25.5 Person Months for one year projection. On the other hand, the expected revenues will be 224,800 €, which means that the FLEXGRID AFAT's expected profit equals to 66,000 € or else ~29-30% profit margin. This estimation is quite promising towards bringing FLEXGRID AFAT services at a higher TRL and thus closer to the market uptake after the end of the project's lifetime.

| | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXPENSES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| | | | | | | | | | | | | | |
| Payroll | 5200 | 5200 | 5200 | 7500 | 8500 | 8500 | 12000 | 12000 | 13500 | 14000 | 15000 | 15400 | **122000** |
| Office (rent) | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | **6000** |
| Finance cost | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | **2400** |
| Legal services | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | **2400** |
| Travel expenses | 700 | 700 | 700 | 1000 | 1000 | 1000 | 1200 | 1200 | 1200 | 1500 | 1500 | 1500 | **13200** |
| Marketing | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | 400 | **4800** |
| Hardware/equipment | 0 | 0 | 0 | 0 | 0 | 4000 | 0 | 0 | 0 | 0 | 0 | 4000 | **8000** |
| **Total** | **7200** | **7200** | **7200** | **9800** | **10800** | **14800** | **14500** | **14500** | **16000** | **16800** | **17800** | **22200** | **158800** |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Integration developer | 0,1 | 0,1 | 0,1 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,5 | 0,5 | 0,5 | **3,9** |
| Product developer (software) | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | **4,5** |
| Product developer (UIX/GUI) | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,5 | 0,3 | 0,5 | 0,5 | **3,3** |
| Syst Administrator | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | **1,2** |
| Energy Engineer/Consultant | 0,2 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,4 | 0,5 | 0,5 | 0,5 | **4,1** |
| Data scientist | 0,2 | 0,2 | 0,2 | 0,4 | 0,4 | 0,4 | 0,6 | 0,6 | 0,6 | 0,8 | 0,8 | 0,9 | **6,1** |
| Account Mngt / Lawyer | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | **1,2** |
| Content Manager (Marketing) | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | 0,1 | **1,2** |
| | | | | | | | | | | | | | |
| **Total** | **1,1** | **1,1** | **1,1** | **1,6** | **1,8** | **1,8** | **2,5** | **2,5** | **2,8** | **2,9** | **3,1** | **3,2** | **25,5** |

**Figure 58: Costs (OPEX) for one year for AFAT service offering as a whole**

| | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| **AFAT service 1** | 1200 | 1200 | 1200 | 3600 | 3600 | 3600 | 7200 | 7200 | 7200 | 9600 | 9600 | 9600 | **64800** |
| **AFAT service 2** | 2500 | 2500 | 2500 | 5000 | 5000 | 5000 | 7500 | 7500 | 10000 | 10000 | 10000 | 12500 | **80000** |
| **AFAT service 3** | 2500 | 2500 | 2500 | 5000 | 5000 | 5000 | 7500 | 7500 | 10000 | 10000 | 10000 | 12500 | **80000** |
| | | | | | | | | | | | | | |
| **TOTAL** | **6200** | **6200** | **6200** | **13600** | **13600** | **13600** | **22200** | **22200** | **27200** | **29600** | **29600** | **34600** | **224800** |

**Figure 59: Revenue streams for one year for AFAT service offering as a whole**

## CBA for FST services

Being part of the FLEXGRID (ATP), FLEXGRID Flexibility Suppliers'(FST) consists of four service offerings, namely:

- FST service #1 (OPEX minimization)
- FST service # 2 (CAPEX minimization)
- FST service #3 (ESP's stacked revenue maximization module)
- FST service #4 (Market Price Forecasting)

Following a modular-by-design approach, each one of the above-mentioned FST service offerings can be exploited as a standalone service or any other combination (e.g., service #1 together with service #3, or service #2 together with service #4, or all four services together, etc.).

**FST service #1 (OPEX minimization)**

The FST service 1 is a SaaS module that offers an optimal scheduling strategy from an ESP perspective. This results in an operational expenditure minimization problem with various transmission-level markets considered complemented with the Reactive Distribution-Level Flexibility Market (R-DLFM). The algorithm itself is not network-aware, hence no network constraints are considered.

The ESP customer will be able to upload its portfolio/datasets (offline). This includes market prices in various transmission-level markets, alongside input for the R-DLFM market prices, and available battery storage units (BSU) capacity and power.

The ESP customer is the main user of the FST service #1, whereas the pricing isn't based on the number of ESP users, but on the total volume of managed assets' power. In that manner we acknowledge that EPSs' portfolios may vary in power and capacity.

The operating expenses (OPEX) and required human capital for one projected year are shown in the Figure 60. In order for UNIZG-FER to offer the FST service 1, a total OPEX of 108.9K Euros for the 1st year of market uptake (including travel and Cloud/H/W equipment and fees) and 14.2 Person Months will be required to serve an initial power volume of up to 45MW until the end of the year.

After debating different models of revenue streams, we have opted for a monthly license plan where ESP user, according to the total assets' power, pays fixed monthly fee. Regarding the expected FLEXGRID revenue streams and based on the case study analysis described above a fixed monthly license per MW served 600 euros per 1 MW has been decided, as shown in Figure 61.

We assume that we will have 1 ESP customer in the first 3 months with power of the flexibility assets about 5 MW. Until the end of the year, it is predicted that combined old and new FST's clients will together have 40 MW. Conclusively, we expect a total of 153K euros revenues, so the expected profits will then be 153K minus 108.9K euros, which equals to 44.1K euros profit for FLEXGRID FST service #1 offering at the end of the year.

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXPENSES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| Payroll | 3 | 3 | 3 | 5 | 5 | 5 | 7 | 8 | 8 | 8 | 8 | 8 | **71** |
| Apartment | | | | | | | | | | | | | **0** |
| Office | | | | | | | | | | | | | **0** |
| Finance cost | | | | | | | | | | | | | **0** |
| Legal services | | | | | | | | | | | | | **0** |
| Travel expenses | 1 | 1 | 1 | 1.5 | 1.5 | 1.5 | 2 | 2 | 2 | 2.5 | 2.5 | 2.5 | **21** |
| Marketing | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.7 | 0.7 | 0.7 | **4.9** |
| Hardware/equipment | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | **12** |
| Other? | | | | | | | | | | | | | |
| **Total** | **4.2** | **4.2** | **7.2** | **6.7** | **6.9** | **9.9** | **9.4** | **10.4** | **13.4** | **11.2** | **11.2** | **14.2** | **108.9** |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| Integration developer | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | **6.4** |
| Product developer (software) | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | **3.3** |
| Product developer (UIX/GUI) | | | | | | | | | | | | | **0** |
| Syst Administrator | | | | | | | | | | | | | **0** |
| Energy Engineer/Consultant | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | **4.5** |
| Data scientist | | | | | | | | | | | | | **0** |
| Account Mngt / PM | | | | | | | | | | | | | **0** |
| Content Manager (Marketing) | | | | | | | | | | | | | **0** |
| Financial Qtr | | | | | | | | | | | | | **0** |
| Salesmen/women | | | | | | | | | | | | | **0** |
| COO | | | | | | | | | | | | | **0** |
| Other? | | | | | | | | | | | | | **0** |
| **Total** | **0.6** | **0.6** | **0.6** | **1** | **1** | **1** | **1.4** | **1.6** | **1.6** | **1.6** | **1.6** | **1.6** | **14.2** |

**Figure 60: Costs (OPEX) for one year for FST service 1 (OPEX minimization)**

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | | **Monthly license fee per MW** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** | |
| FST service 1 | 3 | 3 | 3 | 6 | 6 | 6 | 18 | 18 | 18 | 24 | 24 | 24 | **153** | 0.6 |

**Figure 61: Revenue streams for one year for FST service 1 OPEX minimization - fee per MW of capacity**

### FST service #2 (CAPEX minimization)

The FST service 2 is a SaaS module that offers an optimal investment strategy from an ESP perspective. This results in an investment minimization problem. As for the CAPEX problem, OPEX results are also important. Thus, various transmission-level markets are considered alongside the Reactive Distribution-Level Flexibility Market (R-DLFM). The algorithm itself is network-aware, hence network constraints are considered.

The ESP customer will be able to upload its portfolio/datasets (offline). This includes market prices in various transmission-level markets, alongside input for the R-DLFM market prices, and already available battery storage units (BSU) capacity and power. Important input is also location of the considered flexibility assets.

The ESP customer is the main user of the FST service #2, whereas the pricing is not based on the number of ESP users, but on the total volume of managed assets' power. In that manner we acknowledge that EPSs' portfolios may vary in power and capacity.

The operating expenses (OPEX) and required human capital for one projected year are shown in the Figure 60. For UNIZG-FER to offer the FST service 1, a total OPEX of 108.9K Euros for the 1st year of market uptake (including travel and Cloud/H/W equipment and fees) and 14.2 Person Months will be required to serve an initial power volume of up to 45MW until the end of the year.

After debating different models of revenue streams, we have opted for a monthly license plan where ESP user, according to the total assets' power, pays fixed monthly fee. Regarding the expected FLEXGRID revenue streams and based on the case study analysis described above a fixed monthly license per MW served 600 euros per 1 MW has been decided, as shown in

We assume that we will have 1 ESP customer in the first 3 months with power of the flexibility assets about 5 MW. Until the end of the year, it is predicted that combined old and new FST's clients will together have 40 MW. Conclusively, we expect a total of 153K euros revenues, so the expected profits will then be 153K minus 108.9K euros, which equals to 44.1K euros profit for FLEXGRID FST service #1 offering at the end of the year.

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | | Monthly license fee per ESP customer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** | |
| FST service 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | |
| FST service 2 | 30 | 0 | 0 | 60 | 0 | 0 | 120 | 0 | 0 | 0 | 60 | 0 | **270** | |

**Figure 62: Revenue streams for one year for FST services**

**FST service #3 (ESP's stacked revenue maximization module)**

This FST service 3 offering will include a SaaS module regarding the implementation of a stacked revenue maximization algorithm on demand for the prospective profit-based ESP company (i.e. FLEXGRID customer). It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The ESP customer will be able to upload or integrate its datasets (either online or offline) on the FLEXGRID database and the FST will be able to perform calculations and produce results, based on the ESP user's inputs in ATP (GUI).

The operating expenses (OPEX) and required human capital for one projected year are shown in the Figure 63 below. For ICCS to offer the FST service 3, a total OPEX of 71K Euros for the 1st year of market uptake (including travel and Cloud/H/W equipment and fees) and 10.8 Person Months will be required to serve an initial client volume of up to 5 ESPs until the end of the year.

__Q:__ Why is 3K euros monthly revenues for FLEXGRID FST service #3 assumed? Why would it be beneficial for an ESP business to purchase FLEXGRID FST service #3?
__A:__ We assume the Business-As-Usual (BAU) case, in which the ESP participates in several energy/reserve/balancing markets in a sequential manner (i.e., making Energy/FlexOffer decisions without taking into consideration the state in the subsequent markets). FLEXGRID FST service #3 proposes ESP's co-optimized market participation to maximize its revenues. Based on the scientific paper results published by ICCS research team[76] we have the following case study example:

[76] Link - https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9557813

The ESP owns a total of 5 MW storage capacity at the DN level. The BAU daily profits are 2,415 euros, while FLEXGRID solution can offer 3,815 euros daily profits (i.e. 1,400 euros or ~58% daily profits' increase). This means that in one month the ESP can make 42,000 euros more profits and only spend 3,000 euros for FLEXGRID FST service #3. In case that an ESP owns/operates a total of 1 MW storage capacity, then it would gain ~42,000/5 = **8,400 more euros/month**, which is again quite larger than the 3,000 euros/month. On the other hand, for storage capacity less than 500 KW, there will not be a business case for FLEXGRID. In other words, CBA's result is that FLEXGRID should target for ESP businesses than own/operate at least 500 KW storage capacity.

One problem with the above-mentioned case study is that it assumes ESP's participation in the (DLFM), which is proposed by FLEXGRID project. However, this market does not exist, so if we assume that the ESP cannot participate in a DLFM, then FLEXGRID solution can offer 2,714 euros daily profits, while sequential market participation (BAU scenario) offers 1,918 euros (i.e. 796 euros or ~41% daily profits' increase). This means that in one month the ESP can make 9,500 euros more profits compared to the BAU scenario (i.e., sequential market participation). In case that an ESP owns/operates a total of 1 MW storage capacity, then it would gain ~9,500/5 = **1910 more euros/month**, which is less than the 3,000 euros/month. In other words, it is not economically beneficial for the ESP to purchase FST service #3 if it has storage capacity less than 1.6 MW. In fact, this storage capacity should be above 2-3 MW for the ESP company to be incentivized towards purchasing the FST service #3.

Regarding the expected FLEXGRID revenue streams and based on the case study analysis described above, we assume two main revenue models, namely: i) a fixed monthly license per ESP customer, which equals to 3,000 euros, and ii) a fee which is analogous to the size of the ESP storage capacity portfolio, which equals to 1,000 euros per 1 MW storage capacity.

Regarding option (i), we assume that we will have 1 ESP customer in the first 3 months, 2 customers in the subsequent 3 months, while we expect that this number will rise to 5 customers by the end of the year (cf. 15k euros in December). Conclusively, we expect a total of 96K euros revenues, so the expected profits will then be 96K minus 71K euros, which equals to 25K euros profit for FLEXGRID FST service #3 offering at the end of the year.

As of option (ii), in order for FLEXGRID business revenues to be the same with the respective OPEX (i.e., 71,000 euros), then the ESP customers should have an aggregated storage capacity of 71 MW until the end of the Year 1.

It should be noted that a pay-as-you-go revenue model could also be followed. In this case, each ESP customer would be able to pay for each individual simulation scenario execution (or else a progressive pricing model could be followed). For this revenue model to be eligible for FLEXGRID business, we would need to have several hundreds or even thousands of simulations run within a year. For example, if we had 1,000 simulation runs, this would mean that we should charge this pay-as-you-go service with ~100 euros per simulation run to have a profit of ~30,000 euros at the end of Year 1.

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXPENSES (Europe)** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
| | | | | | | | | | | | | | |
| Payroll | 1,8 | 1,8 | 1,8 | 2,8 | 2,8 | 2,8 | 4 | 4 | 5 | 5 | 5 | 6 | **42,8** |
| Apartment | | | | | | | | | | | | | **0** |
| Office | | | | | | | | | | | | | **0** |
| Finance cost | | | | | | | | | | | | | **0** |
| Legal services | | | | | | | | | | | | | **0** |
| Travel expenses | 0,5 | 0,5 | 0,5 | 0,5 | 1 | 1 | 1 | 1 | 1,5 | 1,5 | 1,5 | 1,5 | **12** |
| Marketing | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | **4,2** |
| Hardware/equipment | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | **12** |
| Other? | | | | | | | | | | | | | |
| **Total** | **2,5** | **2,5** | **5,5** | **3,5** | **4** | **7** | **5,5** | **5,5** | **10** | **7** | **7** | **11** | **71** |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Integration developer | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,4 | 0,5 | **3,2** |
| Product developer (software) | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,4 | 0,4 | 0,4 | 0,5 | **3,2** |
| Product developer (UIX/GUI) | | | | | | | | | | | | | **0** |
| Syst Administrator | | | | | | | | | | | | | **0** |
| Energy Engineer/Consultant | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,3 | **2,8** |
| Data scientist | | | | | | | | | | | | | **0** |
| Account Mngt / PM | | | | | | | | | | | | | **0** |
| Content Manager (Marketing) | | | | | | | | | | | | | **0** |
| Financial Qtr | | | | | | | | | | | | | **0** |
| Salesmen/women | | | | | | | | | | | | | **0** |
| COO | | | | | | | | | | | | | **0** |
| Other? | | | | | | | | | | | | | **0** |
| **Total** | **0,4** | **0,4** | **0,4** | **0,6** | **0,6** | **0,6** | **0,8** | **0,8** | **1,1** | **1,1** | **1,1** | **1,3** | **9,2** |

**Figure 63: Costs (OPEX) for one year for FST service 3 (ESP's stacked revenue maximization)**

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | | Monthly license fee per ESP customer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| FST service 1 | | | | | | | | | | | | | **0** | |
| FST service 2 | | | | | | | | | | | | | **0** | |
| FST service 3 | 3 | 3 | 3 | 6 | 6 | 6 | 9 | 9 | 12 | 12 | 12 | 15 | **96** | 3 |
| FST service 4 | | | | | | | | | | | | | **0** | |
| | | | | | | | | | | | | | | |
| **TOTAL** | **3** | **3** | **3** | **6** | **6** | **6** | **9** | **9** | **12** | **12** | **12** | **15** | **96** | |

**Figure 64: Revenue streams for one year for FST service 3 ESP's stacked revenue maximization – monthly license fee (revenue model option #1)**

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | | Fee per 1 MW equals to 1,000 euros |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| FST service 1 | | | | | | | | | | | | | **0** | |
| FST service 2 | | | | | | | | | | | | | **0** | |
| FST service 3 | 1 | 1 | 1 | 2 | 3 | 3 | 8 | 8 | 8 | 12 | 12 | 12 | **71** | minimum total MWs at the end of the year |
| FST service 4 | | | | | | | | | | | | | **0** | |
| | | | | | | | | | | | | | | |
| **TOTAL** | **1** | **1** | **1** | **2** | **3** | **3** | **8** | **8** | **8** | **12** | **12** | **12** | **71** | |

**Figure 65: Revenue streams for one year for FST service 3 ESP's stacked revenue maximization – fee per MW of storage capacity (revenue model option #2)**

### FST service #4 (Market Price Forecasting)

The FST service 4 will include a Day Ahead market price forecasting service. By using ATP GUI, the ESP/Aggregator user will be able to have market price forecasts for the next day for bidding areas participating in the Nord Pool's Day Ahead market. In addition, he/she will be able to get market price forecasts, actual market prices and Mean Absolute Error (MAE) for earlier dates.
The operating expenses (OPEX) and required Person Months (PMs) for one projected year are shown in Figure 66. To offer the Day Ahead market price forecasting service, the UCY will need 32,000 EUR. This amount corresponds to hardware/equipment and staff effort for 4 Person Months (PMs).

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | One Year Projection | | | | | | | | | | | | | |
| 2 | EXPENSES (Europe) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| 3 | | | | | | | | | | | | | | | |
| 4 | Payroll | 1500 | 1500 | 1500 | 1500 | 2000 | 2000 | 2000 | 2000 | 2500 | 2500 | 2500 | 2500 | 24000 | |
| 5 | Apartment | | | | | | | | | | | | | 0 | |
| 6 | Office | | | | | | | | | | | | | 0 | |
| 7 | Finance cost | | | | | | | | | | | | | 0 | |
| 8 | Legal services | | | | | | | | | | | | | 0 | |
| 9 | Travel expenses | | | | | | | | | | | | | 0 | |
| 10 | Marketing | | | | | | | | | | | | | 0 | |
| 11 | Hardware/equipment | 0 | 0 | 2000 | 0 | 0 | 2000 | 0 | 0 | 2000 | 0 | 0 | 2000 | 8000 | |
| 12 | Other? | | | | | | | | | | | | | | |
| 13 | Total | 1500 | 1500 | 3500 | 1500 | 2000 | 4000 | 2000 | 2000 | 4500 | 2500 | 2500 | 4500 | 32000 | |
| 14 | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | |
| 17 | Person Months (PMs) | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | |
| 19 | Integration developer | | | | 0,2 | 0,2 | 0,3 | | | | | | | 0,7 | |
| 20 | Product developer (software) | 0,2 | 0,2 | 0,2 | | | | | | | | | | 0,6 | |
| 21 | Product developer (UIX/GUI) | | | | | | | | | | | | | 0 | |
| 22 | Syst Administrator | | | | | | | | | | | | | 0 | |
| 23 | Energy Engineer/Consultant | | | | | | | | | | | | | 0 | |
| 24 | Data scientist | 0,1 | 0,1 | 0,1 | 0,2 | 0,2 | 0,2 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 2,7 | |
| 25 | Account Mngt / PM | | | | | | | | | | | | | 0 | |
| 26 | Content Manager (Marketing) | | | | | | | | | | | | | 0 | |
| 27 | Financial Qtr | | | | | | | | | | | | | 0 | |
| 28 | Salesmen/women | | | | | | | | | | | | | 0 | |
| 29 | COO | | | | | | | | | | | | | 0 | |
| 30 | Other? | | | | | | | | | | | | | 0 | |
| 31 | Total | 0,3 | 0,3 | 0,3 | 0,4 | 0,4 | 0,5 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 4 | |
| 32 | | | | | | | | | | | | | | | |

**Figure 66: Costs (OPEX) for one year for FST service 4 (Market Price Forecasting)**

Regarding the expected FLEXGRID revenue (see Figure 67), we assume a fixed monthly license per ESP/Aggregator customer, which equals to 800 EUR. Also, we assume that the ESP/Aggregator will give a profit close to 1,500 EUR per month from load reductions. So, from 1,500 EUR, 800 EUR will be paid for the Day Ahead market price forecasts and will has a profit of 700 EUR. Note that there is no reference. These amounts are a pure assumption.
Other assumptions: We will have 1 ESP/Aggregator customer in the first 3 months, 2 customers in the subsequent 3 months, 3 customers in the subsequent 3 months and 4 customers in last three months.
Revenue (1st year)*:* 24,000-32,000=-8,000.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | One Year Projection | | | | | | | | | | | | | Monthly license fee per ESP/Aggregator customer |
| 2 | REVENUES (Europe) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total | |
| 3 | FST service 1 | | | | | | | | | | | | | 0 | |
| 4 | FST service 2 | | | | | | | | | | | | | 0 | |
| 5 | FST service 3 | | | | | | | | | | | | | 0 | |
| 6 | FST service 4 | 800 | 800 | 800 | 1600 | 1600 | 1600 | 2400 | 2400 | 2400 | 3200 | 3200 | 3200 | 24000 | 800 |
| 7 | | | | | | | | | | | | | | | |
| 8 | TOTAL | 800 | 800 | 800 | 1600 | 1600 | 1600 | 2400 | 2400 | 2400 | 3200 | 3200 | 3200 | 24000 | |
| 9 | | | | | | | | | | | | | | | |

**Figure 67: Revenue streams for one year for FST service 4 (Market Price Forecasting)**

### FST service common costs

FlexSuppliers' Toolkit currently includes four different services that share the same target user and provide help and guidance in various ways. Although technical, human, and financial resources do vary between the four services, many costs may be shared. Hence, we list here the costs that apply for the FST service as whole.

| in .000 (thousand euros) | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXPENSES (Europe)** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| | | | | | | | | | | | | | |
| Payroll | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| Apartment | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | **9.6** |
| Office | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | **18** |
| Finance cost | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | **11** |
| Legal services | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **12** |
| Travel expenses | | | | | | | | | | | | | **0** |
| Marketing | 1.2 | 1.2 | 1.2 | 1.2 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.7 | 1.7 | 1.7 | **17.4** |
| Hardware/equipment | | | | | | | | | | | | | **0** |
| Other? | | | | | | | | | | | | | |
| **Total** | **5.5** | **5.5** | **5.5** | **5.5** | **5.8** | **5.8** | **5.8** | **5.8** | **5.8** | **6** | **6** | **5** | **68** |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Person Months (PMs)** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Integration developer | | | | | | | | | | | | | **0** |
| Product developer (software) | | | | | | | | | | | | | **0** |
| Product developer (UIX/GUI) | | | | | | | | | | | | | **0** |
| Syst Administrator | 1 | 1 | 1 | 1 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.5 | 1.5 | 1.5 | **14.5** |
| Energy Engineer/Consultant | | | | | | | | | | | | | **0** |
| Data scientist | | | | | | | | | | | | | **0** |
| Account Mngt / PM | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **12** |
| Content Manager (Marketing) | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.7 | 0.7 | 0.7 | **5.8** |
| Financial Qtr | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | **6** |
| Salesmen/women | 0.3 | 0.3 | 0.3 | 0.3 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.9 | 0.9 | 0.9 | **6.9** |
| COO | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | **9.6** |
| Other? | | | | | | | | | | | | | **0** |
| **Total** | **3.9** | **3.9** | **3.9** | **3.9** | **4.6** | **4.6** | **4.6** | **4.6** | **4.6** | **5.4** | **5.4** | **5.4** | **54.8** |

These common costs are estimated at about 68K for the observed year. When counted with the estimated revenues from all of the FST services, we conclude that FST may be profitable in the first year of commercial existence.

## CBA for FMCT services

Being part of the FLEXGRID (ATP), FLEXGRID (FMCT) consists of three service offerings, namely:

- FMCT Use Case 2 (Active Power Reserve Market Clearing)
- FMCT Use Case 3 (Reactive Power Reserve Market Clearing)

Following a modular-by-design approach, each one of the above-mentioned FMCT service offerings can be exploited as a standalone service or any other combination.

**FMCT Service #2 (Active Power Reserve Market Clearing)**

The FMCT Use case #2 offering includes a module for the FMO that clears the DLFM for active power reserves in a continuous fashion or as an auction. It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The FMO user will be able to run the market clearing algorithm with the input data from the DSO (distribution network, setpoints, FlexRequests) and input data from the FSP (FlexOffers). Furthermore, the FMO user and DSO user will be able to run "what-if" scenarios and upload its datasets (offline) onto the FLEXGRID database. The required input data for the market clearing includes:

i) Distribution network data: The data that physically defines the distribution network and its constraints (i.e. nodes, lines, resistance, susceptance, min/max line loading, latitude, longitude, min/max voltage, voltage angle, shunt reactance).
ii) Setpoints: (1-hour) for each end node, the active and reactive power injections per time step.
iii) FlexRequest data: A set of FlexRequests by the DSO that specify the node and time step at which flexibility is needed.
iv) FlexOffer data: A set of FlexOffers from one or more FSPs that specify the node and time step at which flexibility is offered.

After the above-mentioned "DLFM" data have been successfully stored/updated in the FLEXGRID central database, then the FMO-user will be able to use ATP GUI to perform calculations and produce results based on the aggregator user's inputs in ATP (GUI)[77]. Via running several scenarios with different sets of FlexOffers the FMO user will be able to evaluate the impact that FlexOffers would have on the following KPIs:

i) DSO's cost/revenues
ii) Social welfare
iii) FSP's revenues
iv) Energy not served (ENS)
v) Curtailment
vi) Total Procured Flexibility

The operating expenses (OPEX) and required human capital for one projected year are shown in the figure below. In order for DTU to offer the FMCT use case #2, a total OPEX of 15,000 euros for the 1st year of market uptake (including product development and payrolls) and 0.4 Person Months will be required to serve an initial client volume of 1 DSO/aggregator until the end of the year.

Now, the critical question is: Why would it be beneficial for an aggregator's business to purchase FLEXGRID FMCT Use case #2? We assume the Business-As-Usual (BAU) case, in which the aggregator/retailer applies a classic network aware market clearing without any flexibility offers or

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requests. In this case, the DSO might be forced to curtail some generation or not serve some of the demand due to the network constraints. The demand in the network will be changing every hour according to an hourly load profile. FLEXGRID FMCT use case#2 proposes a network aware market clearing algorithm which will match the available flexibility offered in the system with the requests.

Let us assume we have 1 DSO, who is using the FMCT interface for clearing their active power reserve market. In this UCS, we considered a Flexibility Market Operator (FMO), who clears a local *active* power *reserve* market after (R-DLFM) the transmission level commitments have been cleared. This means that some of the local generators and loads may already have committed parts of their energy and/or reserve to the wholesale transmission level. The FMO gathers all FlexRequests and FlexOffers for a given timeframe. At gate closure, no further bids are accepted and the network-aware auction-based market clearing algorithm runs. The aim of the FMO is to maximize social welfare by matching all bids that result in feasible power flows. Without loss of generality and within FLEXGRID's context, we assume that the full network model of the DSO is known to the FMO, as well as the active and reactive power setpoints committed in the wholesale transmission level market.

For the CBA results of the network-aware market clearing in UCS 1.2 are evaluated with respect to the reference case without any flexibility in the system. The reference (*ref*) scenario is detailed in the following: The radial 81-bus system is modified in order to represent a future with some renewable penetration and EV penetration. To that end, the setpoints of the system are modified to increase the loads; 87% of all loads have 3kW and 13% of all loads have 4kW. We assume that the baseline dispatch (initial setpoint) is known and results in non-zero values of energy-not served (ENS) and curtailment over the year. For simplicity and to demonstrate our approach, we consider a power factor for all the loads in the system. Additionally, we add three wind farms with an installed capacity of 0.2 MW, 0.1 MW, and 0.2 MW respectively.

The cost of curtailment is assumed 60 €/MWh, the value of lost load is 200 €/MWh. Reserve activation costs are assumed 0, since we consider that the flexibility providers have no operational expenses or opportunity cost. FlexRequest and FlexOffers are generated since there is no DLFM today from which data can be fetched. FlexRequests for reserves are priced at 70 €/MWh for up- and 40 €/MWh for down-regulation. FlexOffers are priced randomly between 25 €/MW and 35 €/MW sampled from a uniform distribution. The yearly load profile and wind generation profile used for the analysis is available here.

The cost and additional revenue generation as compared to the base case is given in Table 65 and Table 66 respectively.

**Table 65: Costs (OPEX) for one year for FMCT service #2**

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Recurring Costs** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| Payroll | | €1,200.00 | €1,200.00 | €900.00 | €600.00 | €900.00 | €900.00 | €1,200.00 | €1,200.00 | €2,400.00 | €1,500.00 | €1,500.00 | €1,500.00 | €15,000.00 |
| Apartment | | | | | | | | | | | | | | €0.00 |
| Office | | | | | | | | | | | | | | €0.00 |
| Finance cost | | | | | | | | | | | | | | €0.00 |
| Legal services | | | | | | | | | | | | | | €0.00 |
| Travel expenses | | | | | | | | | | | | | | €0.00 |
| Marketing | | | | | | | | | | | | | | €0.00 |
| Hardware/equipment | | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 |
| Other? | | | | | | | | | | | | | | |
| **Total** | | €1,200.00 | €1,200.00 | €900.00 | €600.00 | €900.00 | €900.00 | €1,200.00 | €1,200.00 | €2,400.00 | €1,500.00 | €1,500.00 | €1,500.00 | €15,000.00 |
| **Person Months (PMs)** | **PM Cost** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total PM** |
| Integration developer | €3,000.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 |
| Product developer (software) | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Product developer (UIX/GUI) | €3,000.00 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.6 |
| Syst Administrator | | | | | | | | | | | | | | 0 |
| Energy Engineer/Consultant | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 2.9 |
| Data scientist | | | | | | | | | | | | | | 0 |
| Account Mngt / PM | | | | | | | | | | | | | | 0 |
| Content Manager (Marketing) | €3,000.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Financial Qtr | | | | | | | | | | | | | | 0 |
| Salesmen/women | | | | | | | | | | | | | | 0 |
| COO | | | | | | | | | | | | | | 0 |
| Other? | | | | | | | | | | | | | | 0 |
| **Total PM** | | 0.4 | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.8 | 0.5 | 0.5 | 0.5 | 5 |

**Table 66:Revenue streams for one year for FMCT service #2**

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| UCS 1.2 | Number of Aggregators | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Revenue | € 15,612.80 | € 12,764.53 | € 12,262.60 | € 8,021.98 | € 11,583.35 | € 11,947.05 | € 8,871.00 | € 10,797.05 | € 14,644.53 | € 14,502.66 | € 21,243.63 | € 11,224.41 | €153,475.59 |

### FMCT Service #3 (Reactive Power Reserve Market Clearing)

The FMCT service #3 offering includes a module regarding the implementation of a bunch of retail (or else behavioral real-time) pricing algorithms on demand for the energy aggregator/retailer company (i.e., FLEXGRID customer). It should be noted that the respective GUIs are provided by ETRA via the ATP offering.

The FMO user will be able to run the market clearing algorithm with the input data from the DSU (distribution network, setpoints, FlexRequests) and input data from the FSP (FlexOffers). Furthermore, the FMO user, DSO user, and aggregator customer will be able to run "what-if" scenarios and upload its datasets (offline) onto the FLEXGRID database[78]. More specifically, the aggregator user will be able to fill in a well-explained xls template, which contains all required FlexContract data from its portfolio. This xls template can be found in the FLEXGRID GitHub area: https://github.com/FLEXGRID/AFAT-service-2-manage-b2c-flexibility-market. The xls template contains the following data The required input data for the market clearing includes:

i) Distribution network data: The data that physically defines the distribution network and its constraints ( i.e. (nodes, lines, resistance, susceptance, min/max line loading, latitude, longitude, min/max voltage, voltage angle, shunt reactance). 1-hour) for each end user's smart energy meter (cf. *"desired consumption"* xls sheet).

ii) Setpoints:Baseload energy consumption data (1-hour) for each end nodeuser, the active and reactive power injections per time stepwhich represents the inflexible energy consumption.

iii) FlexRequest data:Curtailable load data (1-hour) A set of FlexRequests by the DSO that specify the node and time step at which flexibility is neededfor each end user, which equals to (i) minus (ii).

[78] Alternatively, the aggregator/retailer user will be able to send the complete xls file to the FLEXGRID admin and then the latter will be able to easily update the FlexContract data inside the FLEXGRID central database.

iv) Shiftable load data (1-hour). For example, each end user may have one or more shiftable devices. For each user's set of shiftable devices, there is a start/end time and the deadline until which the devices can be operated.

v) FlexOffer data: A set of FlexOffers from one or more FSPs that specify the node and time step at which flexibility is offered. for each end user, which equals to (i) minus (ii).for each end user. The FlexOffer is a 5-step curve of price/quantity pairs for each 1-hour timeslot.

After the above-mentioned "DLFMFlexContract" data have been successfully stored/updated in the FLEXGRID central database, then the FMOaggregator user will be able to use ATP GUI to perform calculations and produce results based on the aggregator user's inputs in ATP (GUI)[79]. Via running several scenarios with different sets of FlexOffersthe FMOretail pricing schemes, the aggregator user will be able to evaluate the impact that new FlexOffersContracts (with its end users) would have on the following KPIs:

vii) DSOAggregator's cost/revenues
viii) Social welfare
ix) FSP's revenues
x) Energy not served (ENS)
xi) Curtailment
xii) Total Procured FlexibilityQuantity of aggregated flexibility offers and requests matched in the system

The operating expenses (OPEX) and required human capital for one projected year are shown in the figure below. In order for DTU to offer the FMCT services #3 or #2 separately or together a total OPEX of 15,000 euros for the 1st year of market uptake (including product development and payrolls) and 0.4 Person Months will be required to serve an initial client volume of 1 DSO/aggregator until the end of the year.

Now, the critical question is: Why would it be beneficial for an aggregator's business to purchase FLEXGRID FMCT Use case #3? We assume the Business-As-Usual (BAU) case, in which the aggregator/retailer applies a classic network aware market clearing without any flexibility offers or requests. In this case, the DSO might be forced to curtail some generation or not serve some of the demand due to the network voltage or line flow constraints. The demand in the network will be changing every hour according to an hourly load profile. FLEXGRID FMCT service #3 proposes a network aware reactive power market clearing algorithm which will match the available flexibility offered in the system with the requests.

Let us assume we have 1 DSO, who is using the FMCT interface for clearing their reactive power reserve market. In this UCS, we considered a Flexibility Market Operator (FMO), who clears a local *receive* power *reserve* market after (R-DLFM) the transmission level commitments have been cleared. This means that some of the local generators and loads may already have committed parts of their energy and/or reserve to the wholesale transmission level. The FMO gathers all FlexRequests and FlexOffers for a given timeframe. At gate closure, no further bids are accepted and the network-aware auction-based market clearing algorithm runs. The aim of the FMO is to maximize social welfare by matching all bids that result in feasible power flows. Without loss of generality and within FLEXGRID's context, we assume that the full network model of the DSO is known to the FMO, as well as the active and reactive power setpoints committed in the wholesale transmission level market.

[79] More details about indicative inputs and outputs and respective demonstrations of AFAT service 2 will be provided in FLEXGRID D6.3.

For the CBA results of the network-aware market clearing in UCS 1.3 are evaluated with respect to the reference case without any flexibility in the system. The reference (*ref*) scenario is detailed in the following: The radial 81-bus system is modified in order to represent a future with some renewable penetration and EV penetration. To that end, the setpoints of the system are modified to increase the loads; 87% of all loads have 3kW and 13% of all loads have 4kW. We assume that the baseline dispatch (initial setpoint) is known and results in non-zero values of energy-not served (ENS) and curtailment over the year. For simplicity and to demonstrate our approach, we consider a power factor for all the loads in the system. Additionally, we add three wind farms with an installed capacity of 0.2 MW, 0.1 MW, and 0.2 MW respectively.

The cost of reactive power curtailment is assumed 0 €/MWh, the value of lost load (reactive) is also assumed to be 0€/MWh. Reserve activation costs are assumed 0, since we consider that the flexibility providers have no operational expenses or opportunity cost. FlexRequest and FlexOffers are generated since there is no DLFM today from which data can be fetched. FlexRequests for reserves are priced at 70 €/MWh for up- and 40 €/MWh for down-regulation. FlexOffers are priced randomly between 25 €/MW and 35 €/MW sampled from a uniform distribution. The yearly load profile and wind generation profile used for the analysis is available here[80].

The cost and additional revenue generation as compared to the base case is given in Figure 68 and Figure 69 respectively. The revenues for UCS 1.3 are coming out to be negative for the DSO because as of now it hasn't been assigned any cost to the reactive power energy not served or curtailed. Further study will be needed to properly price these quantities

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Recurring Costs** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| Payroll | | €1,200.00 | €1,200.00 | €900.00 | €600.00 | €900.00 | €900.00 | €1,200.00 | €1,200.00 | €2,400.00 | €1,500.00 | €1,500.00 | €1,500.00 | €15,000.00 |
| Apartment | | | | | | | | | | | | | | €0.00 |
| Office | | | | | | | | | | | | | | €0.00 |
| Finance cost | | | | | | | | | | | | | | €0.00 |
| Legal services | | | | | | | | | | | | | | €0.00 |
| Travel expenses | | | | | | | | | | | | | | €0.00 |
| Marketing | | | | | | | | | | | | | | €0.00 |
| Hardware/equipment | | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 | €0.00 |
| Other? | | | | | | | | | | | | | | |
| **Total** | | €1,200.00 | €1,200.00 | €900.00 | €600.00 | €900.00 | €900.00 | €1,200.00 | €1,200.00 | €2,400.00 | €1,500.00 | €1,500.00 | €1,500.00 | €15,000.00 |
| **Person Months (PMs)** | **PM Cost** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total PM** |
| Integration developer | €3,000.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 0 | 0.3 |
| Product developer (software) | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 1.2 |
| Product developer (UIX/GUI) | €3,000.00 | 0.2 | 0.2 | 0.1 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 | 0 | 0.6 |
| Syst Administrator | | | | | | | | | | | | | | 0 |
| Energy Engineer/Consultant | €3,000.00 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 2.9 |
| Data scientist | | | | | | | | | | | | | | 0 |
| Account Mngt / PM | | | | | | | | | | | | | | 0 |
| Content Manager (Marketing) | €3,000.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Financial Qtr | | | | | | | | | | | | | | 0 |
| Salesmen/women | | | | | | | | | | | | | | 0 |
| COO | | | | | | | | | | | | | | 0 |
| Other? | | | | | | | | | | | | | | 0 |
| **Total PM** | | 0.4 | 0.4 | 0.3 | 0.2 | 0.3 | 0.3 | 0.4 | 0.4 | 0.8 | 0.5 | 0.5 | 0.5 | 5 |

**Figure 68. Costs (OPEX) for one year for FMCT service #2 and #3**

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **REVENUES (Europe)** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| UCS 1.2 | Number of Aggregators | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Revenue | € 15,612.80 | € 12,764.53 | € 12,262.60 | € 8,021.98 | € 11,583.35 | € 11,947.05 | € 8,871.00 | € 10,797.05 | € 14,644.53 | € 14,502.66 | € 21,243.63 | € 11,224.41 | €153,475.59 |
| UCS 1.3 | Number of Aggregators | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Revenue | -€ 18,063.31 | -€ 15,807.01 | -€ 16,800.99 | -€ 14,049.64 | -€ 15,077.03 | -€ 15,954.55 | -€ 14,713.51 | -€ 15,327.97 | -€ 17,320.18 | -€ 17,142.07 | -€ 18,932.07 | -€ 16,500.45 | -€195,688.78 |

**Figure 69. Revenue streams for one year for FMCT service #2 and #3**

[80] European-Transmission-and-Market-Models: GitHub - antosat/European-Transmission-and-Market-Models

**FMCT service common costs**

For DTU to offer the FMCT services #3 or #2 together, a total OPEX of 15,000 euros for the 1st year of market uptake (including product development and payrolls) and 0.4 Person Months will be required to serve an initial client volume of 1 DSO/aggregator until the end of the year (as if the services were separately offered due to the way the algorithm is define). The case #3 analysis does not show a real benefit as the inputs form the economical point for view regarding the DSO information are not clear enough. At this stage and considering the novelty of the algorithms developed it is not possible to extract clear conclusion for the CBA of the whole FMCT services.

## CBA for ATP services

The ATP is a platform that will work as a common place for the different actors to deliver and run simulations to define the best strategy for participation on the flexibility markets. The ATP is formed by the three main modules developed during the project, each of which hosts the different algorithms that are the backbone of the platform.

Additionally, to the specific costs per services presented on the previous annexes, the platform as a whole has an additional cost regarding operation and maintenance. In the figure below the additional costs are presented.

| | | One Year Projection | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Recurring Costs** | | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| Payroll (O&M) | | €3.250,00 | €250,00 | €0,00 | €250,00 | €0,00 | €1.250,00 | €0,00 | €250,00 | €900,00 | €0,00 | €0,00 | €750,00 | €6.900,00 |
| O&M | | €750,00 | €0,00 | €0,00 | €0,00 | €0,00 | €750,00 | €0,00 | €0,00 | €0,00 | €0,00 | €0,00 | €0,00 | €1.500,00 |
| Hardware/equipment | | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €250,00 | €3.000,00 |
| Legal services | | | | | | | | | | | | | | €0,00 |
| Travel expenses | | | | | | | | | | | | | | €0,00 |
| Marketing | | | | | | | | | | | | | | €0,00 |
| Other? | | | | | | | | | | | | | | |
| **Total** | | €4.250,00 | €500,00 | €250,00 | €500,00 | €250,00 | €2.250,00 | €250,00 | €500,00 | €1.150,00 | €250,00 | €250,00 | €1.000,00 | €11.400,00 |
| **Person Months (PMs)** | **PM Cost** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total PM** |
| Integration developer | €3.000,00 | 0,5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,3 | 0 | 0 | 0 | 0,8 |
| Product developer (software) | | | | | | | | | | | | | | 0 |
| Product developer (UIX/GUI) | €2.500,00 | 0,2 | 0,1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,3 |
| Syst Administrator | €2.500,00 | 0,3 | 0 | 0 | 0 | 0 | 0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0,6 |
| Energy Engineer/Consultant | €2.500,00 | 0,1 | 0 | 0 | 0 | 0 | 0,2 | 0 | 0 | 0 | 0 | 0 | 0,2 | 0,5 |
| Data scientist | | | | | | | | | | | | | | 0 |
| Account Mngt / PM | | | | | | | | | | | | | | 0 |
| Content Manager (Marketing) | €2.500,00 | 0,1 | 0 | 0 | 0,1 | 0 | 0 | 0 | 0,1 | 0 | 0 | 0 | 0,1 | 0,4 |
| Financial Qtr | | | | | | | | | | | | | | 0 |
| Salesmen/women | | | | | | | | | | | | | | 0 |
| COO | | | | | | | | | | | | | | 0 |
| Other? | | | | | | | | | | | | | | 0 |
| **Total PM** | | 1,2 | 0,1 | 0 | 0,1 | 0 | 0,5 | 0 | 0,1 | 0,3 | 0 | 0 | 0,3 | 2,6 |

**Figure 70. Added costs (OPEX) of operating the ATP**

Most of the added costs for the ATP will be related with the maintenance of the serves in which the ATP would be installed, and also the personnel costs related with the possible needs of APIs adaptation to new market characteristics. Finally, the control of the possible bugs and programing problems will also represent a significant part of the added cost.

Based on the costs and the potential revenues, it is possible to perform a simple CBA to see the benefits of owing the ATP. Figure 71 and Figure 72 below show the total OPEX of the ATP and the potential revenues identified throughout this annex.

| Service/Module | COSTS per services | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Total |
| **AFAT service 1** | 1.500 € | 1.500 € | 3.500 € | 900 € | 1.200 € | 3.800 € | 1.500 € | 1.500 € | 4.400 € | 1.800 € | 1.800 € | 4.700 € | **28.100 €** |
| **AFAT service 2** | 1.800 € | 1.800 € | 1.800 € | 2.800 € | 2.800 € | 6.300 € | 5.500 € | 5.500 € | 6.000 € | 6.400 € | 6.400 € | 9.900 € | **57.000 €** |
| **AFAT service 3** | 2.300 € | 2.300 € | 2.300 € | 3.200 € | 3.200 € | 6.700 € | 5.000 € | 5.000 € | 5.000 € | 6.000 € | 6.000 € | 9.900 € | **56.900 €** |
| **FST service 1** | 4.200 € | 4.200 € | 7.200 € | 6.700 € | 6.900 € | 9.900 € | 9.400 € | 10.400 € | 13.400 € | 11.200 € | 11.200 € | 14.200 € | **108.900 €** |
| **FST service 2** | 2.500 € | 2.500 € | 5.500 € | 5.500 € | 4.000 € | 7.000 € | 5.500 € | 5.500 € | 10.000 € | 7.000 € | 7.000 € | 11.000 € | **73.000 €** |
| **FST service 3** | 2.500 € | 2.500 € | 5.500 € | 5.500 € | 4.000 € | 7.000 € | 5.500 € | 5.500 € | 10.000 € | 7.000 € | 7.000 € | 11.000 € | **73.000 €** |
| **FST service 4** | 1.500 € | 1.500 € | 3.500 € | 1.500 € | 2.000 € | 4.000 € | 2.000 € | 2.000 € | 4.500 € | 2.500 € | 2.500 € | 4.500 € | **32.000 €** |
| **FMCT** | 1.200 € | 1.200 € | 900 € | 600 € | 900 € | 900 € | 1.200 € | 1.200 € | 2.400 € | 1.500 € | 1.500 € | 1.500 € | **15.000 €** |
| **ATP as a whole** | 4.250 € | 500 € | 250 € | 500 € | 250 € | 2.250 € | 250 € | 500 € | 1.150 € | 250 € | 250 € | 1.000 € | **11.400 €** |
| **TOTAL** | **17.500 €** | **17.500 €** | **30.200 €** | **26.700 €** | **25.000 €** | **45.600 €** | **35.600 €** | **36.600 €** | **55.700 €** | **43.400 €** | **43.400 €** | **66.700 €** | **455.300 €** |

**Figure 71. Total OPEX cost of the ATP including the all the services.**

| Service/Module | REVENUES per services | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sept** | **Oct** | **Nov** | **Dec** | **Total** |
| **AFAT Customers** | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 4 | 5 | 6 | 7 | 7 | **7** |
| **FST customers** | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 5 | **5** |
| **FMCT customers** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **1** |
| MW | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **AFAT service 1** | 1.200 € | 1.200 € | 1.200 € | 2.400 € | 2.400 € | 2.400 € | 4.800 € | 4.800 € | 6.000 € | 7.200 € | 8.400 € | 8.400 € | **50.400 €** |
| **AFAT service 2** | 2.500 € | 2.500 € | 2.500 € | 5.000 € | 5.000 € | 5.000 € | 10.000 € | 10.000 € | 12.500 € | 15.000 € | 17.500 € | 17.500 € | **105.000 €** |
| **AFAT service 3** | 2.500 € | 2.500 € | 2.500 € | 5.000 € | 5.000 € | 5.000 € | 10.000 € | 10.000 € | 12.500 € | 15.000 € | 17.500 € | 17.500 € | **105.000 €** |
| **FST service 1** | 600 € | 600 € | 600 € | 600 € | 1.800 € | 1.800 € | 1.800 € | 2.400 € | 2.400 € | 3.000 € | 3.000 € | 3.000 € | **21.600 €** |
| **FST service 2** | 600 € | 600 € | 600 € | 600 € | 1.800 € | 1.800 € | 1.800 € | 2.400 € | 2.400 € | 3.000 € | 3.000 € | 3.000 € | **21.600 €** |
| **FST service 3** | 3.000 € | 3.000 € | 3.000 € | 3.000 € | 9.000 € | 9.000 € | 9.000 € | 12.000 € | 12.000 € | 15.000 € | 15.000 € | 15.000 € | **108.000 €** |
| **FST service 4** | 800 € | 800 € | 800 € | 800 € | 2.400 € | 2.400 € | 2.400 € | 3.200 € | 3.200 € | 4.000 € | 4.000 € | 4.000 € | **28.800 €** |
| **FMCT** | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | 2.500 € | **30.000 €** |

**Figure 72. ATP revenue projection considering all the services.**

Based on the projections made in this annex and considering that each service is managing only 1MW of capacity, the FLEXGRID ATP has potential to be profitable during the first year of operation. The potential expected turnover would be 15,100 €. This shows very limited profitability of the platform, which shows the need expand the pool of clients during the coming years if the service aims to be viable.