Demonstration of **Inte**lligent grid technologies for renewables **Inte**gration and **Inte**ractive consumer participation enabling **Inte**roperable market solutions and **Inte**rconnected stakeholders

WP 8 – Replicability, scalability and exploitation

Economic and regulatory scalability and replicability of the InteGrid smart grid functionalities

D8.2

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Executive Summary

This report presents the results of the work done in Tasks 8.3 - Economic SRA of the implemented smart grid functionalities - and 8.4 - Regulatory replicability of the implemented smart grid functionalities - of the InteGrid project.

The different InteGrid HLUCs are grouped into four different clusters. The first group, named “Flexibility Management for Optimized MV Network Operation”, comprises HLUC01, HLUC06 and HLUC12 (technical VPP). The HLUC01 scope is the short-term management of distributed energy resources (DER) to solve grid constraints (e.g. voltage or congestions) and to optimize MV network operation (such as losses minimization) in different locations and periods. The second group, the “Flexibility Management for Optimized LV Network Operation” cluster, integrates HLUC02, HLUC06 and HLUC09. HLUC02 concerns the voltage control of LV grids instead, leveraging the flexibility from the resources owned by the DSO or the one stemming from domestic customers equipped with the Home Energy Management System (HLUC09). The third group, the “Large customer cVPP” cluster, joins HLUC05, HLUC06, HLUC08 and HLUC12 (commercial VPP). MV industrial customers with flexibility capabilities, such as wastewater treatment plants (HLUC08), can make available their flexibility for manual frequency restoration reserve (mFRR) services to the TSO, through an independent market player known as commercial Virtual Power Plant (HLUC12). Finally, the fourth cluster, named “Office Buildings Aggregation”, combines HLUC10 and HLUC06. Office buildings flexibility equipped with chilling systems can either be exploited to manage imbalances by a Balance Responsible Party (BRP) or to be sold on Frequency Restauration Reserve (FRR) markets. This flexibility is communicated via gm-hub (HLUC06), which is in the heart of InteGrid and is common to all clusters.

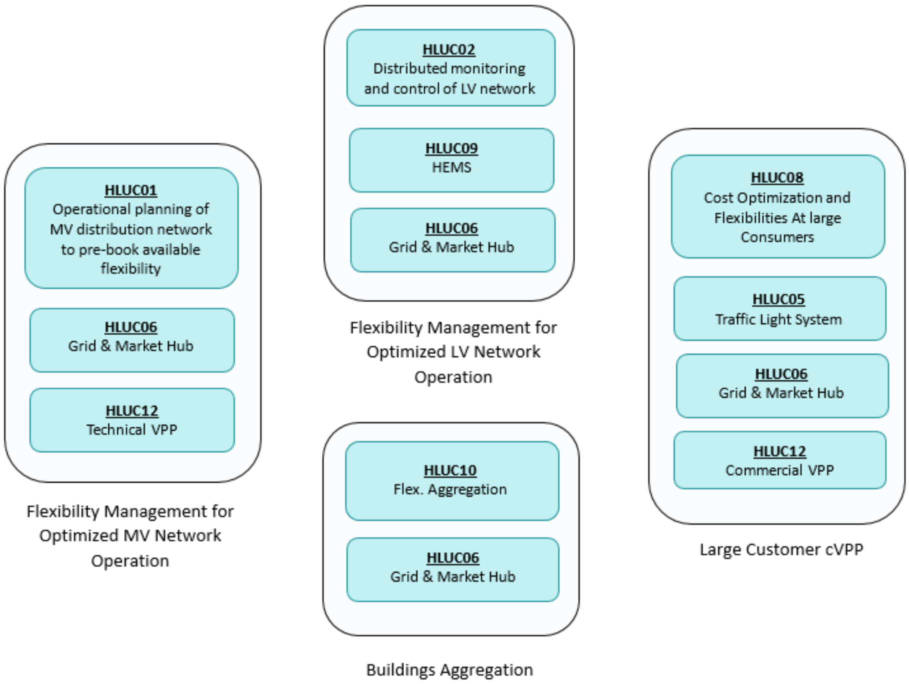


Figure 1: Grouping of the HLUC within four clusters.

The structure of this document can be divided into three main acts, where the complete analysis under the different points of view and their interaction are exposed. Firstly, the deliverable presents an analysis of the economic impact of scaling-up and replicate a set of InteGrid solutions. Based on the results obtained in the technical SRA analysis from Task 8.1, and after defining a set of scenarios and assumptions, the aforementioned clusters have been assessed to determine its economic interest under different technical and macroeconomic conditions, monetizing both involved costs and benefits. An international replicability analysis has been performed for Portugal and Slovenia, two of the demo countries, whenever possible. An allocation of costs and benefits among stakeholders, prior to the definition of suitable regulation, is also presented. Finally, some of the input variables have been subject to sensitivity analysis and, in the most relevant cases, to Monte Carlo simulation.

Furthermore, as a complement to the technical and economic SRA, and building on the work of WP7, the suitability of the regulatory conditions to allow the deployment of the proposed solutions has been analysed through a regulatory replicability analysis. In order to enrich such study, a set of countries, beyond those evaluated in WP7 (Portugal, Slovenia, Sweden, Austria and Spain), has been considered. The main goal is to identify the regulatory factors that may act as barriers or enablers for an effective and efficient deployment of the proposed technologies and solutions.

Lastly, this report also combines the outcomes of both previous analyses in order to discuss how regulation may affect the economic consequences of replication and scaling-up, i.e. how regulation affects the allocation of costs and benefits among stakeholders, internalization of external costs, etc.

Economic SRA

A cost-benefit analysis has been conducted for each of the four clusters of InteGrid solutions to estimate its economic feasibility under a diversity of conditions/environments that might limit or favour the deployment, considering the overall and stakeholders' perspectives, and by looking at the net present worth and the internal rate of return.

For Cluster 1, which consisted on the application of the InteGrid tools to medium voltage networks, the analysis allows concluding that its economic interest and potential to scale up depends on the network characteristics, particularly the networks must be stressed by the integration of significant amounts of renewable energy. It was observed that smaller scale applications in stressed networks, even when not economically viable, can become interesting once they are scaled up. In general, it seems there is no business case for flexibility operators. The results suggest that the technical VPP is a concept with low perspectives of success, but this view is too simplistic since when higher penetrations of renewable energy are considered, the flexibility of generation and demand is actually needed to solve the network issues.

In Cluster 2, as for Cluster 1, the characteristics of the networks are key. This cluster captures the most value in larger rural networks with high renewable energy penetration. When scaled up, this cluster can prove interesting for the same type of low voltage networks, even with moderate penetration. However, the scale must be big enough as the concession of EDP Distribuição in Portugal since the same does not hold true for Slovenia given the significantly smaller network of Elektro Ljubljana. In addition, it was shown that the flexibility provided by HEMS can be more advantageous for the DSO than investing in solutions such as OLTC transformers and batteries. However, this is a high-risk option in a real implementation since it depends on the engagement of domestic consumers.

Cluster 3 sheds light on the requirements for the profitable operation of commercial VPPs, while illustrating also a particular application for a wastewater treatment plant in Portugal. Essentially the replicability analysis demonstrated that almost all scenarios were viable in Slovenia. The exact opposite happened in the case of Portugal. Under current regulation, the risks for a commercial VPP to operate in Portugal are regarded as too high by the sensitivity analysis and Monte Carlo simulation performed over the input variables. The particular application to the wastewater plant also validated this reasoning.

Cluster 4 focused on considering the application of flexibility offered by a set of office buildings, considering an aggregator. However, it was considered that was technically qualified to offer aFRR, the cluster application proves to be viable for aFRR (and not for mFRR), attending to the current markets design.

Regulatory Replicability

The regulatory replicability analysis presented in this InteGrid deliverable looked at ten different countries, namely Portugal, Slovenia, Sweden, Austria, Spain, Belgium, France, Germany, Great Britain, and Italy. The first five countries are the InteGrid target countries, while the last five are the other EU Member States chosen for the replicability analysis based on the several regulatory aspects that could be informative in the context of this analysis. For each cluster, several regulatory barriers were identified and analysed for the five target countries and the selected EU Member States.

In order to assess the compatibility of the four clusters with regard to the national regulatory frameworks in the ten countries, a list of potential barriers to replicability was identified. Based on this list, key guiding questions were elaborated for each topic and for each cluster. Finally, the answers to these questions in each country could lead to the conclusion on how compatible each cluster is in each country. With that regard, some methodological aspects should be highlighted however. Firstly, the main sources of information used for this analysis, especially for the countries outside the InteGrid consortium, were recognized surveys and reports by European institutions such as ENTSO-E and the JRC. These surveys however, can contain eventual imprecisions. Additionally, this deliverable shows that many regulatory aspects are currently being changed, mainly due to the implementation of the Networks Codes. Therefore, several topics here analysed are expected to change rapidly in many countries.

From a regulatory perspective, the four clusters can be grouped into two main concepts, namely **active grid operation using flexibilities** (clusters 1 and 2) and **demand-side participation in balancing markets** (clusters 3 and 4). The former is mainly assessed from the perspective of the DSO that needs the proper incentives to procure flexibility for grid operation in the MV and LV network respectively. The latter is focused on the aggregator (cVPP) and the flexibility provider (DER). These agents need a proper balancing market design and aggregation rules for the replication of clusters 3 and 4.

The replicability of cluster 1 is associated to a great extent to the DSO revenue regulation, the existence of local flexibility markets, and the incentives for the reduction of energy losses. The analysis of the ten countries shows that most of them still have a CAPEX-oriented regulatory framework. The UK and to some degree Italy are the ones that escape this trend. The former has an advanced economic regulation for DSOs, combining several innovative mechanisms, while the latter is shifting to TOTEX approach. The existence of local flexibility platforms is still limited in most countries. However, the UK and Germany have already implemented large-scale trials or even an initial commercial implementation. Finally, incentives for the reduction of losses are present in most countries, although in many cases there are elements that dilute the strength of these incentives. Moreover, it was observed that they rarely consider the potential impact of DER on grid losses.

From the point of view of regulation, clusters 1 and 2 are very similar. Nonetheless, since cluster 2 requires the flexibility provision by residential consumers, tariff design is an additional topic to consider. Regulated charges and retail tariffs will play an important role in providing price signals to consumers, and consequently incentivizing them to adopt the HEMS. However, the large weight of regulated charges, and particularly policy costs and taxes, on the overall retail tariff tend to weaken the flexibility incentives sent through network tariffs and energy prices. In this regard, Slovenia and the UK are the countries with a more favourable cost structure enabling stronger flexibility signals.

Overall, the results show that clusters 1 and 2 are still far from being totally compatible with current regulation in most countries, mostly due to the lack of advanced local flexibility mechanisms and a network regulation that still tends to favour grid reinforcement over the use of flexibility.

The key regulatory aspects for clusters 3 and 4 are the balancing market design and rules on aggregation. Replicability of these two clusters require that balancing markets should not only allow for the participation of demand-response but also products should be designed in such a way that demand participation is encouraged in a level playing field. For cluster 3, we specifically focus on the mFRR product, while for cluster 4 the focus is the aFRR. This research concludes that the former is a lot more open for demand response that the latter. The aFRR is still closed to DR participation in many of the analysed countries, and conditions for participation are stricter.

Aggregation also plays a key role in the compatibility of both clusters 3 and 4. In general, a correlation between the openness of balancing markets to DR and the possibility of DR aggregation in these markets can be observed. In other words, when markets (aFRR and mFRR) are open to demand response, they are also open to aggregated demand response. Nevertheless, it does not mean that products and aggregation rules (such as prequalification requirements) are always suitable for this activity. Moreover, clusters 3 and 4 present important differences regarding aggregation. Considering the in cluster 3, the cVPP is the aggregator, two more aspects have to be considered, namely the possibility of aggregating different types of DER and the rules on independent aggregators. The analysis showed that some countries such as France and Belgium have more advanced regulatory frameworks for aggregators, including rules on balancing responsibility for independent aggregators. On the other hand, countries such as Portugal and Spain are lagging on these aspects, although changes are expected soon as the Network Codes are implemented.

From a regulatory perspective, cluster 3 presents a good replication potential in several countries considered in this report. France and Belgium are clearly the most compatible ones, while Germany, Austria and Slovenia can also be considered compatible to some extent. Cluster 4 however, is less compatible, mainly due to the restrictions for DR participation in aFRR. Germany and Slovenia are the most compatible, although many barriers exist even in these two countries.

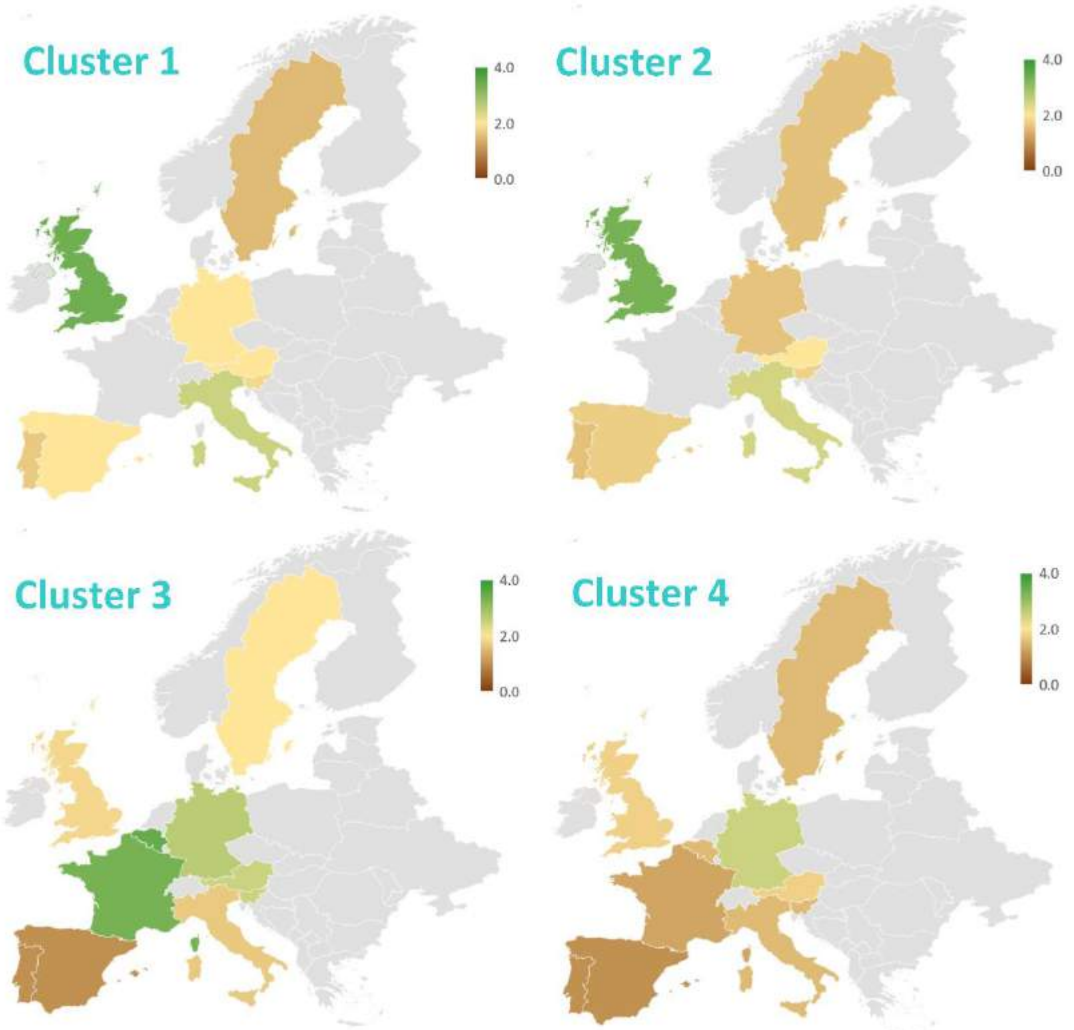


Figure 2: Overall regulatory replicability of InteGrid's Clusters (0: low compatibility; 4: high compatibility).

Economic and regulatory interaction

This deliverable looks in depth at the economic scalability and replicability as well as the regulatory replicability of the different clusters considered. However, these two aspects are not independent from each other. Regulation greatly influences the potential for economic scalability and replicability. More specifically, regulation can impact the allocation of the calculated costs and benefits among stakeholders, or whether external costs are internalized. For this reason, this report also made an additional exercise, consisting on the identification of the main regulatory aspects that could have an impact on the results observed by the economic SRA.

For clusters 1 and 2, the economic SRA showed that the DSO may benefit meaningfully from the reduction in voltage deviations by using flexibility. This could be seen as a proxy for grid reinforcement deferral, as this would be a natural way for the DSO to solve recurrent voltage problems in the long-term. Most regulatory frameworks however, tend to promote capital-intensive solutions over OPEX-based alternatives; in fact, in many countries DSOs need to reduce OPEX on a yearly basis. Thus, the use of flexibility would require a regulation to some extent agnostic to the cost structure and/or the recognition of the OPEX associated with the flexibility procurement.

For the tVPP, the economic SRA showed a limited economic potential of the use of flexibility, largely due to the limited constraints in the network. In order to have a more favourable business case, VPPs could provide services in multiple markets, and DSO procurement of flexibility can be done not only base on the energy activated, but also on the capacity reserved. Specifically, for cluster 2, the economic SRA reveals that the biggest benefit for residential consumers is the energy savings from the HEMS, rather than the provision of flexibility. Therefore, tariff design can play an important role in incentivizing consumer to opt for the installation of the HEMS. Dynamic tariffs or real-time pricing options for retail tariffs can give price signals for the consumers, enabling savings by the HEMS. The regulated charges can also have a relevant effect, as they may distort these price signals, particularly when they include a large share of policy-driven costs and/or taxes.

Cluster 3 and 4, on the other hand, focus on the provision of balancing services by flexibility providers, aggregated by retailers or cVPPs. The economic SRA showed firstly the importance of the balancing procurement method for the overall viability of these clusters. The procurement of capacity in a market-based fashion can improve the economic results for aggregators and flexibility providers. Another conclusion from the economic SRA is the relevance of the portfolio of the aggregators, both in the number of aggregated units and the type of units (in terms of flexible capacity available). This reinforces the need for appropriate aggregation rules, that may enable aggregation in a seamless way. Finally, product definition can also be an important barrier to economic replicability. Products that require bid symmetry or even compliance to a predefined upward-downward ratio may undermine the potential benefits for aggregators and consequently for flexibility providers.

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

ACER	Agency for the Cooperation of Energy Regulators
AdTA	Águas do Tejo Atlântico
aFRR	Automatic Frequency Restoration Reserve
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
CA	Consortium Agreement
CAPEX	Capital Expenditures
CBA	Cost Benefit Analysis
CEER	Council of European Energy Regulators
CEP	Clean Energy Package
CHP	Combined Heat and Power
cVPP	Commercial Virtual Power Plant
DCF	Discounted Cash Flow
DER	Distributed Energy Resources
DG	Distributed Generation
DoA	Description of Action
DR	Demand Response
DSO	Distribution System Operator
EBGL	Electricity Balancing Guideline
EC	European Commission
ESCO	Energy Service Company
EV	Electric Vehicle
FAT	Full Activation Time
FCR	Frequency Containment Reserve
FO	Flexibility Operator
FRR	Frequency Restauration Reserve
GA	Grant Agreement
Gm-hub	Grid and Market Hub
HEMS	Home Energy Management System
HLUC	High-Level Use Case
HV	High Voltage
ICCP	Inter Control Centre Protocol
ICT	Information and Communication Technology
IRR	Internal Rate of Return
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LV	Low Voltage

LVC	Low Voltage Controller
LVSE	Low Voltage State Estimation
mFRR	Manual Frequency Restoration Reserve
MPOPF	Multi-Period Optimal Power Flow
MV	Medium Voltage
MVLA	MV Load Allocator
NPV	Net Present Value
NRA	National Regulatory Authority
OLTC	On-Load Tap Changer
OPEX	Operational Expenditures
PPA	Power Purchase Agreement
PV	Photovoltaic
RAB	Regulatory Asset Base
RES	Renewable Energy Systems
RR	Replacement Reserve
SoC	State of Charge
SRA	Scalability and Replicability Analysis
TLS	Traffic Light System
ToE	Transfer of Energy
TOTEX	Total Expenditure
ToU	Time of Use
TSO	Transmission System Operator
tVPP	Technical VPP
VAT	Value Added Tax
VoLL	Value of Lost Load
VPP	Virtual Power Plant
W2F	Water to Flexibility
WACC	Weighted Average Cost of Capital
WP	Work Package
WWT	Wastewater Treatment

1. Introduction

1.1. Aims and scope of the report

This report presents the results of the work done in Tasks 8.3 – Economic Scalability and Replicability Analysis (SRA) of the implemented smart grid functionalities - and 8.4 - Regulatory replicability of the implemented smart grid functionalities - of the InteGrid project.

Firstly, the deliverable presents an analysis of the economic impact of scaling-up and replicate a set of InteGrid solutions. Similarly, to the approach followed to perform the technical SRA (see D8.1), HLUCs have been grouped into a set of clusters in order to perform a consistent analysis. Based on the results obtained in the technical SRA analysis from Task 8.1, and after defining a set of scenarios and assumptions, these clusters have been assessed to determine its economic interest under different conditions/environments, quantifying both involved costs and benefits. An allocation of costs and benefits among stakeholders is also presented. Finally, some of the input variables have been subject to sensitivity analysis and, in the most relevant cases, to Monte Carlo simulation.

Furthermore, as a complement to the technical and economic SRA, and building on the work of Work Package 7 (WP7), the suitability of the regulatory conditions to allow the deployment of the proposed solutions has been analysed through a regulatory replicability analysis. In order to enrich such study, a set of countries, beyond those evaluated in WP7 (Portugal, Slovenia, Sweden, Austria and Spain), has been considered. The main goal is to identify the regulatory factors that may act as barriers or enablers for an effective and efficient deployment of the proposed technologies and solutions.

Lastly, this report also combines the outcomes of both previous analyses in order to discuss how regulation may affect the economic consequences of replication and scaling-up, i.e. how regulation affects the allocation of costs and benefits among stakeholders, internalization of external costs, etc.

1.1. Document structure

The remainder of this document is organized as follows. First, section 2 provides an overview of the methodological approach followed to carry out the economic and regulatory dimensions of InteGrid's SRA. Secondly, section 3 describes the scenarios, assumptions and main results obtained from the economic SRA performed in Task 8.3. In turn, section 4 presents the work done and results obtained in the regulatory replicability analysis performed in the scope of Task 8.4. The results of both previous studies are discussed jointly in section 5. Lastly, section 6 concludes.

2. Methodology overview

2.1. From HLUCs to functional clusters

Within InteGrid project, the Smart Grid technologies are organized into 12 High-Level Use Cases (HLUCs). As it has been detailed in D8.1 report, one of the main challenges the SRA faced was to deal with the interactions between the smart grid solutions from an extra-HLUC perspective. In fact, most HLUCs have strong interactions at the business, functional, information and communication levels. To illustrate these, the following clusters have been created (Figure 3).

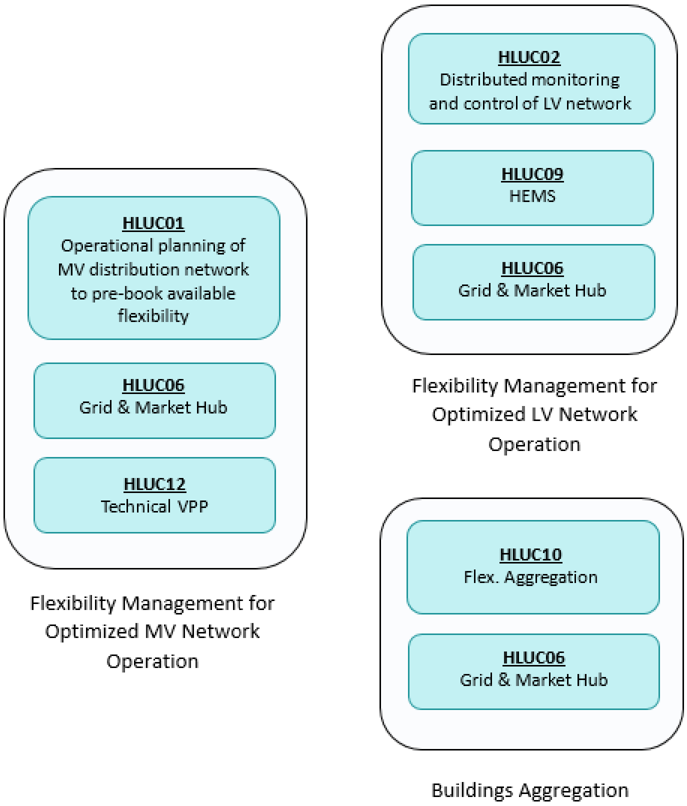


Figure 3: Grouping of the HLUC within four clusters.

- Cluster 1: “Flexibility Management for Optimized MV Network Operation”

The first group, named “Flexibility Management for Optimized MV Network Operation”, comprises HLUC01, HLUC06 and HLUC12 (technical VPP). The HLUC01 scope is the short-term management of distributed energy resources (DER) to solve grid constraints (e.g. voltage or congestions) and to optimize MV network operation (such as losses minimization) in different locations and periods. The smart grid tools composing HLUC01 are the MV Load/RES Forecasting System, the MV Load Allocator and the Multi-period Optimal Power Flow. The MV customers’ flexibility is aggregated and delivered to the distribution system operator (DSO) by a technical Virtual Power Plant (HLUC12), to help him fulfil its objective. If one focus on the technical VPP alone, without considering the interactions with the MV management tools, it is not possible to capture the full potential and the benefits of flexibility. The communication between the two parties and the pre-booking of flexibility is ensured by the Grid & Market Hub platform (gm-hub) of HLUC06. In fact, the gm-hub appears in all clusters since it is an enabler of the other solutions and its cost must be considered when assessing the economic worthiness of the cluster.

- Cluster 2: “Flexibility Management for Optimized LV Network Operation”

The second group integrates HLUC02, HLUC06 and HLUC09. HLUC02 concerns the voltage control of LV grids instead, leveraging the flexibility from the resources owned by the DSO or the one stemming from domestic customers equipped with the Home Energy Management System (HLUC09). Similarly, to the previous cluster, if one focusses on the HEMS alone, without considering the interactions with the LV management tools, it is not possible to capture the full potential and the benefits of flexibility. The smart grid tools composing HLUC02 are the LV Load/RES Forecasting System, the LV State Estimator and the LV Controller. The gm-hub (HLUC06), operating as a hub to exchange information, allows the DSO to receive information about multi-period HEMS flexibility and to send flexibility activation requests, without any intermediate actor such as the aggregator.

- Cluster 3: “Large customer cVPP”

The third group joins HLUC05, HLUC06, HLUC08 and HLUC12 (commercial VPP). MV industrial customers with flexibility capabilities, such as wastewater treatments plants (HLUC08), can make available their flexibility for manual frequency restoration reserve (mFRR) services to the TSO, through an independent market player known as commercial Virtual Power Plant (HLUC12). Since these flexibilities come from resources connected to the distribution system, their activation must be evaluated by the DSO with the Traffic Light System (HLUC05). The assessment results are submitted to the gm-hub (HLUC06) from which the VPP can extract information about the technical constraints.

- Cluster 4: “Office Buildings Aggregation”

The fourth group combines HLUC10 and HLUC06. Office buildings flexibility equipped with chilling systems can either be exploited to manage imbalances by a Balance Responsible Party (BRP) or to be sold on Frequency Restauration Reserve (FRR) markets. This flexibility is communicated via gm-hub (HLUC06).

Table 1 presents which domains of the SRA are considered for each individual HLUC. From an economic perspective, the remaining HLUCs/solutions which have not been investigated in this report, due to a very limited scope of analysis or difficulty on recreating proper assessment conditions in a simulation environment, will be later on addressed by the Cost Benefit Analysis (CBA), integrated in WP7, based upon the experience returned from the demos.

Table 1: Domains considered for the SRA of the HLUC

HLUC ID	Domains considered for the SRA
HLUC01	Functionality, ICT, Economic, Regulatory
HLUC02	Functionality, ICT, Economic, Regulatory
HLUC03	-
HLUC04	-
HLUC05	Functionality, ICT, Economic, Regulatory
HLUC06	ICT, Economic, Regulatory
HLUC07	-
HLUC08	Functionality, Economic, Regulatory
HLUC09	Functionality, ICT, Economic, Regulatory
HLUC10	Functionality, Economic, Regulatory
HLUC11	Functionality
HLUC12	Functionality, ICT, Economic, Regulatory

2.2. Economic SRA overview

Economics play a key role in determining if a given project will be replicated or scaled up. Within the same country (intranational replicability analysis), there may be changes to certain context variables that not only affect the technical feasibility, but also the economic. For example, when a HLUC is moved from an urban area to a rural one, it will for sure encounter different electrical characteristics. A voltage control solution developed for resistive networks (rural), where more voltage violations are susceptible of arising, can have a less significant added value in inductive networks (urban). In the latter case, the benefits may not be enough to justify its deployment in all the distribution networks within a country. Another example is the diversity of controllable resources that can be exploited to deal with network problems that can result in different operational costs.

Concerning the scalability, even if InteGrid tools can deal with the current amount of Distributed Energy Resources (DER), it is interesting to determine from an economic perspective what will happen if the quantity of DER is scaled-up significantly in density as a future energy option towards decarbonization or if the solution is deployed in another network area with a high penetration of DER. Do the benefits increase proportionally? What about the costs?

Another important aspect is the potential existence of economies of scale. If the marginal costs of the cluster decrease as the implementation area of the solution increases, then the project is well positioned to be scalable in size. One common example of scalable projects is in IT related services, where once created they can handle an increasing number of clients without much increase in cost. This is the case of most InteGrid technologies under analysis (e.g. algorithms, platforms). In terms of benefits, their percentage increase must at least be kept at the same rate as the costs increase. Therefore, even considering a set of assumptions, it is pertinent to estimate the economic impact of deploying these solutions to a broader level.

From an international (replicability) perspective, it is relevant to assess how changes in macroeconomic variables from country to country affect the economic interest of the project such as inflation rate, wholesale electricity price or even CO_2 emission factors. Different geographies and contexts will determine different impacts on benefits quantification. Furthermore, there is also the need to confirm if the business model holds interesting in the regulatory context of different countries: it may be that the compensation associated to the application of a given cluster may result profitable in one country and not in another.

To conclude on the economic worthiness of the scale increase and replication, a cost-benefit analysis has been conducted per cluster, namely looking at the Net Present Value (NPV) and the Internal Rate of Return (IRR). A cluster is only scalable if the NPV is equal or greater than before scaling and it is considered as replicable if its application in another region/country leads to a positive NPV. Different scenarios have been assessed. A quantitative international analysis has been performed for Portugal and Slovenia, two of the demo countries, whenever possible.

Since different stakeholders can profit from the project's implementation, a distribution of the costs and benefits, which were previously identified and quantified, has been made per cluster. The NPV has been calculated for each beneficiary and from an overall (cluster) perspective; the total costs/benefits are the sum of the costs/benefits to all actors.

In addition, two other types of analysis have been considered to account uncertainty introduced by the input macroeconomic variables: sensitivity analysis and Monte Carlo simulation. The first with the objective of exploring the results' robustness to the variation of these parameters while the second of providing a measurement of the deployment risk. Monte Carlo simulation has only been performed in the cases that the sensitivity analysis results indicate that the macroeconomic variables play a relevant role on the feasibility of implementation.

The steps comprising the economic SRA methodology are the following:

1. Project characterization with a brief description of the technologies in analysis;
2. Description of the scalability and replicability scenarios;
3. Identification and monetization of benefits;
4. Quantification of costs;
5. Allocation of costs and benefits amongst the beneficiaries;
6. Definition of the economic and financial boundary conditions;
7. Discussion of results;
8. Sensitivity analysis and Monte Carlo analysis.

2.3. Regulatory SRA overview

The goal of the regulatory SRA is to identify barriers and drivers for the scalability and replicability of the selected clusters posed by power system regulation. Barriers are rules that can be found in all or some of the countries analysed and that constrain the well-functioning of the clusters, whereas regulatory drivers are found when certain solutions are enabled and incentivized by regulation.

Regulation includes all the rules about which services can be provided, the different roles of agents, the remuneration of certain activities, etc. With respect to replicability, the regulatory SRA studies whether the use case tested in one country can be replicated in another country under the existing regulation in that country. The regulatory topics covered include DSO Economic Regulation, DSOs as a system optimizer and market facilitator, retail tariffs and metering, and aggregation and balancing market design.

The rationale behind this selection can be found in the aims of the selected clusters. On the one hand, clusters 1 and 2 imply a significant shift in the traditional approaches to distribution grid planning and operation. Power distribution is a regulated activity due to its condition of natural monopoly; therefore, regulation, more than market conditions, plays a key role in enabling or promoting such changes. More specifically, the focus will be placed on topics related to DSO revenue regulation and any regulation on the role of DSOs as market facilitators and active system operators.

On the other hand, clusters 3 and 4 are different approaches to introduce demand-side participation in balancing markets and/or improve their functioning. Hence, regulation about aggregation and market design need to be assessed, including rules about who can participate in which market either explicit or implicit in the product and market design. However, contrary to generation units in most countries (at least not that directly), demand-side resources may face barriers inherent to retail tariffs and metering regulation. This makes this, together with market access, one of the most important topics within regulation when looking at replicability of the clusters.

The following steps have been followed. This analysis first needs to identify what regulatory topics are the most relevant to each cluster, in line with the previous discussion. Next, the different alternatives for each one of the selected regulatory topics need to be characterized. Since regulation is practically specific to each country, a set of countries has been selected for the analysis in order to consider a wide range of regulatory conditions. This selection builds on the target countries considered in WP7 adding a few additional European countries deemed interesting for the SRA. This characterization will be made through the work done in WP7 for the target countries plus an additional desk research to extend the analysed to the additional countries chosen. Subsequently, a comparative analysis of the regulation in the different countries will be performed to finally assess the regulatory replicability and scalability potential of the selected clusters.

The main output of the regulatory SRA is an identification of the existing barriers and drivers embedded in the regulation that hamper, enable or promote the replication or scaling-up of the InteGrid solutions. Regulatory options that ought to be phased out or best practices may be identified. This work needs to be coordinated with WP7 whose aim is to indicate which rules and regulation should be adapted in the future. As a final caveat, it is relevant to note that the ultimate goal is not to facilitate the development of the tested solutions at any cost, but to identify the extent to which their development is advisable from an overall system perspective. For instance, removing a regulatory condition may be extremely beneficial for the development of a given solution or stakeholder, but it may lead to an inefficient outcome overall.

The outcome of this regulatory SRA will be combined with those of the technical and economic SRAs so that those solutions that have shown a better performance from a technical and economic standpoint are prioritized in the SRA roadmap proposed at the end of the project.

3. Economic SRA

3.1. Review of Smart Grid Tools

In this section, one provides an overview of the InteGrid solutions comprising each cluster with the goal of contextualizing the reader and helping him understand the SRA scenarios in analysis, which are later detailed in this document. For further details, please consult the following project's references [REF D2.2, D2.3 and D6.1].

3.1.1. Cluster 1

The **Multi-Period Optimal Power Flow (MPOPF)** module is a smart grid function for Medium Voltage networks operational planning and flexibility management. It aims to provide a plan capable to optimize the network state while keeping the grid power flows and voltage magnitudes within admissible ranges. These targets are achieved by identifying and reserving flexibility-based actions to meet the grid technical constraints while focusing on a specific objective, such as flexibility cost minimization or network power losses minimization. The MPOPF function considers various types of control variables, working over DSO assets (e.g. capacitor banks, storage systems and transformers with OLTC capabilities), demand response from industrial/commercial consumers and the reactive power control of generators.

It is composed by two different operation modes – the predictive management and real-time assessment. By exploiting the available forecasts and thanks to its capability to simultaneously gather and process the data for n-hours ahead, the predictive module reserves flexibility offers to solve the anticipated technical constraints violation. Within this single optimization problem, several different multi-temporal constraints capable to illustrate inter-temporal dependencies can be implemented, ensuring that the optimal decisions taken for early periods already consider what will be the optimal decisions for later periods. Due to potential changes on the predicted network conditions, a close to real-time assessment needs to be carried out. By doing so, the near real-time operation validates the flexibility plan defined in the predictive module.

Moreover, the **MV Load Allocator** module (MVLA) supports both operation modes of the MPOPF. This tool is intended to provide an estimation of the active and reactive powers as well as the voltage phasors in each secondary substation of the MV grid, enhancing network's observability. It has the capability to process the forecasts and effectively answer to potential lack of information (network locations with no forecasts) due to the absence of historical data.

As referred before, the MPOPF tool is fed with several types of data coming from different sources. Namely, the network topology and corresponding updates, which are provided by the DSO, load and RES forecasts for a pre-defined time horizon, which are computed by the **Load and Renewable Generation (RES) forecasting systems**, and the flexibility available for each resource, which is published in the **gm-hub platform** and delivered by a market player (e.g. **technical VPP**).

The **gm-hub** is in the heart of InteGrid, being common to all clusters. According to [REF D6.1], the gm-hub can be defined as "cloud-based solution to support the provision of services in a neutral standardized way between DSOs (primary actor of this central platform) and other stakeholders like retailers, transmission system operators (TSOs), aggregators, group of consumers and energy services providers (e.g., ESCO, data analytics companies). A specific objective is to facilitate market access allowing new business models and services while ensuring efficient and secure network operation as well as highest standards of data security. The gm-hub operates in a regulated domain, thus all the embedded services are regulated and subjected to a suitable regulatory framework for data management and provision. Nevertheless, this central platform should be perceived as an enabler of non-regulated services from service providers that can grow around the gm-hub ecosystem. In fact, the word "market" is much broader than the electricity market since it encompasses both wholesale and retailing markets, as well as energy services trading like energy efficiency, consumer engagement and gamification and forecasting."

Finally, the **technical VPP** is a new business model that aggregates and controls the active power of DER in a pool to support the distribution grid operation. The type of flexibility can be various including RES and demand response. It is operated independently from the DSO either by a flexibility operator – independent market player – or a retailer.

3.1.2. Cluster 2

In InteGrid, a set of smart grid functions were developed to actively manage the LV distribution network by exploiting residential consumers' flexibility alongside resources property of the DSO, such as grid storage units and On-Load Tap Changer (OLTC) transformers at MV/LV substations. The last function of tool chain is the **Low Voltage Controller (LVC)** which goal is to solve voltage constrains and imbalances that might arise in the network. It is composed by two main modes of operation: the preventive control mode and the real-time control mode.

The preventive control mode determines a set of control action plans to avoid foreseeable voltage violations that may occur in the LV network in the near future. It depends on the **Load and RES forecasting systems** and the **Home Energy Management System (HEMS)** devices (through **gm-Hub platform**) to share the Load/RES forecast for each node and the available flexibilities, respectively.

The ranking of the resources is established according to the following criteria by priority, with the overall objective of minimizing the grid operation costs:

- Resource type: Priority is given to DSO-owned resources (transformers with OLTC capability, followed by energy storage devices), then to the flexibility from domestic clients via their HEMS;
- Electrical distance to the voltage violation node: Priority is given to resources located in the same phase that are closer to the voltage violation node;
- State of Charge (SoC): In case of overvoltage, devices with a lower SoC are prioritized; in case of undervoltage, devices with higher SoC are prioritized;
- Contract characteristics.

The real-time control mode is responsible for the management of the LV network in real-time, comparing the forecasted grid conditions and control action plan with the actual grid conditions at the implementation period and checks their adequacy to address a voltage problem. The **Low Voltage State Estimator (LVSE)** is a tool designed to provide a real-time snapshot of the LV network comprising voltage magnitudes and active power injections at each phase of every node and provide useful information to the LVC. This algorithm takes advantage of smart meters' information that is stored as historical data alongside some real-time measurements to reconstruct a global image of the system, while avoiding full knowledge about network topology and its electrical characteristics.

HEMS describes an energy management process at residential consumers premises that enables the maximization of the self-consumption and self-sufficiency through advanced loads' monitoring and control functionalities to minimize customers' energy bill. Moreover, it supports user active participation in grid management by determining the potential energy use flexibility from the household, considering user comfort definitions, the configuration preferences of participating appliances and systems and the selected optimization criteria. Towards the client house, the HEMS receive information about energy consumption from smart meter as wells as the flexibility activation commands (control set-points). The gm-hub operates as a hub to exchange information, allowing the DSO to receive information about HEMS flexibility and to report its activation to the client.

3.1.3. Cluster 3

The **commercial VPP** is a new business model that pools and controls the active power of DER to participate on the balancing market for tertiary reserve. The type of flexibility can be various including RES and demand response. Usually, a VPP enables flexibility use on top of the regular electricity supply value chain, so it is essential to communicate not only with the DERs in the field and with the receivers of flexibility services but also with DSOs and BRP to exchange metering data, baselines and schedules in order to guarantee a seamless integration of the VPP activities. The gm-hub plays a central role in facilitating many of these communication channels.

The location of the flexibility resources within a commercial VPP has a significant impact as their activation might arise technical constrains at the distribution system, if they are connected in the same network area. The **Traffic Light System** is a DSO tool for validation of flexibility bids offered in the control reserve market operated by the TSO. This validation tool is separated into two services, *ex-ante* and *pre-activation*. Ex-ante evaluation is done before gate closure of the mFRR market and pre-activation is done after gate closure, where bids are already selected by the TSO, and before actual activation. This group of solutions is running in Slovenia.

In the scope of InteGrid, Águas do Tejo Atlântico (AdTA), a MV industrial customer in Portugal, is exploring the flexibility of their own wastewater treatment plants based on their internal processes with two different goals:

1. Provide flexibility to the DSO and TSO. For this purpose, the **Water2Flex (W2F)** function has been developed and it quantifies the flexibility based on two approaches:

    a. Empirical flexibility, based on a flexibility matrix constructed with domain knowledge and energy audit, which can be used by the technical and/or commercial VPP to prepare flexibility offers for the next day.

b. Data-driven flexibility of wastewater pumping station estimated in real-time and that can be used during emergency grid operation.

2. Minimize electrical energy consumption of wastewater pumping station (p-Optimizer function).

All information sources from online monitoring data and numerical models are integrated in the **AQUASAFE** IT platform, which provides an advanced, refined environmental diagnosis in real time to local wastewater human operators.

3.1.4. Cluster 4

Commercial buildings connected to the LV and MV distribution networks can deliver flexibility through managing thermal inertia for tenants' comfort and related energy consumption. The flexibility of these buildings can either be procured to manage imbalances by a Balance Responsible Party or to be sold on the balancing markets for secondary or tertiary reserve. The aggregation takes place in the **Energy Services Platform**.

In the demonstrator, EDP Comercial plays the role of retailer and four office buildings of the company (one with real data and three simulated), already possessing an advanced Building Management System (BMS), were selected for testing. They are located on different parts of Portugal mainland. A BMS is a computer-based system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems.

3.2. Description of Scenarios

The economic SRA has several relations with the other analysis, as illustrated in Figure 4, which essentially consists on the provision of inputs to this work. For instance, our first two tasks were to gather InteGrid's solutions costs from the different technological partners and to understand the business models potentially enabled by the project, both with the help of WP7. In the latter case, it was essential to define the involved stakeholders and the distribution of the benefits and the costs. The regulatory analysis also influenced the economical SRA since there are benefits that changed from country to country (e.g. remuneration scheme employed on tertiary reserve markets). Nevertheless, the main source of input to the economic SRA is the functionality-oriented SRA. Its goal was to assess the performance of the tools within a given cluster and compute Key Performance Indicators (KPIs) in several scenarios. Those KPIs that could be translated into quantitative (monetizable) benefits have been used as basis for calculations performed under this analysis. Moreover, the ICT-oriented SRA contributed with information regarding the additional systems needed under scaling scenarios.

Consequently, alongside the colleagues of the functionality oriented SRA, common scenarios have been targeted for both domains to assess each cluster as a whole. The economic SRA objective is to measure the benefits and the costs of the solutions groups under a diversity of technical and macroeconomic conditions to determine if it is economically interesting to implement them in each case from a global and stakeholders' perspective. The scenarios addressing the different dimensions of scalability and replicability for each cluster are detailed in the next sections.

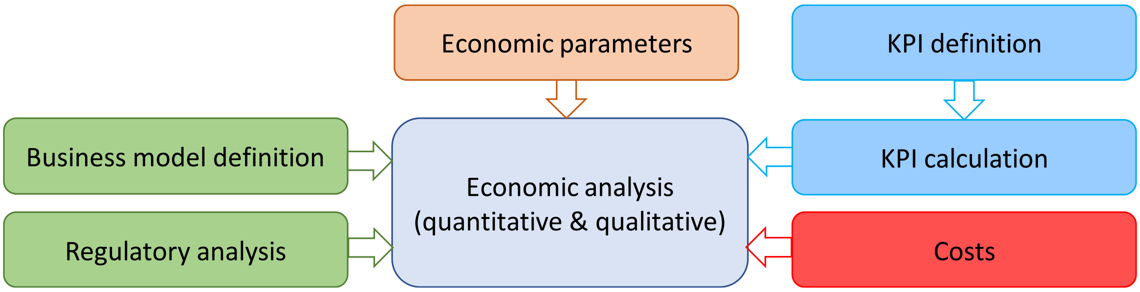


Figure 4: Inputs for the economic SRA.

When the application of the tools within a given cluster enhanced the current business, such as decreasing network losses or improving the quality of supply, there was the need to define baselines. These baselines serve as references to compare the business as usual with the improvements brought by InteGrid. For instance, the economic SRA assumes the deployment of certain business requirements as baseline, which is the case of the smart meters and the advanced metering infrastructure (AMI). On the other hand, there are new streams of revenue deriving from emerging business models supported by InteGrid, which were not previously available.

3.2.1. Cluster 1

In what respects the international replicability, the functionality oriented SRA scope included simulations on the Slovenian and Portuguese MV demonstrators. The scenarios not only tried to reproduce the current conditions of the demos but also to capture the expected changes in the coming years for the power system environment through an increasing DER penetration (scalability in density) whilst exploiting different controllable resources that are currently used by the DSO (traditional solutions) or were developed in the scope of InteGrid (intranational replicability). A brief description of the networks and the scenarios considered in the economic SRA is provided in the following.

3.2.1.1. Slovenia

The Slovenian MV demo network (Figure 5) has the following characteristics:

- 20 kV distribution grid, located in Domžale municipality near Ljubljana city, with 720 nodes, 710 branches and 399 customers;
- It is composed by 4 network islands which are not electrically connected between each other, meaning that any changes in generation or consumption in one network island will not affect the other. Each island has one HV/MV transformer with a nominal power of 31.5 MVA. In total, 4

HV/MV transformers, installed in the primary substations Domžale and Mengeš, supply the demo grid network.

- It also includes portions of the LV network. There are 2 MV/LV substations.

The technical VPP portfolio is the same as the demo's one: it is comprised by 11 clients, providing upward and downward flexibility, and their price on flexibility activation has been considered.

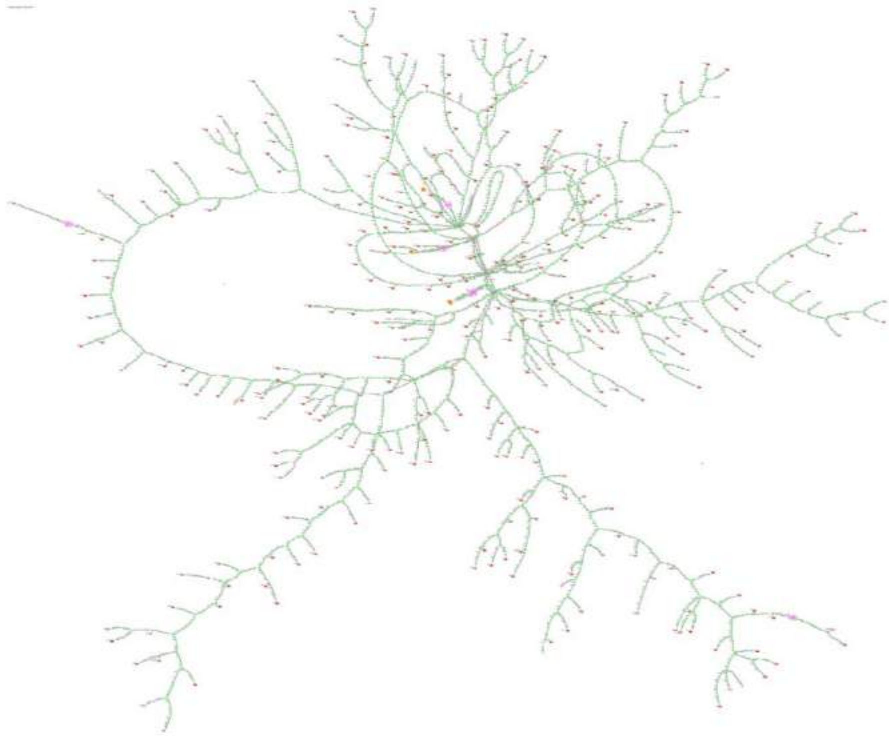


Figure 5: Slovenian demo overview.

In order to limit the number of scenarios in analysis, the impact of forecasting and allocation errors on the performance of the MV MPOPF was not assessed. Since these are functional aspects related with data quality issues, impacting negatively the outcoming results, we preferred to focus our analysis in operational scenarios created by different network conditions while assuming the availability of perfect historical/real-time metering data.

The simulations were executed by the preventive mode of the MPOPF tool and for a 24-hour time horizon considering the available load and RES forecast data. The voltage limits were set to $\pm5\%$ of the nominal voltage. For more technical details about the simulations, please consult [REF 8.1].

Three scenarios have been considered by the economic SRA: the first illustrates the current operating conditions of the network while the other two are futuristic scenarios with a higher penetration of RES. All of them were carried out with the object of minimizing the flexibility cost to the DSO. In the first two scenarios, the voltage violations present in the baselines were overcome independently through the following controllable resources: 1) active power operated by the technical VPP, 2) OLTC transformers and 3) capacitor bank. In the last scenario, a combination of them dealt with the network problems. The baselines are a result of power flow studies aiming to observe the network status when no optimization is performed. A more detailed description is provided below. The one-day technical results have been assumed as the same for all 365 days in a year. This is only an approximation to reality, as it is well known that the grid configuration can change significantly for example from weekends to working days and it may even depend on seasonal conditions.

The capacitor bank of 10 Mvar nominal power in the technical simulations does not exist in reality; it was introduced to show the potential of the tools on exploiting different controllable resources. In the sub scenarios S14 and S24, the typical costs of this equipment (both CAPEX and OPEX) have been accounted on the economic assessment.

If there is any scenario with a negative NPV, the economic SRA will try to investigate the impact on the cluster's profitability of a larger scale roll-out departing from the economic results at the demo scale. Given the number of transformers with a nominal power of 31.5 MVA in Elektro Ljubljana concession and outside the capital (which is an urban network), one can estimate how many networks with the size of the MV demo network could exist in this DSO concession area. All benefits, costs of hardware and costs of non-scalable software should be multiplied by this number whilst the costs of scalable software remain the same. As explained before, one common example of scalable solutions is in IT related services, where once created they can handle an increasing number of clients without much increase in cost. Those are the MPOPF, the forecasting systems, the MV Load Allocator and the gm-hub – essentially the DSO's tools. Although this analysis does not rely on simulations, it will allow to have an idea if the business case improves when scaling in size based on the available numbers.

Scenario #1

Description: Slovenian MV demo network – current network state.

Baseline: Before the application of InteGrid tools.

Objective: Measure the costs and benefits of InteGrid tools implementation to solve an undervoltage constrain while minimizing the flexibility cost for the DSO. Different controllable resources have been used:

- Scenario #12: Active flexibility from the technical VPP
- Scenario #13: OLTC transformers
- Scenario #14: Capacitor bank

Scenario #2

Description: Due to a modest RES installed capacity in the Slovenian demo, two PV generation groups were introduced in different feeders to challenge the MV managements tools: the first, with 3.5 MW installed power, was connected on network 1 while the second, with 9 MW, was connected on network 3.

Baseline: Before the application of InteGrid tools.

Objective: Measure the costs and benefits of InteGrid tools implementation to solve the voltage constrains while minimizing the flexibility cost for the DSO. Different controllable resources have been used:

- Scenario #22: Active flexibility from the technical VPP;
- Scenario #23: OLTC transformers;

- Scenario #24: Capacitor bank.

Scenario #3

Description: Increase the installed power of the RES introduced in the Scenario #2 in 30% (worst case) while the flexibility resources keep the same size. Observe the effect of a higher RES penetration in the technical problems identified in the previous scenario.

Table 2: Active and reactive nominal power of RES introduced in the Slovenian demo network (normal conditions and 30% increase).

	PV Generator #1		PV Generator #2	
	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
Normal conditions	3,5	0,8	9	1,65
+30% increase	4,55	1,04	11,7	2,14

Baseline: Before the application of InteGrid tools.

Objective: Measure the costs and benefits of InteGrid tools implementation to overcome the violations of the operational constrains while minimizing the flexibility cost for the DSO. Different controllable resources have been used:

- Scenario #32: Whereas the active flexibility from the technical VPP was used to solve the line congestion, the tap changer dealt with the overvoltage occurrences.

3.2.1.2. Portugal

The 10-kV distribution network, located in Mafra, is connected to the transmission grid by a 60/10 kV primary substation. This substation contains 2 HV/MV transformers with tap changing capabilities (20 MVA each) and 2 capacitor banks with 0.57 Mvar of nominal power each. The MV grid is comprised by 855 nodes, 10 feeders, 75 MV customers, 4 RES – one cogeneration and three wind parks – and 155 MV/LV substations.

Once more, the impact of forecasting and allocation errors on the performance of the MV MPOPF is not assessed. The simulations were executed by the preventive mode of the MPOPF tool and for 24 hours considering the available load and RES forecast data. This timeframe particularly refers to the 26th of September 2018. As per the standard EN 50160, the considered voltage limits are between 0.9 and 1.1 p.u.. For additional technical details about the simulations, please consult [REF D8.1].

The two functional SRA scenarios have been considered by the economic SRA: one illustrates the current operating conditions of the network whereas the other is a future scenario with a higher penetration of DER (renewable generation and load). As in the first scenario no technical problems arose in the baseline, the flexibility available in the distribution grid was used to another purpose: reduce the power losses. The active power losses were minimized by resorting independently to: 1) the active power from the technical VPP and 2) the OLTC transformers. In the last scenario, a combination of resources dealt with the network problems. The baselines are a result of power flow studies aiming to observe the network status when no optimization is performed. A more detailed description is provided below. The one-day technical results have been assumed as the same for all 365 days in a year.

Scenario #1

Description: Portuguese MV demo network – current network state.

Baseline: Before the application of InteGrid tools.

Objective: Measure the costs and benefits of implementing InteGrid tools to minimize the active power losses in the demo network by exploiting different controllable resources.

- Scenario #12: Active flexibility from the technical VPP;
- Scenario #13: OLTC transformers.

Scenario #2

Description: Increase DER penetration in three feeders of the Portuguese MV demo network.

- Two wind parks with installed power of 5.8 MW and 3.1 MW were connected to the same feeder;
- A third wind park with installed capacity of 2.91 MW to a second feeder;
- Five 100 kW EV charging stations and one MV customer with a 2.056 MW of peak power to another feeder.

Baseline: Before the application of InteGrid tools.

Objective: Measure the costs and benefits of implementing InteGrid tools to solve technical problems while minimizing the flexibility activation cost for the DSO. A combination of different resources had been used to overcome the several technical problems, which appeared at the same hours of the day:

- Scenario #22: While the active flexibility operated by the technical VPP tackled the overloads and undervoltage problems (in the latter case, it was particularly the flexibility from Mafra WWT plant), the OLTC transformers dealt with the overvoltage events.

3.2.2. Cluster 2

A real LV Portuguese network with a secondary substation feeding three main feeders was used. For the purpose of the technical simulations, this rural network has been modified in order to integrate higher levels of DER than currently to challenge the voltage control tools. It is composed by 33 buses, 32 lines and an energy storage device located at the secondary side of the MV/LV substation as depicted in Figure 6. All RES connected to the network are of PV type while HEMS devices were distributed for the customers in the network.

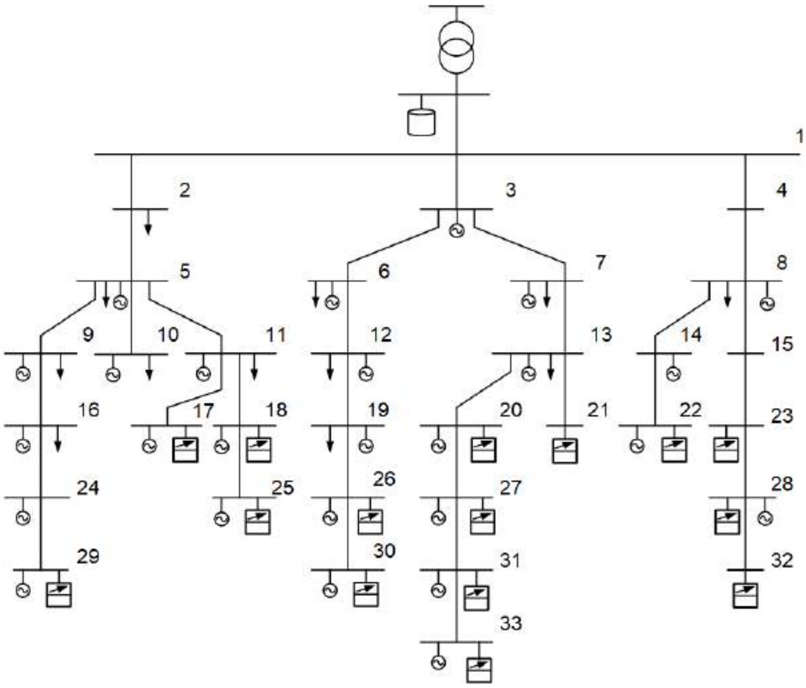


Figure 6: Single-line diagram of the simulation network. Scenario #1.

With the goal of limiting the number of scenarios in analysis, the impact of forecasting and estimation errors on the performance of the LVC is not assessed. Since these are functional aspects related with data quality issues, impacting negatively the outcoming results, we preferred to focus our analysis in scenarios created by different network conditions whereas assuming the availability of perfect historical/real-time metering data.

The simulations were run for the preventive mode of the LVC tool. The preventive mode was run for a control period of 24 hours ahead, with a frequency of 4 action plans per hour (every 15 minutes). A three-phase model of the network was assumed. The HEMS flexibility band was set to ± 10% of the consumption in each hour while the voltage in each node cannot exceed ± 10% of the nominal voltage. For more technical details about the simulations, please consult [REF 8.1].

Two baseline scenarios have been created: 1) in the absence of InteGrid tools (power flow study); and 2) application of InteGrid tools to solve the voltage violations while resorting to curtailment of microgeneration and load which are not connected to the grid via HEMS. The objective of the last baseline scenario is to measure the amount of microgeneration and demand that would need to be curtailed to comply with voltage limits without the flexibility provision of HEMS and DSO owned equipment[1]. The voltage control strategy for LV grids deployed in InteGrid, leveraging the information from the AMI, enables a coordinated operation of the available DER in order to tackle voltage violations that may occur (active management), using also other control alternatives.

[1] It is worth mentioning that the option of selecting controllable microgenerators and loads was kept to retain the LVC algorithm developed in InteGrid compatible with grids where not all controllable resources are connected to the grid via HEMS.

A total of 4 main scenarios has been covered by the economic SRA. Concerning the intranational replicability, not only the potential of different flexibility resources to solve voltage violations have been analysed but also the network impedance (resistive vs. inductive character). Overhead networks are predominantly resistive networks (high R/X ratio) while underground networks are more inductive networks (low R/X ratio). Scalability in density has been assessed considering higher amounts of DER penetration (moderate vs. severe). In addition, scenarios where the network have been extended from to 33 nodes to 150 nodes have also been taking into account. A more detailed description is provided below. The one-day technical results have been assumed as the same for all 365 days in a year.

Like has been proposed for Cluster 01, a large-scale rollout at a regional/national level is intended to be carried out but for some scenarios, given the transformers' characteristics installed in LV urban and rural networks within EDP Distribuição concession. Calculations consist on scaling proportionally the estimated hardware and the calculated benefits of a single network to the number of existing representative networks while the identified software costs remain the same, unless the ICT-oriented SRA indicated any relevant scalability constrain. In addition, economies of scale in the deployment of HEMS are part of the analysis.

Finally, since no simulations were performed on LV grids of other countries, an intranational replicability analysis has been made for Slovenia, departing from the Portuguese technical results but considering its country-specific macroeconomic variables and EL's LV distribution system size, since their LV grid characteristics are not that different from the Portuguese ones.

Scenario #1

Description:

- LV rural network with 33 nodes and 150 kVA transformer;
- Severe penetration of DER;
- 33 HEMS distributed in the network.

Objective: Measure the costs and benefits of InteGrid predictive management strategy for LV control by exploiting different controllable resources.

- Scenario #11: Before the application of InteGrid tools (Baseline 1)
- Scenario #12: Microgeneration curtailment and load shedding (Baseline 2)
- Scenario #13: HEMS flexibility
- Scenario #14: HEMS flexibility + Energy Storage
- Scenario #15: Transformer with OLTC capabilities + HEMS + Energy Storage

Scenario #2

Description:

- LV rural network with 150 nodes and 500 kVA transformer;
- Moderate penetration of DER;
- 82 HEMS distributed in the network.

Objective: Measure the costs and benefits of InteGrid predictive management strategy for LV control by exploiting different controllable resources under these conditions.

Scenario #21: Before the application of InteGrid tools (Baseline 1)

- Scenario #22: Microgeneration curtailment and load shedding (Baseline 2)
- Scenario #23: HEMS flexibility
- Scenario #24: HEMS flexibility + Energy Storage
- Scenario #25: Transformer with OLTC capabilities + HEMS + Energy Storage

Scenario #3

Description: Network of Scenario #2 with higher integration of DER.

- LV rural network with 150 nodes and 500 kVA transformer;
- Severe penetration of DER;
- 150 HEMS distributed in the network.

Objective: Measure the costs and benefits of InteGrid predictive management strategy for LV control by exploiting different controllable resources.

- Scenario #31: Before the application of InteGrid tools (Baseline 1)
- Scenario #32: Microgeneration curtailment and load shedding (Baseline 2)
- Scenario #33: HEMS flexibility
- Scenario #34: HEMS flexibility + Energy Storage
- Scenario #35: Transformer with OLTC capabilities + HEMS + Energy Storage

Scenario #4

Description: Network of Scenario #3 with a high X/R ratio (inductive network).

- LV urban network with 150 nodes and 500 kVA transformer;
- Severe penetration of DER;
- 150 HEMS distributed in the network.

Objective: Measure the costs and benefits of InteGrid predictive management strategy for LV control by exploiting different controllable resources.

- Scenario #41: Before the application of InteGrid tools (Baseline 1)
- Scenario #42: Microgeneration curtailment and load shedding (Baseline 2)
- Scenario #43: HEMS flexibility
- Scenario #44: HEMS flexibility + Energy Storage
- Scenario #45: Transformer with OLTC capabilities + HEMS + Energy Storage

3.2.3. Cluster 3

For a commercial VPP, the international replicability of the business model is especially relevant since balancing markets vary from country to country; product definition, technical rules and pricing for mFRR may be different.

Slovenia is a small market with a reduced use of balancing energy. mFRR is procured on a market base through yearly tenders and, most recently, through monthly actions as well. The minimum bid size is 1 MW divided into 24 daily one-hour blocks. It is open to demand response, although some requirements like 24/7 availability to participate makes it difficult for some technologies and puts an additional constraint in the design of aggregators' portfolio (Smart Energy Europe, 2018). mFRR products are paid on activation (pay-as-bid) and availability.

With the assistance of CyberGrid, an economic model was setup from the flexibility operator's perspective, where the possible revenues from mFRR market participation in Slovenia considering a generic portfolio are compared against the costs of the commercial VPP in terms of CAPEX and OPEX, including eventual penalties for underperformance. Moreover, a distribution of the benefits and costs with the flexibility providers (large customers willing to participate in the electricity markets) is also carried out. The balancing needs of the TSO, based on historical data, are expected to be the same with or without the commercial VPP.

Following the same assumptions, a replicability analysis has been made of the commercial VPP business model considering the market rules in Portugal. Nowadays, mFRR is not open to demand response and is provided by balancing areas which include conventional generators and pumped storage consumption units under the same BRP. These balancing areas are required to present price offers for the whole available upward and downward capacity in a daily basis. Although providers offer capacity, only activated mFRR is remunerated. The used energy is valued at the marginal price of the up or down auctions.

Within this scope, a couple of scenarios are covered by the economic SRA. Changes on key technical parameters such as size of the pool (up and down) and the average DER flexibility, from a scalability perspective, were carried out to conclude about the economic worthiness of this business model in both countries and to identify potential deployment barriers. Such ranges of variation have been chosen as the simulations intend to be representative and not exhaustive samples. For these scenarios, the analysis did not consider the detail of the flexibility profiles pooled (i.e., daily or seasonal variations). Therefore, either the DER flexibility profiles complement each other to ensure the tradeable capacity simulated or offer the same amount of flexibility 24/7 during the year.

The simulations have been performed based on 2018's data and considering the following assumptions:

- A minimum backup pool volume of 10% in both upward and downward directions, reducing the tradeable capacity to 90%.
- The penalties for underperformance are 10% of the revenues from mFRR participation.
- 40% of the revenues earned (capacity and energy fees) and 60% of the penalties for underperformance are shared with DER owners. The reason behind the revenue's distribution assumed, it is because this value allows both aggregator and DER owners either to coexist or non-coexist, minimizing strange cases such as the NPV of commercial VPP being negative while DER owners are profiting. Any indirect cost related to the providers, namely the VPP operating costs, is not being pass on to clients; thus, a part of the revenues should be retained.

The impact of the TLS on the flexibility activation was not evaluated since the technical simulations on the demo networks have shown that a great amount of flexibility must be mobilized in order to create any constrains in the distribution grid. Moreover, in opposition to the technical one, the commercial VPP can aggregate different resources spread across different network areas. Nonetheless, its costs were included in the investment analysis as it is a requirement for an integrated and proper functioning of the cluster.

In InteGrid, the flexibility of MV industrial customers, namely wastewater treatment plants owned by AdTA – a Portuguese wastewater utility –, was explored. These plants consist of internal energy intensive processes with their individual flexibility potentials. They can be activated based on specific parameters like activation type, maximum or minimum runtime, time of availability and peak power. Based on the knowledge of these processes for Alcântara and Mafra plants (flexibility matrices), the functional SRA generated 100 scenarios where the processes are started randomly at different time throughout the day. These flexibility profiles have been used by the economic SRA to evaluate the potential gains on the mFRR market over a year based on historical data. Moreover, the two WWT plants were pooled to determine if an aggregator such as the commercial VPP would be profitable selling exclusively their flexibility. In this analysis, the costs of AQUASAFE IT platform (one time) and W2F function (two times, one per each WWT plant) are also included in the economic assessment.

Similarly to the functionality-oriented SRA, the energy optimization function developed by INESC TEC (p-optimizer), which enables the WWT operators to reduce consumption and optimize energy bills, is out-of-scope since no simulations were carried out due to the difficulty of recreating the processes in a simulation environment.

Scenario #1

Description: Changes on the commercial VPP pool characteristics while participating in the Slovenian mFRR market.

- Variation of the pool's size upward and downward from 0 to 30 MW and of the average DER capacity from 0.5 MW (MV customers with limited flexibility) up to 2 MW (MV customers with a more significant flexibility).

Objective: Determine for a given pool if the commercial VPP is profitable attending to the current rules, price of mFRR products and needs of the TSO ELES (2018 data).

Scenario #2

Description: Changes on the commercial VPP pool characteristics while participating in the Portuguese mFRR market.

- Variation of the pool's size upward and downward from 0 to 30 MW and of the average DER capacity from 0.5 MW (MV customers with limited flexibility) up to 2 MW (MV customers with a more significant flexibility).

Objective: Determine for a given pool if the commercial VPP is profitable attending to the current rules, price of this reserve and needs of the TSO REN (2018 data).

Scenario #3

Description: Calculate the potential gains achieved by Alcântara and Mafra WWT plants individually on the Portuguese mFRR market, attending to the price of reserve and needs of the TSO REN in 2018.

Objective: Determine if a commercial VPP pooling the flexibility of the two plants is profitable. The revenues on the mFRR are shared between the flexibility operator and AdTA.

3.2.4. Cluster 4

Based on the flexibility profiles calculated in the scope of D8.1, the goal of the economic SRA with respect to this cluster is twofold: 1) to determine the potential gains of a pool of 100 office buildings in the frequency restauration reserve market with manual activation and also with automatic activation as a matter of replicability; and 2) to assess if EDP Comercial in the role of aggregator can profit from selling the flexibility of this pool, attending to the different market designs and their conditions in the year of 2018. These office buildings are required to have already installed a building management system (part of the baseline).

In Portugal, aFRR is provided on a market basis, by mostly thermal and hydro units. Procurement is done as a single product that needs to include both upwards and downwards capacity (“regulation band”). The proportion between these must be the same as the relation between up and down capacity required by the TSO for the whole system, which is 2/3 upward and 1/3 downward with a tolerance of 5%. In this market, there are both availability and activation payments. The price of aFRR activation is the same as the mFRR activation price.

The following couple of scenarios have been analysed. The aggregation platform expenditure is fixed regardless the number of buildings aggregated. Nevertheless, the number of RTUs installed (2 per building) is proportional to those.

Scenario #1

Description: Calculate the potential gains achieved by a pool of 100 office buildings on the Portuguese mFRR market, attending to the price of reserve and needs of the TSO REN in 2018.

Objective: Determine if an aggregator pooling the flexibility of 100 office buildings competing in the Portuguese mFRR market is profitable.

Scenario #2

Description: Calculate the potential gains achieved by achieved by a pool of 100 buildings on the Portuguese aFRR market, attending to the price of reserve and needs of the TSO REN in 2018.

Objective: Determine if an aggregator pooling the flexibility of 100 office buildings competing in Portuguese aFRR market is profitable.

3.3. Benefits

Given the idea that assets/tools provide a set of functions that can in turn enable Smart Grid which can be eventually monetised, the JRC methodology proposes mapping (1) assets/tools on to functionalities and (2) functionalities on to benefits (Joint Research Centre, 2012). The relevance of these mapping exercises rests on two factors: they assist in thinking of sources of benefits, making a complete set of estimated benefits more likely, and they make possible the evaluation of the impact of a project.

InteGrid's solutions were mapped against 33 functionalities, grouped in 6 main categories, and then the identified functionalities were linked to the benefits they potentially enable from a list of 22, grouped in 4 main categories. The activated benefits are listed in Table 3.

Table 3: Benefits identification.

		Functionalities			
		Cluster #1	Cluster #2	Cluster #3	Cluster #4
Economic Benefits	Optimised Generator Operation				
Economic Benefits	Deferred Generation Capacity Investments	•	•		
Economic Benefits	Reduced Ancillary Service Cost			•	•
Economic Benefits	Reduced Congestion Cost				
Economic Benefits	Deferred Transmission Capacity Investments				
Economic Benefits	Deferred Distribution Capacity Investments	•	•		
Economic Benefits	Reduced Equipment Failures				
Economic Benefits	Reduced Distribution Equipment Maintenance Cost				

	Reduced Distribution Operation Cost				
	Reduced Meter Reading Cost				
	Reduced Electricity Theft				
	Reduced Electricity Losses	●	●		
	Detection of anomalies relating to Contracted Power				
	Reduced Electricity Cost	●	●	●	●
Reliability Benefits	Reduced Sustained Outages				
	Reduced Major Outages				
	Reduced Restoration Cost				
	Reduced Momentary Outages				
	Reduced Voltage Sags and Swells	●	●		
Environmental Benefits	Reduced CO_2 Emissions	●	●		
	Reduced Sox, Nox, and PM-10 Emissions	●	●		
Security Benefits	Reduced Oil Usage				
	Reduced Wide-scale Blackouts				

In the course of work, certain benefits proved not straightforward to quantify. For instance, the estimation of distribution capacity investments deferral would require a significant amount of additional simulations with network planning tools to address the different scalability and replicability conditions in the scenarios. Consequently, this benefit was left out-of-scope of analysis. Nevertheless, its quantification and comparison of a classical (network) investment-based philosophy versus the use flexibility for the operation of the network can be expected as part of the CBA work (WP7), considering the field conditions. Moreover, reducing peak load demand and flattening the load curve may potentially decrease the generation capacity required, leading to fewer investments. It is also very complex to assess this benefit. However, DER flexibility and InteGrid's advanced management solutions may help to reduce conventional generation costs since they allow a higher integration of renewable energy sources in the distribution grids. This benefit can be particularly relevant on countries where fossil fuels are imported and not an endogenous resource.

The reduced ancillary services cost results from the provision of flexibility to the TSO in the secondary and tertiary reserve markets. The aggregation and participation of DER with lower bidding prices could eventually displace the current market agents (with higher prices) and, consequently, reduce the average cost of these frequency restauration reserve markets. Nevertheless, it is extremely hard to predict and monetize this reduction without incurring on significant assumptions or recurring to a dedicated simulation tool. Hence, the analysis of Cluster 03 and Cluster 04 focusses on the business models of the flexibility operator/aggregator (revenues vs. costs), attending to the current markets' framework and the TSO's historical needs.

Excepting the abovementioned benefits, all others identified are calculated and their monetization formulas are presented below. They were based upon CBA general guidelines and other smart grid projects.

- **Reduced Energy Losses Cost**

$$C_{losses} = Losses \times Price\ losses$$

$$C_{losses}^{reduction} = C_{losses}^{baseline} - C_{losses}^{Integrid}$$

Where,

$Losses$: Active energy losses [MWh];

$Price\ losses$: Unitary cost of active energy losses [EUR/MWh];

- **Avoided Voltage Deviation Cost**

Source: Adapted from Sustainable R&D project (Gonzáles et al., 2015)

The presence of voltage deviations over the technical limits jeopardizes the electricity supply and their reduction translates into an improvement on the security of power supply. In case there is a deficit of generation in the system to meet the demand, it has been assumed that the DSO would interrupt part of the consumption to correct the voltage values. The Value of Lost Load (VoLL), which represents the value that consumers attribute to continuity of supply, has been applied whenever undervoltage violations occur.

If there is oversupply, the natural course of action for the DSO would be curtailing part of the renewable generation to restore the voltage values. The cost of energy curtailment has been applied whenever there are overvoltage problems in the network. This cost has been assumed to be in line with the day ahead market price. Hence, the cost of voltage deviations is as follows:

- *Undervoltage events*

$$C_{VD} = P_i \times time \times VoLL$$

$$C_{VD}^{reduction} = C_{VD}^{baseline} - C_{VD}^{Integrid}$$

Where,

P_i: Load shedded [kW];

$time$: Deviation period [hour];

$VoLL$: Value that electricity users give to uninterruptedness of power supply [EUR/kWh];

- *Overvoltage events*

$$C_{VD} = P_i \times time \times Curtailment_{cost}$$

$$C_{VD}^{reduction} = C_{VD}^{baseline} - C_{VD}^{Integrid}$$

Where,

P_i: Generation curtailed [kW];

$time$: Deviation period [hour];

$Curtailment_{cost}$: Value that producers are remunerated per kWh of RES curtailment [EUR/kWh];

- **CO_2 Emissions Savings due to Renewables**

Source: JRC (Flego et al., 2018)

CO_2 emissions savings have been calculated by accounting the additional RES integration in the distribution grid enabled by InteGrid's smart functions. Therefore, this benefit was formulated as follows:

$$CO_{2,savings} = Price\ CO_2 \times emission\ factor \times \Delta EE_{RES}$$

$$\Delta EE_{RES} = \Delta EE_{RES}^{Integrid} - \Delta EE_{RES}^{baseline}$$

Where,

$emission\ factor$: Tonnes of carbon emissions per MWh of electricity energy (country specific) [tCO2/MWh].

ΔEE_{RES}: Renewable energy generated from the additional RES integration enabled on an annual basis by the project with respect to the baseline [MWh/year].

$CO_{2,price}$: European CO_2 market price [EUR/MWh].

- **Avoided Fossil Fuels Cost due to Renewables**

Source: Adapted from JRC (Flego et al., 2018)

A higher percentage of demand satisfied through renewable generation means a lower use of conventional energy. Alongside environmental benefits, fossil fuel reduction could also improve security of supply at the country level by lowering the need for imports (for instance, natural gas), representing also a benefit at societal, macroeconomic and geopolitical levels.

$$Fossil\ fuel_{savings} = \frac{Price\ fuel\ \times\ \Delta EE_{RES}}{\eta_{PP}}$$

$$\Delta EE_{RES} = \Delta EE_{RES}^{Integrid} - \Delta EE_{RES}^{baseline}$$

Where,

ΔEE_{RES}: Renewable energy generated from the additional RES capacity enabled on an annual basis by the project with respect to the baseline [MWh/year]. It represents the amount of fossil fuel-based energy displaced by renewable energy sources.

$Price\ fuel$: Fossil fuel price [EUR/MWh]

η_{PP}: Conventional power plant efficiency [%]

Most of EU' imports of natural gas come from three countries: Russia, Norway and Algeria. According to IEA Statistics (IEA, 2020), in the year of 2018, the natural gas still was the source of 25.5% of the power produced in Portugal; however, in Slovenia, its impact in the generation mix is much less substantial. In Slovenia, the predominant fossil fuel burned in conventional power plants is coal (around 27%) - brown coal and lignite - which is a local energy resource (European Commission, 2017), while natural gas has a share of 2.8%. Due to the different degree of relevance, this benefit has been accounted for Portugal only.

- **Remuneration on flexibility provision (Reduced Electricity Cost)**

Depending on the balancing market rules, flexibility providers (either directly or indirectly through a market player) can be paid on availability and/or activation. For the purpose of this analysis, based on historical data, the potential earnings of market participation have been calculated by the following formulas:

$$Capacity\ provision = Capacity\ price \times Capacity$$

$$Energy\ activation = Energy\ price \times ratio \times Capacity$$

Where,

$Capacity$: Available flexibility offered to the TSO [MW]

$Capacity\ price$: Price of booking reserve [EUR/MW]

$ratio$: Division between the energy activated by the TSO and the capacity provided by all players [MWh/MW]

$Energy\ price$: Price paid by mobilizing reserve [EUR/MWh]

In the case of **grid support to the DSO**, the economic SRA has assumed that the flexibility is remunerated on activation only.

- **Reduced electricity bill (Reduced Electricity Cost)**

Particularly in the case of Cluster 2, HEMS also allows residential customers to optimize their energy consumption. The typical achievable savings in the electricity bill (annual basis) enabled by this function have also be accounted as a side but not less relevant benefit.

Although bill savings would probably imply additional savings in fuel costs and CO_2 emissions, the approach followed prevents a double counting of these benefits. The societal benefits are computed accounting only for the fuel and emissions costs that are achieved only thanks to the increased RES production integrated, thus excluding the ones corresponding to the end-user savings.

3.4. Costs

Since most of the data was shared within InteGrid consortium and due to its confidential nature, it is not possible to present the discriminated costs of the solutions. However, figures of the total software and hardware costs in terms of capital (CAPEX) and operating expenditure (OPEX) per cluster are provided below when considering just one system/device of each component. It has been assumed that the implementation of the solutions is completed in year 0 (2019) and the flow of benefits starts in year 1 (2020).

Table 4: Costs of Cluster 01 implementation.

Cluster #1	
Software Costs	**2019 prices**
Generation and Load Forecasting Systems	
MV Load Allocator	
MPOPF	
Gm-Hub	
Technical VPP	
CAPEX (EUR)	~ 821 000
OPEX (EUR/year)	~ 288 000
Hardware Costs	**2019 prices**
RTU (Technical VPP)	
Capacitor Bank 10 Mvar (Slovenian demo network)	
CAPEX (EUR)	~ 9 430
OPEX (EUR)	~ 230

Table 5: Costs of Cluster 02 implementation.

Cluster #2		
Software Costs		**2019 prices**
Generation and Load Forecasting Systems		
LV State Estimator		
LV Control Tool		
Gm-Hub		
	CAPEX (EUR)	~ 206 000
	OPEX (EUR/year)	~ 38 000
Hardware Costs		**2019 prices**
OLTC transformer (100 kVA or 500 kVA)		
Lithium-ion battery 50 kW/100 kWh		
HEMS[2]		
Smart plug		
Energy Consumption Monitor		
	CAPEX (EUR)	~ 72 000 – 90 000
	OPEX (EUR/year)	~ 950 – 1 550

Table 6: Costs of Cluster 03 implementation.

Cluster #3		
Software Costs		**2019 prices**
Commercial VPP		
Traffic Light System		
Gm-Hub		
AQUASAFE IT platform (Scenario #3 only)		
Water2Flex (Scenario #3 only)		
	CAPEX (EUR)	~ 176 000
	OPEX (EUR/year)	~ 99 555
Hardware Costs		**2019 prices**
RTU (expecting Scenario #3)		
	CAPEX (EUR)	~ 1 000

[2] HEMS has been considered a plug & play solution; thus, the user can install it without requiring technical support.

Table 7: Costs of Cluster 04 implementation.

Cluster #4	
Software and Hardware Costs	**2019 prices**
Aggregation Platform	
RTU	
Traffic Light System	
Gm-Hub	
CAPEX (EUR)	~ 120 000
OPEX (EUR/year)	~ 53 500

Similarly to smart meters and concentrators devices, the considered lifetime of the equipment installed in the clients' premises (i.e. RTUs, HEMS, smart plugs and energy consumption monitor) is 10 years. Therefore, their CAPEX appears two times in the economic model, in the year 0 and the year 10. Moreover, no OPEX was foreseen for these devices, meaning that hardware operating costs on the tables above relates to others such as batteries and OLTC transformers.

On the other hand, since the life expectancy of the software components and the equipment installed in the distribution grid goes beyond the time horizon of the analysis (later identify in section 3.6 with other macroeconomic/financial assumptions), their CAPEX is only reflected in the year zero.

3.5. Beneficiaries and CB Allocation

In the next tables, we present how costs and benefits have been split in the analysis among the different players (society included), per each cluster. In the absence of a regulatory framework for the HLUC under analysis, this choice was based upon the previous work developed on the definition of roles and actors (WP1) and on the definition of business models (WP7). Nevertheless, we would like to highlight that, once a regulatory framework has been defined, the allocation of the costs and benefits will probably be different, and likely to guarantee an advantageous outcome to all players involved. For the purpose of InteGrid, a business model can be understood as a set of business strategies chosen by a certain agent in order to generate economic benefit. These business strategies can combine multiple instruments, and the economic benefits can be generated by different sources of revenue streams and cost reductions [REF D7.5]. The total costs/benefits are the sum of the costs/benefits to all stakeholders. The transfer payments among those cancel each other out, not contributing to the overall perspective.

In cluster 01, the DSO, as distribution system optimiser and neutral market facilitator, bears the costs related to all smart functions to improve the MV grid management tools and the gm-hub. For the sake of simplicity, it has been assumed that the forecast provision is done internally by the DSO and not outsourced to a "forecast provider". In reality, these costs can be pass on later to the electricity users through the tariff; however, we do not enter in that level of detail. Moreover, it also pays a given cost for exploiting flexibility of other resources that are not yours. The only benefit it captures regards the reduction of the active power losses when applicable.

On the other hand, the flexibility operator is responsible for the costs of its own technical VPP. Its stream of revenue is the volume of flexibility pre-booked and ultimately activated by the DSO, within its portfolio. Finally, other social parties such as electricity consumers in general perceive an enhancement in the quality of service and citizens at large benefit from reduced CO_2 emissions and primary energy savings.

Table 8: Cluster 01. Distribution of costs and benefits among the different stakeholders.

DSO	Flexibility Operator	Society
CAPEX and OPEX • Forecasting Systems • MV Load Allocator • MPOPF • Gm-Hub • Power equipment **OPEX** • Cost of flexibility (Technical VPP) **Benefits** • Reduced power losses Costs (DSO)	**CAPEX and OPEX** • Technical VPP • RTUs **Benefits** • Revenue from flexibility provision to the DSO	**Benefits** • Reduced voltage deviations costs • CO_2 emissions savings • Avoided fossil-fuel costs

In Cluster 02, just as in Cluster 01, the DSO, as distribution system optimiser and neutral market facilitator, bears the costs related to the all smart functions to improve the LV grid management tools and the gm-hub. For the sake of simplicity, it has been assumed that the forecast provision is done internally by the DSO. In reality, these costs are pass on later to the electricity users; however, we do not enter in that level of detail. Moreover, it also pays a given cost for taking advantage of flexibility of other resources that are not yours. The only benefit it captures regards the reduction of the active power losses.

HEMS owners are residential customers/prosumers equipped with this device. As mentioned before, HEMS allows the user to reduce their electricity bill and estimates the household's flexibility to support the DSO, respecting its comfort requirements. In our perspective, since it is not mandatory and is outside the DSO's concession area, only a fraction of residential customers/prosumers will have it; thus, its cost must be directly paid by their users. Additionally, in this cluster between the DSO and the HEMS owners, there is not an aggregator figure that could possibly cover HEMS cost in exchange of the customers' flexibility.

Finally, other social parties such as electricity consumers in general perceive an enhancement on the quality of service and citizens at large benefit from reduced CO_2 emissions and primary energy savings.

Table 9: Cluster 02. Distribution of costs and benefits among the different stakeholders.

DSO	HEMS owners	Society
CAPEX and OPEX • Forecasting Systems • LV State Estimator • LV Control tool • Gm-Hub • Power equipment **OPEX** • Cost of flexibility (HEMS) **Benefits** • Reduced Power Losses Costs (DSO)	**CAPEX** • HEMS and another household's equipment **Benefits** • Cost reduction in the electricity bill • Revenue from flexibility provision	**Benefits** • Reduced Voltage Deviations Costs • CO_2 emissions savings • Avoided fossil-fuel costs

In Cluster 03, the DSO as a neutral market facilitator only bears the costs related to the gm-hub and the Traffic Light System. They are required for an integrated and proper functioning of the cluster. In reality, these costs are pass on later to the electricity users; however, we do not enter in that level of detail. No benefits are foreseen for this stakeholder.

The flexibility operator is responsible for the costs related to pooling flexibility from customers and converting it into balancing market services. Its stream of revenue relates to the volume of flexibility pre-booked and ultimately activated by the TSO, within its portfolio. When considering the WWT plants flexibility, from our point of view, AdTA pays the investment and operating costs of AQUASAFE and Water2Flex, which are necessary tools to make use of their internal processes' flexibility. A share of the aggregator's benefits/costs is pass on to AdTA, comprising its gains with flexibility provision.

Table 10: Cluster 03. Distribution of costs and benefits among the different stakeholders.

DSO	Flexibility Operator	AdTA
CAPEX and OPEX • TLS • Gm-Hub	**CAPEX and OPEX** • Commercial VPP • RTUs **Benefits** • Revenue from tertiary regulation services provision (FO's share)	**CAPEX and OPEX** • AQUASAFE • Water2Flex **Benefits** • Revenue from tertiary regulation services provision (AdTA's share)

In Cluster 04, the DSO as a neutral market facilitator bears the costs related to the gm-hub and the Traffic Light System. They are required for an integrated and proper functioning of the cluster. In reality, these costs are pass on later to the electricity users; however, we do not enter in that level of detail. No benefits are foreseen for this stakeholder.

The energy retailer EDP Comercial as an aggregator is responsible for the costs related to pooling flexibility from customers and converting it into balancing market services. Its stream of revenue relates to the volume of flexibility pre-booked and ultimately activated by the TSO, within its portfolio of office buildings.

Table 11: Cluster 04. Distribution of costs and benefits among the different stakeholders.

DSO	Aggregator
CAPEX and OPEX • TLS • Gm-Hub	**OPEX** • Energy Services platform (also known as, aggregation platform) **CAPEX** • RTUs **Benefits** • Revenue from frequency restauration reserve services provision

3.6. Economic Boundary Conditions

The main assumptions and input data employed in the economic SRA are listed in Table 12 and Table 13. Moreover, some of them have been considered for sensitivity analysis. References as well as explanations for the main assumptions are provided in the following.

Table 12: Financial and economic assumptions used in InteGrid economic SRA.

	Portugal	Slovenia	Units	Sensitivity Analysis
Time Horizon	11		Years	No
Real Social Discount Rate	5%		%	Yes
Real Financial Discount Rate	15%		%	Yes
Natural Gas Price	20		EUR/MWh	Yes
Domestic Value of Lost Load	5.89	4.32	EUR/kWh	Yes
Non-Domestic Value of Lost Load	3.44	4.68	EUR/kWh	Yes
Energy Losses Cost	49.52	43.67	EUR/MWh	Yes
Capacity price mFRR+/mFRR-	N/A	4.45/4.34	EUR/MW/h	Yes
Energy price mFRR+/mFRR-	73/40	249.5/-	EUR/MWh	Yes

	2020	2025	2030	Units	
Carbon Price (2016 prices)	15	22.5	33.5	EUR/t	No

Table 13: Input data for benefit calculations.

	Portugal	Slovenia	Units	Sensitivity Analysis
CO_2 emission factor	0.37	0.56	t/MWh	Yes
Ratio mFRR+/mFRR-	87.6/302.9	12.5/0	MWh/MW	No
Electricity cost savings	10		%	Yes
CCGT efficiency plant	57.9		%	No

- **Time Horizon**

The time horizon of the analysis is a crucial parameter. An approach to set it considers the project assets' lifetime. According to JRC guidelines for conducting a CBA of smart grid projects, in the case of investments including assets with a different lifetime, the renewal of the asset with a shorter lifetime should be included as an additional cost in the economic assessment. Since the shortest lifetime is 10 years, a time horizon of analysis of 11 years has been chosen.

- **Discount rate**

The discount rate takes into account the time value of money (the idea that the money available now is worth more than the same amount of money available in the future) and the risk of anticipated future cash flows. The discount rate typically has a significant impact on the assessment of smart grid projects because costs are incurred predominantly at the beginning while they often provide benefits in the long-term.

Different discount rates can be used in calculating the NPV, depending on the perspective adopted and the stakeholders considered. Recognizing the societal value of smart grid investments under Cluster 01 and Cluster 02, a social discount rate has been applied. Discounting costs and benefits at this discount rate provide the value the project gives to society regardless of the actual project funding costs. In Annex III of the Implementing Regulation 2015/207 on CBA methodology of investment projects for 2014-2020 programming period, the European Commission (EC) recommends that a social discount rate of 5 % shall be used as a benchmark in Cohesion Member States, which is the case of Portugal and Slovenia (European Commission, 2015). It was subject to sensitivity analysis on a range of variation of ±1%.

In the case of Cluster 03 and Cluster 04, the assessment has been made in a private investor's point of view. After consulting with CyberGrid, a financial discount rate of 15% has been taken as a working assumption due to the high level of risk of a commercial aggregator business case. A range of variation of ± 2 % has been considered in the sensitivity analysis.

Both discount rates have been assumed to be expressed in real terms, therefore the analysis was carried out at constant prices (no inflation considered), i.e. with prices fixed at a base-year which is 2019.

- **Natural gas price**

Figure 7 shows the evolution of the whole day-ahead gas prices on gas hubs in the EU from 2016 until the end of the second quarter of 2019 (European Commission, Directorate-General for Energy, 2019). As can be observed, European hub prices were averaging around 12-17 €/MWh in the second quarter of 2019, which was lower than the range in Q1 2019 (18-21 €/MWh), as well as the range in Q2 2018 (20-24 €/MWh). In fact, in the second quarter of 2019 hub prices in Europe were down by 27-42% in year-on-year comparison. Looking at the volatility of the natural gas price on EU over time, this price has been set to 20 EUR/MWh in the base case. Once subject to sensitivity analysis, it has been changed in range from 10 EUR/MWh to 30 EUR/MWh.

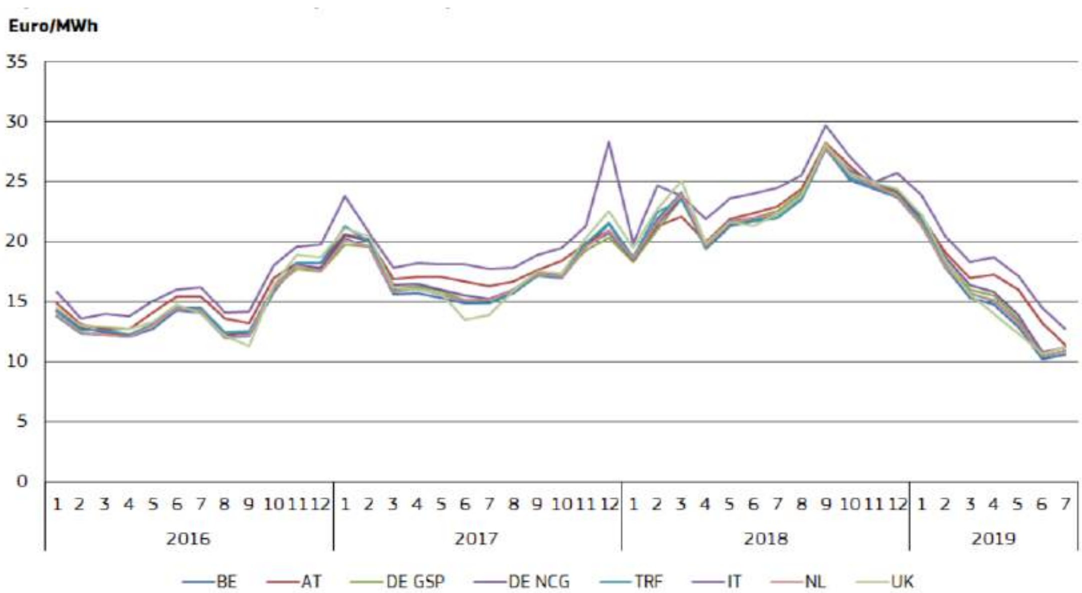


Figure 7: Evolution of the day-ahead natural gas price on EU's gas hubs between 2016 and mid-2019. Source: (European Commission, Directorate-General for Energy, 2019)

- **Value of Lost Load**

The Value of Lost Load (VoLL) represents the cost to economy per kWh of electricity not supplied. The Agency for the Cooperation of Energy Regulators (ACER) ordered recently a study on the estimation of this social indicator in Europe, where country-specific values for domestic and non-domestic consumers are provided (CEPA, 2018).

For Portugal, the domestic VoLL is 5.89 EUR/kWh and for Slovenia is 4.32 EUR/kWh. Since the study covers a wide range of industries and services, an average VoLL for non-domestic customers has been assumed: in the case of Portugal is 3.44 EUR/kWh and in Slovenia is 4.68 EUR/kWh. The non-domestic VoLL has been applied when analysing MV networks (Cluster 01) while the domestic VoLL when analysing LV networks (Cluster 02). It is interesting to observe that in Portugal, this indicator is higher for the domestic sector than for the non-domestic, while in Slovenia is precisely the opposite.

Both customer-type VoLL have been subjected to sensitivity analysis. While in the case of non-domestic customers, the industries/services with the highest and lowest VoLL have been chosen as maximum and minimum respectively, in the case of domestic customers, there is not any indication of the uncertainty associated and, consequently, a small range of variation has been arbitrated.

- **Active Power Losses Cost**

The economic impact of energy losses can be represented in a simplified way as an energy purchase at the wholesale market price. According to ENTSOE transparency platform (ENTSO-E, 2020), the annual average day-ahead price in 2014-2018 period was 49.52 EUR/MWh for Portugal and 43.67 EUR/MWh for Slovenia. In Figure 8 is depicted the evolution of the day-ahead market prices for both countries in the analysed period. A range of ± 10 EUR/MWh variation has been considered in the sensitivity analysis.

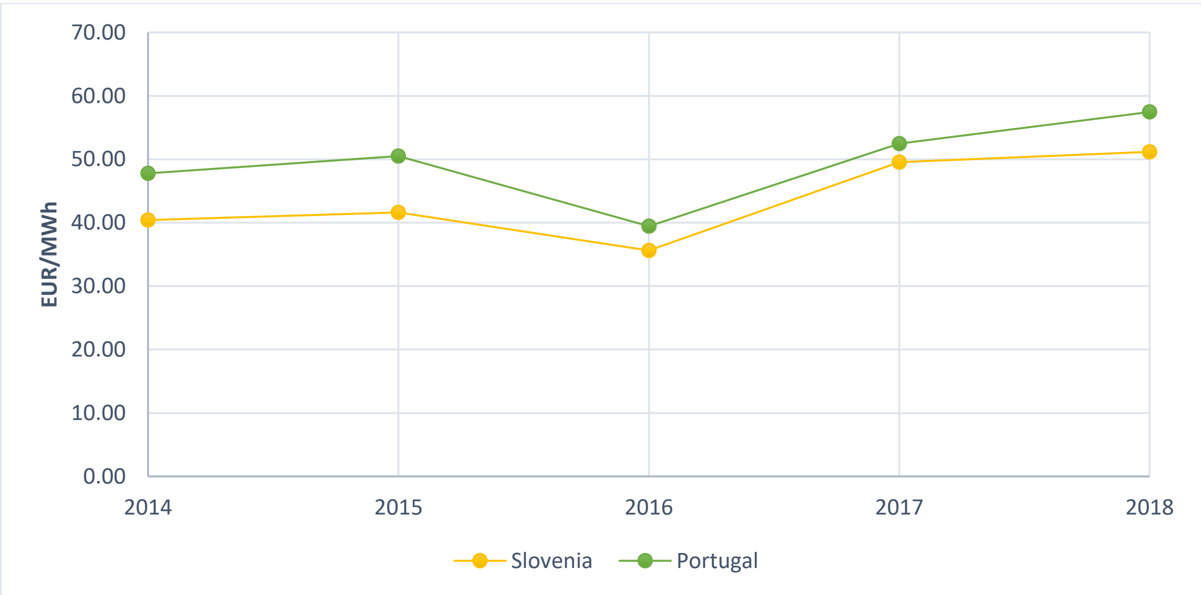


Figure 8: Annual average day-ahead market prices between 2014 and 2018 in Slovenia and Portugal.

- **Price of carbon emissions**

European CO_2 emission permits are traded on a dedicated market. The carbon prices by 2020, 2025 and 2030 projected by EC's Reference Scenario 2016 (long-run) have been considered (European Commission, 2016). For the other coming years in analysis, a linear interpolation has been done. These values have been converted to 2019 prices attending to the average historical inflation between the years of 2016 and 2018 (country-specific). According to OCDE, the average annual inflation rate in Portugal was 1.18% and in Slovenia was 1.6% (OECD, 2020).

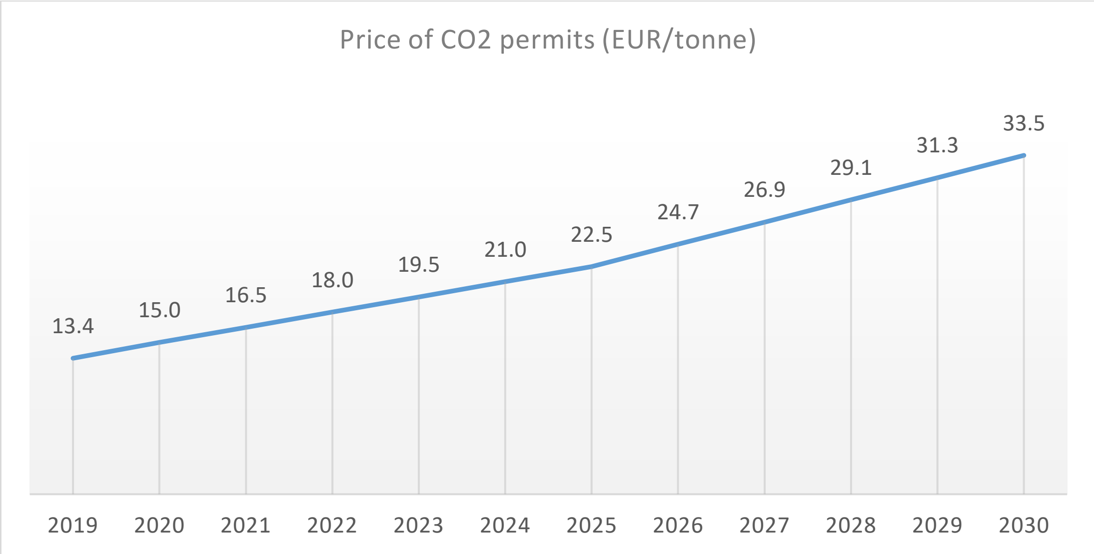


Figure 9: Evolution of CO_2 permits price in the coming years before inflation.

- **Emission factor**

The emission factor is a country-specific coefficient that translates a unit of electricity consumed into the corresponding amount of greenhouse gas emissions, namely CO_2. The Covenant of Mayors is a European initiative by which towns, cities and regions voluntarily commit to reducing their CO_2 emissions beyond the 20 % target. Its guidebook of how to develop a sustainable energy action plan provides country-specific emission rates for both Standard and Life Cycle Assessment approaches (Covenant of Mayors, 2010). While the standard emission factors, following the Intergovernmental Panel on Climate Change (IPCC) principles, cover all CO_2 emissions that occur due to energy consumption within a given territory, the LCA emission factors take in consideration the overall life cycle of the energy carrier.

For the base case, standards emissions factors have been selected. The standard emission rate is 0.369 tCO_2/MWh for Portugal and 0.557 tCO_2/MWh for Slovenia. Nevertheless, this variable has been considered to sensitivity analysis within a range of 0 tCO_2/MWh to the LCA emission factor of each country, which is 0.75 $tCO_2 \cdot eq/MWh$ for Portugal and 0.602 $tCO_2 \cdot eq/MWh$ for Slovenia.

- **Capacity price in the upward/downward mFRR**

In Slovenia, mFRR products are also paid on availability. In 2018, yearly and monthly bilateral contracts were established to book positive and negative balancing capacity. Short-term auctions fit better the use case of the commercial VPP operation, particularly because it may have problems to fulfil an annual contract if the Traffic Light System will curtail the available flexibility. As published by the Slovenian TSO (ELES, 2020), the accepted bids in the monthly auctions within the limited prices range are provided in Table 14. The most frequent price paid on upward capacity (mode) have been used, which is 4.45 EUR/MW/h. This variable has been subjected to sensitivity analysis where the maximum is 4.49 EUR/MW/h and the minimum is 3.95 EUR/MW/h.

Table 14: Prices of Procured mFRR (monthly actions) in Slovenia in the year of 2018. [3]

Time Period	Bids (MW)	Capacity price [EUR/MW/h]	Energy price [EUR/MWh]	Direction
January 2018	26	3,99	240	Up
	10	4,35	240	Up
March 2018	16	3,99	249,5	Up
	5	4,34	240	Up
	10	4,35	249,5	Up
	5	4,45	249,5	Up
April 2018	5	3,95	240	Up
	5	4,34	249,5	Up
	21	4,45	249,5	Up
	5	4,49	249,5	Up
May 2018	7	4,42	249,5	Up
	15	4,45	249,5	Up
	14	4,49	249,5	Up
June 2018	5	4,43	249	Up
	7	4,42	249,5	Up
	21	4,45	249,5	Up
July 2018	5	4,42	249	Up
	7	4,42	249,5	Up
	15	4,45	249,5	Up
	9	4,49	259	Up
August 2018	7	4,42	249,5	Up
	5	4,45	249	Up
	23	4,49	259,5	Up
September 2018	7	4,44	249,5	Up
	6	4,45	249	Up
	23	4,49	259,5	Up
October 2018	9	4,43	249,5	Up
	27	4,49	259,5	Up
November 2018	9	4,45	249,5	Up

[3] No information has been found on February 2018.

	5	4,47	249	Up
	22	4,49	259,5	Up
December 2018	36	4,42	259,5	Up

As observed, no downward tertiary reserve was booked through monthly contracts by the TSO in 2018. Therefore, in order not to limit the economic performance of the commercial VPP, it has been assumed that the operator participated in the yearly tender to sell downward flexibility. According to ENTSO-E, in this year, a small bid of 10 MW downward reserve had been accepted from a load resource for a capacity price of 4.34 EUR/MW/h. In addition, two other offers of higher volumes were purchased, and their booking prices of 4.28 EUR/MW/h and 4.45 EUR/MW/h have been used as variation extremes in the sensitivity analysis.

- **Energy price in the upward/downward mFRR**

According to the information available on the Portuguese TSO website (REN, 2020), 2018's average mFRR regulation prices on energy activation in Portugal were 73.1 EUR/MWh up and 39.9 EUR/MWh down. These variables have been subjected to sensitivity analysis. The maximum and the minimum variation correspond to the highest and the lowest remuneration price on energy activation, respectively, during 2018. In the upward direction, these values were 18 EUR/MWh and 180.3 EUR/MWh. In the downward direction, these values were 0 EUR/MWh and 70 EUR/MWh. Figure 10 shows the reserve price variation in Portugal.

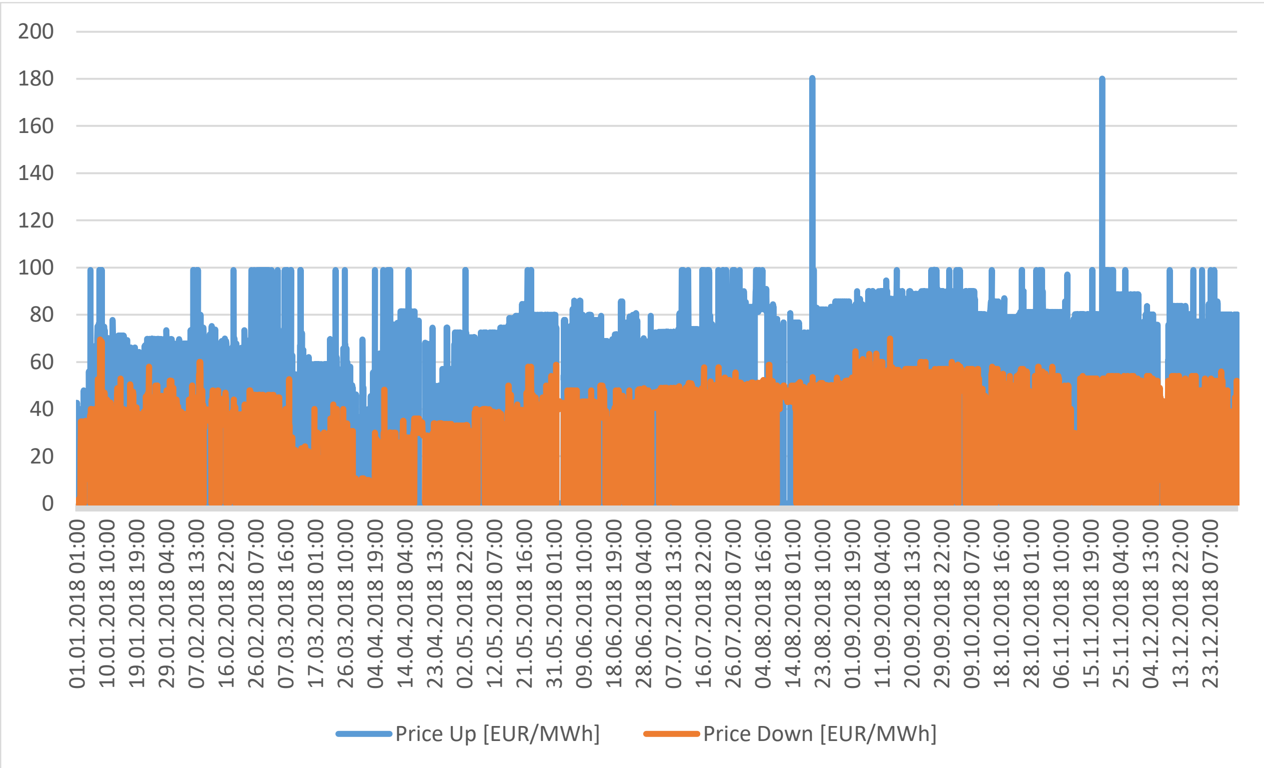


Figure 10: Energy price up and down of the Portuguese tertiary reserve market in 2018.

In Slovenia, no activation on the downward mFRR occurred in this year. As per the table above, the most frequent upward energy price has been considered, which was 249.5 EUR/MW/h. This price has been changed between 259.5 EUR/MW/h (maximum price) and 240 EUR/MW/h (minimum price) in the sensitivity analysis. In this concern, one can observe that the range of variation in the Portuguese market is much higher than in Slovenian market.

- **Ratio upward/downward mFRR**

The ratio between the volume of reserve activated (MWh) and the capacity delivered (MW) for all the bidders/participants is an indicator that measures the needs of the TSO and the competition in the tertiary reserve market. It allows to have an idea of the fraction of capacity that is effectively activated by looking at the past years. In 2018, in Portugal, this ratio was 87.6 hours up and 302.9 hours down. In the same year, in Slovenia, this ratio was 12.5 hours up and 0 hours down.

- **Electricity cost savings**

As mentioned in Section 3.1.2, HEMS not only enables the participation of residential customers on grid voltage control but also allows to optimize their energy consumption. An energy cost reduction of 5% in the monthly bill due to the energy optimization function of HEMS have been accounted on the economic assessment, proportionally to the number of HEMS installed in the networks. The baseline assumes a peak demand around 7 kW without any PV installation, considering Portugal average climatological conditions and the Spanish dynamic tariff. In the optimized scenario, the consumption is shifted to hours with lower energy prices. In other words, this will translate into approximately 61 EUR/year of energy cost savings to each residential customer equipped with this device. This parameter has been subjected to sensitivity analysis in a 3% - 7% range.

3.7. Discussion of Results

To conclude on the economic worthiness of the scale increase and replication, a discounted cash flow analysis has been conducted. The discounted cash flow (DCF) is a valuation method used to estimate the value of an investment based on its future cash flows. DCF analysis attempts to figure out the value of a project/solution today, based on projections of how much money it will generate in the future.

The DCF is dependent upon determining the future cash flows associated with a project/solution and then discounting these cash inflows (benefits) and outflows (costs) to find the net present value (NPV). The NPV is a mathematical technique for translating each of these projected annual cash flow amounts into today-equivalent amounts so that each year’s projected cash flows can be summed up in comparable terms. Its formula is as follows:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Where,

R_t is the net cash inflow-outflows during a single period t;

i is the discount rate;

t is the period number.

A positive net present value indicates that the projected earnings generated by a project/solution exceeds the anticipated costs. In this case, it is assumed that the investment will be profitable, while an investment with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value Rule, which dictates that only investments with positive NPV values should be considered.

A cluster of HLUCs will only be scalable if the NPV is equal or greater than before scaling. Differently from the case of scalability, a group of HLUCs will be considered replicable if its application in another region/country leads to a positive NPV.

The internal rate of return (IRR) is the discount rate that makes the NPV of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV does. This metric is relevant in investment analysis where the different stakeholders have a different cost of capital (i.e., WACC).

3.7.1. Cluster 1

3.7.1.1. Slovenia

Table 15 shows the NPVs obtained for the scenario #1 and #2. The total NPV considers all costs and benefits of the business case while the different stakeholders' NPV considers the costs and benefits allocated in 3.5 section.

Table 15: Cluster 01. Slovenia. NPV obtained for scenarios #1 and #2.

	NPV			
Scenario ID	**Total**	**DSO**	**FO**	**Society**
S12	-1 741 884 €	-1 334 734 €	-1 130 914 €	723 764 €
S13	-607 635 €	-1 331 399 €	0 €	723 764 €
S14	-617 975 €	-1 341 740 €	0 €	723 764 €
S22	-1 083 336 €	-1 434 997 €	-1 030 651 €	1 382 312 €
S23	50 913 €	-1 331 399 €	0 €	1 382 312 €
S24	40 573 €	-1 341 740 €	0 €	1 382 312 €

One can observe that the deployment of this group of advanced solutions at the Slovenian demonstrator level is not economically feasible, from an overall perspective, when exploiting MV customers demand response (i.e., sub scenario S12 and S22). Both the DSO and the flexibility operator incur in a net loss. Nevertheless, when resorting to the DSO owned resources, the cluster's NPV is either significantly less negative (sub scenarios S13 and S14) or even positive (sub scenarios S23 and S24), since the technical VPP related costs were not included and society has the same profits. The IRR of sub scenarios S23 and S24 is 7% and 6,6%, respectively.

Society's NPV is greater in the scenarios where the two PV generators have been included than in the current network conditions. The increased added value to this stakeholder is essentially due to: 1) the activation of the CO_2 emission saving benefit; and 2) the improvement on the quality of service being more significant because the baseline in this case presents voltage constrains at a higher extend. In scenario 22, the FO's NPV becomes less negative as more flexibility is activated to deal with the several overvoltage deviations. On the other hand, the DSO bears further operating costs due to the use of flexibility.

The economic figure of increasing RES penetration by 30% (scalability in density) is depicted below. When considering the technical VPP, it still is not interesting from an economic perspective to implement this group of solutions at the Slovenian demo scale. The stakeholders' NPV reinforce their values following the same trend has in the sub scenario #2. Society has a higher NPV than before. The FO's NPV becomes further less negative since even more flexibility is activated but now to tackle a line congestion. On the other hand, the DSO has even more costs related to the increased flexibility bill, although in this scenario the overvoltage problems were solved by resorting to its own equipment.

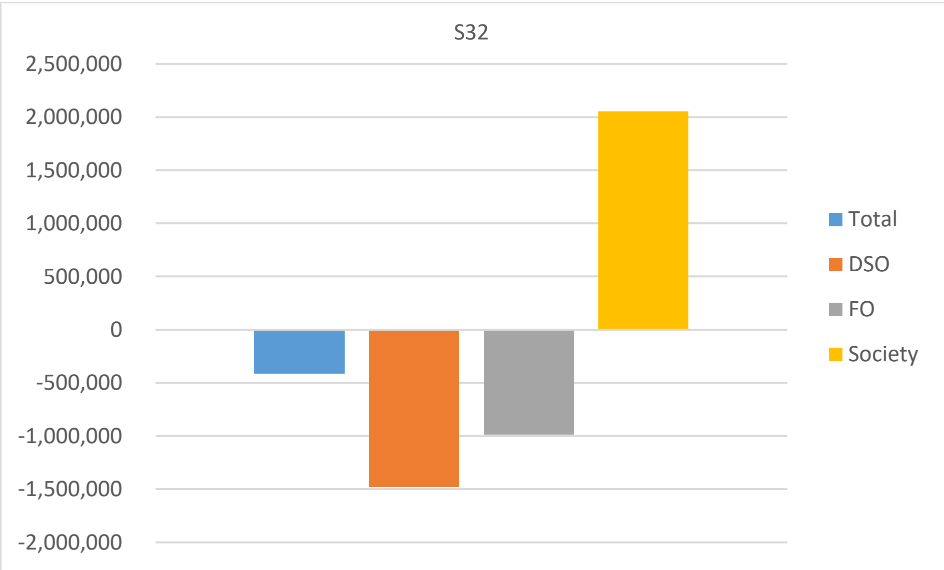


Figure 11: Cluster 01. NPV results of sub scenario S32.

Sub scenarios S32 was subject to scalability in size analysis in order to verify if the overall NPV becomes greater than zero, particularly when the technical VPP is providing flexibility. Attending to the number of existing transformers with a nominal power of 31.5 kVA within EL's concession and outside Ljubljana city, it has been considered as reasonable to extend the deployment area to 5 times the scale of the Slovenian demo. The anticipated technical VPP costs and the calculated benefits for the demo grid are 5 times greater (scale in size) while the DSO's costs remain equal excepting for the flexibility and the capacitor bank costs. According to the ICT-SRA, the simulations performed to this cluster did not show any scalability constrains. Given its local action, there are 5 technical VPP with the same characteristics as in the demo (one per grid).

Once assuming a great RES penetration in the Slovenian distribution network and increasing the initial implementation area of Cluster 01 solutions, the overall NPV is now positive but is being fully supported by the gains of society (Figure 12). As anticipated, the FOs' NPV results worse than before scaling as the NPV is 5 times negative. The IRR in this case is 48,7%.

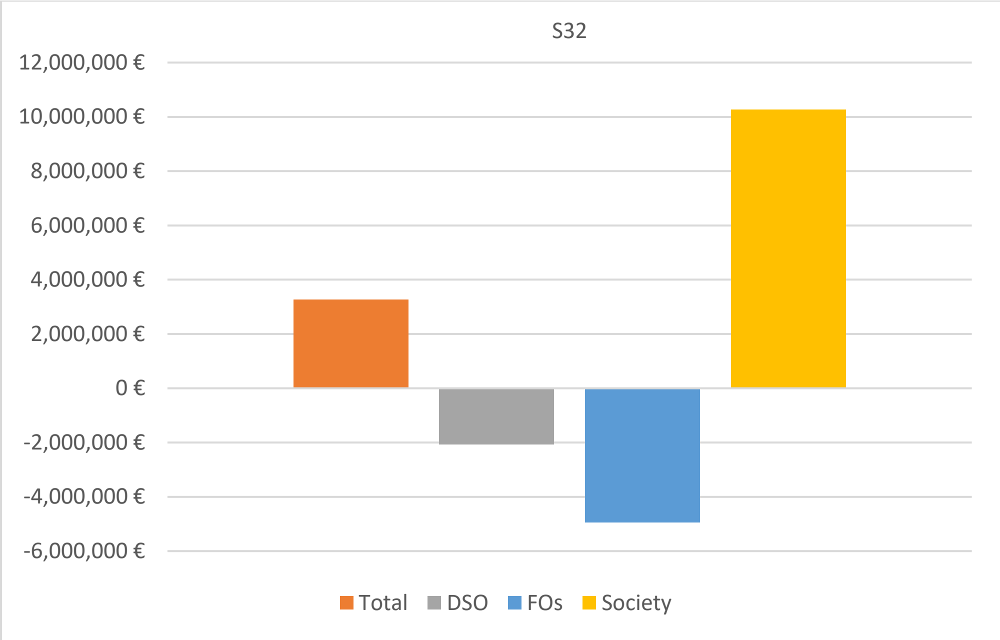


Figure 12: NPV results of scaling in size sub scenario S32.

Note

Since no simulations were performed to determine the amount of RES or load which would be necessary to curtail or reduce to correct the voltage violations in the scenarios, this amount was estimated based upon the relation observed between active power injected/consumed and the voltage in the nodes at the deviation periods (sensitivity of the node voltage to active power). The required average values for load shedding and curtailment, in percentage, are summarized below.

S1	Load Shedding	14,7%
S2	PV curtailment	42,5%
S3	PV curtailment	44,3%

3.7.1.1. Portugal

Table 16 shows the NPVs obtained for the scenario #1 and #2. The total NPV considers all costs and benefits of the business case while the different stakeholders' NPV considers the costs and benefits allocated in 3.5 section.

Table 16: Cluster 01. Portugal. NPV obtained for scenarios #1 and #2.

	NPV			
Scenario ID	**Total**	**DSO**	**FO**	**Society**
S12	-1 789 583 €	-4 978 211 €	3 188 639 €	0 €
S13	-1 209 788 €	-1 209 788 €	0 €	0 €
S22	4 485 577 €	-1 470 811 €	-419 363 €	6 375 752 €

As can be seen, in scenario S12, although the overall and DSO's NPV are negative, the FO's NPV results positive. Since the RES are dependent on meteorological conditions to increase their local injection, a cogeneration source was considered. Its flexibility was always entirely exploited by the MPOPF to reduce the active power losses during the 24-hour period, justifying the fact that this is the only scenario within Cluster 01 simulations in which the technical VPP appears as profitable. Consequently, the DSO has a further negative NPV since there is a payment transfer related to flexibility among these two stakeholders.

In scenario S13, the primary substation OLTCs were used to accomplish the same goal. Here, the only stakeholder is the DSO since it bears all the costs and captures the only benefit in analysis, which relates to the reduction of active power losses costs. This same benefit was not enough to cover the expenditures.

Finally, the total NPV results positive for scenario S22, which considers a higher DER penetration than in scenarios #1. The gains of society, due to the improvement of the security of supply, reduction of CO_2 emissions and avoided fossil-fuel costs, are turning, in these specific conditions, this group of solutions as economically interesting from a global perspective, even at a demo scale. The NPV for the FO is negative as the cheapest flexibilities are activated to tackle the technical problems.

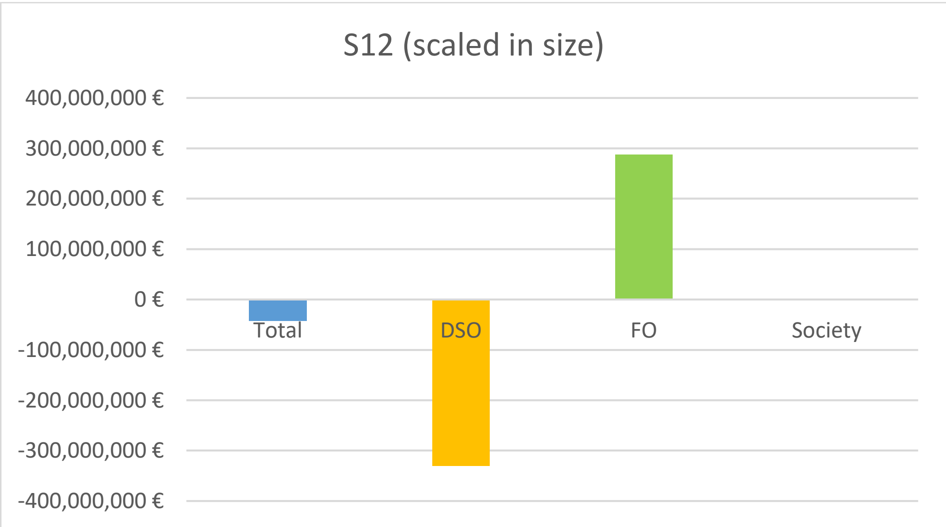


Figure 13: NPV results of scaling in size sub scenario S12.

Sub scenarios S12 has been subject to scalability in size analysis in order to verify if the business case improves, particularly when the technical VPP is providing flexibility. According to EDP Distribuição own information, there are 90 HV/MV substations similar to Mafra's substation power grid. The technical VPP costs and the calculated benefits for the demo grid are 90 times greater while the DSO's costs remain equal except for the flexibility costs. According to the ICT-SRA, the simulations performed to this cluster did not show any scalability constrains. Given its local action, there are 90 technical VPP with the same characteristics as in the demo (one per grid).

If the MPOPF and the other tools are only explored with the purpose of minimizing the active power losses, even when increasing the implementation area, it may not justify their implementation as per Figure 13 below. Nevertheless, this would naturally depend on the existence of specific incentive schemes allowing DSOs to benefit from a reduction in network losses as well as on the strength of these incentives.

Note

Once again, since no simulations were performed to determine the amount of RES or load which would be necessary to curtail or reduce to correct the voltage violations in the scenarios, this amount was estimated based upon the relation observed between active power injected/consumed and the voltage in the nodes at the deviation periods (sensitivity of the node voltage to active power). The average values, in percentage, are summarized below.

S2	PV curtailment	7 %
	Load shedding	20 %

3.7.1.2. Conclusions

One of the most relevant insights of this analysis relies on the profitability of the technical VPP. As observed in the simulations, the technical VPP might have an important role in future conditions of the network, since the large-scale integration of DER can create a number of technical problems and of different nature (e.g. over/under voltage and overload) arising at the same hours of the day. A diversity of resources should be at the disposal of the DSO, as its own resources might not be enough to deal with these issues.

Nevertheless, in most scenarios where the cheapest flexibility is chosen to tackle the network problems, the earnings of the technical VPP were not enough to cover its expenditures, if the flexibility products were only paid on mobilization. There are other alternatives for the definition of the flexibility products and its remuneration that could mitigate the risk by providing a more stable and predictable revenue stream. For instance, tVPPs could be remunerated based on availability (capacity) besides activation. On the other hand, this would increase the operating costs for the DSO.

Moreover, VPP operators, as a non-regulated agent, should be active in several markets/services to ensure profitability. A VPP providing services exclusively to the DSO, especially if network problems arise sporadically and depending on meteorological conditions, may not receive enough revenues to be feasible, facing therefore very high business risks.

A better business case was obtained in those situations where the distribution grid is more stressed, i.e. when DER penetration was high (scalability in density). Smaller scale applications in stressed networks, which are not interesting from an economic perspective, can become interesting once they are scaled up. Therefore, increasing scale can be a condition for economic feasibility. Differently, the overall net benefits are virtually negligible in situations where the grid is not stressed and, as for network losses reduction, they do not seem a main driver for these solutions.

3.7.2. Cluster 2

3.7.2.1. Portugal

Table 17 shows the NPV of the different scenarios obtained for Portugal. As explained before, the total NPV considers all costs and benefits of the business case while the different stakeholders' NPV considers the costs and benefits allocated in the section 3.5. For the purpose of this analysis, one has taken the assumption that end-users flexibility is paid on activation at 60% of the average day-ahead market price in this country. Nevertheless, this variable does not affect the overall NPV since its payment transfer among the DSO and the HEMS owners, cancelling each other out.

Table 17: Cluster 02. NPV of the different scenarios obtained for Portugal for a single network.

	NPV			
Scenario ID	**Total**	**DSO**	**HEMS owners**	**Society**
S13	-519 348 €	-522 232 €	929 €	1 956 €
S14	-573 497 €	-576 375 €	922 €	1 956 €
S15	-546 597 €	-548 624 €	71 €	1 956 €
S23	-458 675 €	-523 674 €	2 180 €	62 819 €
S24	-512 771 €	-577 757 €	2 167 €	62 819 €
S25	-561 717 €	-624 807 €	271 €	62 819 €
S33	321 811 €	-522 191 €	1 242 €	842 760 €
S34	267 698 €	-576 204 €	1 143 €	842 760 €
S35	218 533 €	-625 106 €	878 €	842 760 €
S43	-520 746 €	-522 155 €	911 €	497 €
S44	-574 920 €	-576 327 €	910 €	497 €
S45	-569 791 €	-570 613 €	324 €	497 €

As can be seen, the total NPV is negative for most of scenarios excepting for sub scenarios of the third group. This is an indication that, in these cases, is not economically interesting to implement this group of solutions at a single network scale, in the simulated technical conditions, from a global perspective. Nevertheless, the allocation of costs and benefits is not evenly distributed across stakeholders. Whilst the economic assessment from the DSO perspective is always negative, the net benefits for HEMS owners and society are generally positive. Naturally for the group of residential customers equipped with HEMS, the NPV increases as the number of these devices grows in the network among the scenarios. Particularly for society, the lowest added value is in inductive networks since there are less voltage problems to be solved.

For the sake of clarification, scenarios S14 and S44 (HEMS + ES flexibility) have a worst overall NPV than S15 and S45 respectively (all controllable devices flexibility), because 1) the OLTC transformer was able to solve all voltage violations and no other flexibility was needed (following the merit order) and 2) the Total Costs of Ownership (TCO) of this power equipment assumed are currently lower than for the energy storage system (ES). On the other hand, in scenario S25 and S35, the flexibility of the on-load tap changers revealed as insufficient to deal with the overvoltage occurrences in larger networks, requiring the exploitation of ES and end-user's flexibility as well.

In what respects the scalability in density, one can observe that sub scenarios S3.X with a severe integration of DER have a better total NPV than sub scenarios S2.X with a moderate integration of DER. In order to verify if the business case becomes economically viable (NPV above zero) when scaled in size, the sub scenarios SX.4 with a negative NPV have been subjected to this analysis. Economies of scale in HEMS deployment were modelled by a L-shaped average cost function, based upon the numbers observed in smart meters' deployment. As depicted in Figure 14, the average cost per unit declines up to the *minimum efficient scale* (MES) and beyond that point it is the same.

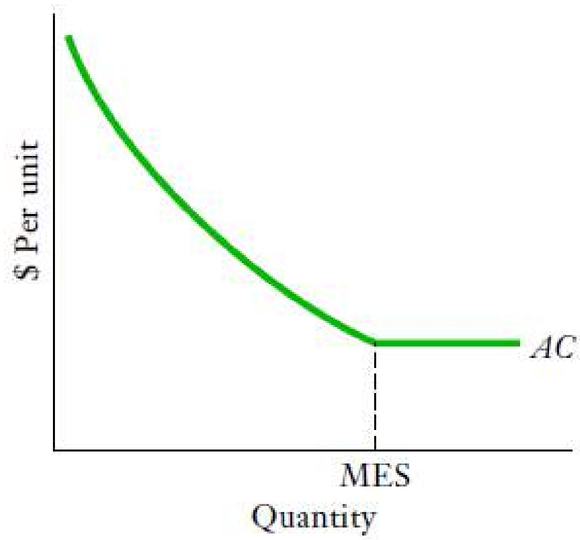
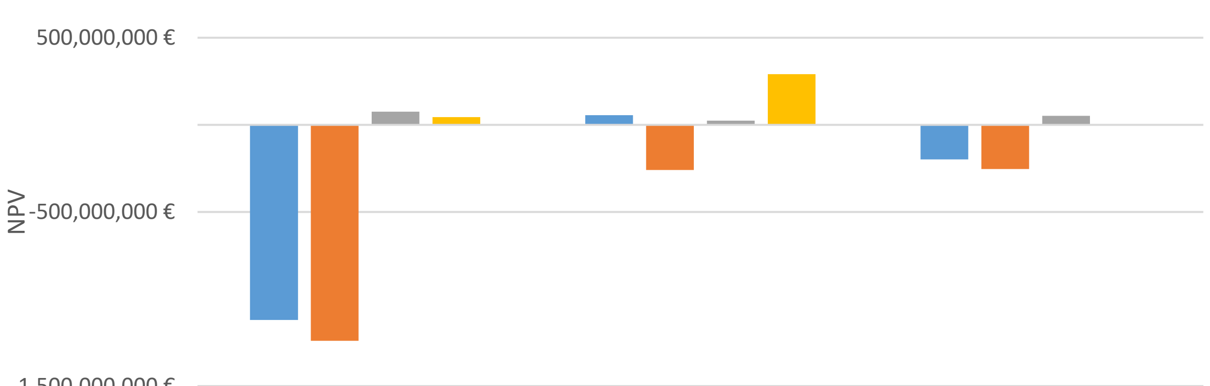


Figure 14: Economies of scale. L-shaped average cost curve. Source: (Besanko et al., 2012)

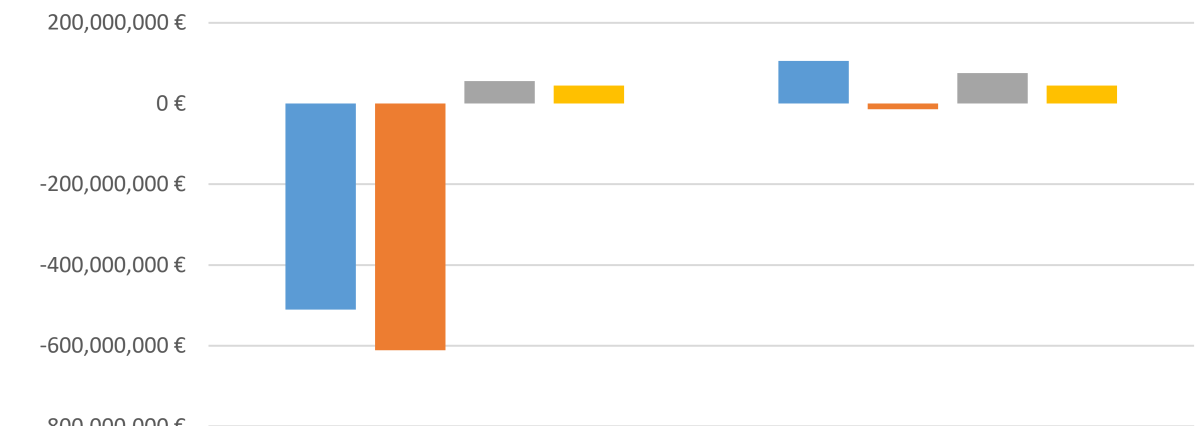
For the purpose of this analysis, the number of LV grids with an installed transformer capacity of approximately 150 kVA and 500 kVA were associated to three representative types as per the technical simulations – small rural, big rural and big urban networks –, assuming most rural networks are aerial and most urban networks are underground. In the case of Portugal, 47% of the existing LV networks in the country have been accounted. As mentioned before, the estimated hardware and the calculated benefits for a single network are scaled proportionally to the number of existing representative networks while the identify software costs remain equal. According to the ICT-oriented SRA work [REF D8.1], no scalability constrains have been founded. The results are presented in Figure 15.

When resorting to a combination of HEMS and ES flexibility, a wider-scale deployment results in a positive NPV for the cluster only for big rural networks (scenario S24) with an overall IRR of 8.47%. This is mainly because the societal benefits are particularly large. Eventually, the decline in batteries and storage systems costs foreseen in the coming years may turn them into potential solutions for electric utilities, since as of today their application does not seem economically advantageous to all network topologies.



	S14	S24	S44
Total	-1,119,290,095 €	55,266,665 €	-199,187,663 €
DSO	-1,238,705,325 €	-259,624,265 €	-253,023,592 €
HEMS owners	75,168,681 €	24,823,562 €	51,539,252 €
Society	44,246,548 €	290,067,368 €	2,296,678 €

Figure 15: Cluster 02. NPV results of selected scenarios after increasing the implementation area (scalability in size) in Portugal.



	S15	S13
Total	-510,730,828 €	105,716,013 €
DSO	-610,888,670 €	-13,835,758 €
HEMS owners	55,911,294 €	75,305,222 €
Society	44,246,548 €	44,246,548 €

Figure 16: Cluster 02. NPV of the remaining sub scenarios #1 after scaled in size. Portugal.

This analysis has been extended for the other scenarios of group 4 since S41 has the worst NPV in order to determine if other resources combinations are profitable. As can be seen in Figure 16, when operating the LV networks with the OLTC transformers, the NPV, although it is better, is still negative for the cluster as a whole and for the DSO. Nevertheless, the exclusive use of HEMS flexibility results positive in both perspectives. For scenario 13, the overall IRR is 18.37%.

3.7.2.2. Slovenia

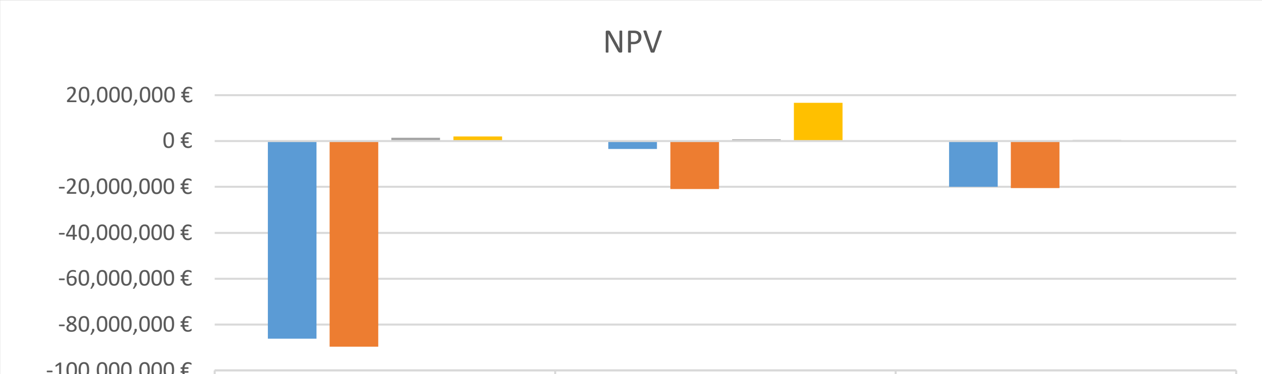
In terms of international replicability, the intention was to encompass the other two demo countries: Slovenia and Sweden. Since this group of solutions was implemented only in Portugal and no simulations were performed on Slovenian or Swedish LV grids, it could be assumed that the technical results obtained in the case of Portugal would be similar for other countries, in case their LV grid topology was not much different from the Portuguese one. This happens to be valid for Slovenia but not for Sweden, according to the data received from the DSOs. For instance, in Sweden, the number of feeders per similar rated power transformers is significantly higher than in Portugal or Slovenia, meaning the results cannot be adapted to the reality of this country and additional simulations must be performed for a proper assessment. Therefore, the replicability analysis will be narrowed to Slovenia, considering its country-specific macroeconomic characteristics and the LV system size under Elektro Ljubljana concession.

Table 18 shows the net present values (NPVs) of the different scenarios obtained for Slovenia. The results in the overall perspective are worst as well as for all stakeholders, with scenario S35 driven to the negative side.

Table 18: Cluster 02. NPV of the different scenarios obtained for Slovenia for a single network.

	NPV			
Scenario ID	**Total**	**DSO**	**HEMS owners**	**Society**
S13	-520 146 €	-522 163 €	827 €	1 190 €
S14	-574 295 €	-576 307 €	822 €	1 190 €
S15	-547 363 €	-548 624 €	71 €	1 190 €
S23	-475 657 €	-523 434 €	1 944 €	45 834 €
S24	-529 760 €	-577 525 €	1 932 €	45 834 €
S25	-578 709 €	-624 802 €	260 €	45 834 €
S33	96 962 €	-522 126 €	1 134 €	617 955 €
S34	42 845 €	-576 156 €	1 046 €	617 955 €
S35	-6 297 €	-625 065 €	813 €	617 955 €
S43	-520 950 €	-522 094 €	842 €	303 €
S44	-575 121 €	-576 265 €	841 €	303 €
S45	-569 986 €	-570 613 €	324 €	303 €

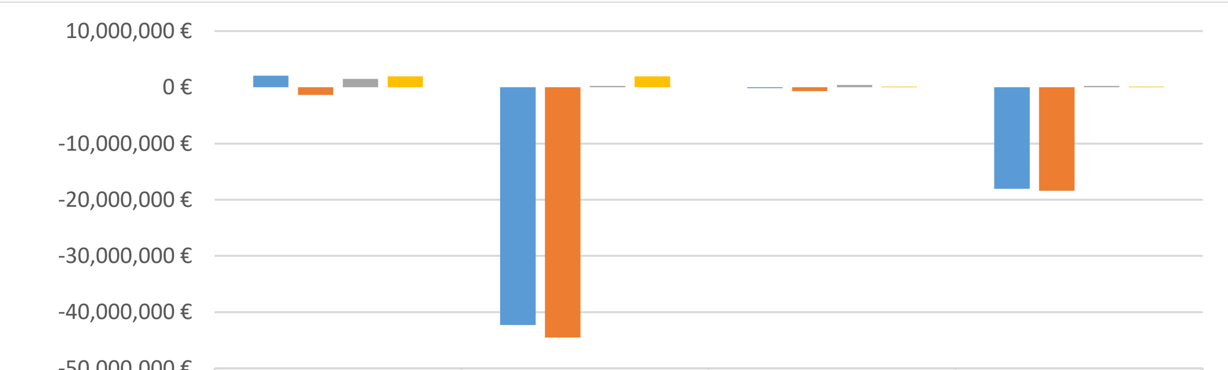
The same scenarios have been scaled in size as for Portugal. Moreover, economies of scale in HEMS deployment were modelled by an identical L-shaped average cost function. The number of LV networks with an installed capacity of approximately 150 kVA and 500 kVA were associated to three representative types as per the technical simulations – small rural, big rural and big urban networks –, according to their grid topology. In the case of Slovenia, 49% of the existing LV networks in the concession of EL have been accounted. When comparing both concessions (up to 630 kVA transformer capacity), the total number of LV grids reported by EL is about 7% of the total number advanced by EDP Distribuição.



	S14	S24	S44
Total	-86,218,377 €	-3,483,990 €	-19,907,579 €
DSO	-89,622,186 €	-20,918,443 €	-20,458,317 €
HEMS owners	1,464,463 €	705,175 €	440,299 €
Society	1,939,346 €	16,729,278 €	110,440 €

Figure 17: Cluster 02. NPV results of selected scenarios after increasing the implementation area (scalability in size). Slovenia.

The results are presented in Figure 17. Since the number of LV networks in EL's concession is much smaller, when scaling-up the initial implementation area, the NPV of scenario S24 is also negative.



	S13	S15	S43	S45
Total	2,045,113	-42,318,719	-134,893	-18,033,167
DSO	-1,367,371	-44,498,935	-686,131	-18,395,271
HEMS owners	1,473,139	240,869	440,799	251,665
Society	1,939,346	1,939,346	110,440	110,440

Figure 18: Cluster 02. NPV of the remaining sub scenario #1 and #4 after scaled in size. Slovenia.

The analysis has been also was extended to other scenarios. From Figure 18, only when resorting to HEMS flexibility in small resistive networks, the business case turns out to be economically viable. As it has been already mentioned, InteGrid's voltage control for LV networks was developed for those resistive, where more voltage violations are susceptible of arising; it seems, at least for Slovenia, the benefits may not justify the solutions' deployment in inductive networks.

3.7.2.3. Conclusions

Based upon the results presented, since the HEMS costs are presumably borne by their users, the use of the flexibility they provide seems to be the most profitable option for the DSO, because it allows avoiding additional CAPEX and OPEX with batteries and OLTC transformers to increase flexibility in the LV networks. Nevertheless, the risk is twofold: residential customers may not buy this technology or, even if they do, they may not engage in grid support. At least two possible solutions come to mind:

1) The implementation of dynamic tariffs that follow the energy price in the spot market to encourage HEMS acquisition. Significant energy savings can be achieved when combining the HEMS energy optimization function with this type of retail tariff, as simulations have shown. From a system perspective, it would also potentially allow to reduce the peak demand.
2) Set as a grid connection requirement into the self-consumption legal framework (if it exists), the acquisition of HEMS when installing a PV residential system and/or EV charger since these devices impact the most on the LV grid (bundling scheme). Nevertheless, we recognise that this option can questionable, as it may be considered a barrier itself for microgeneration adoption.

While such definitions are not in place, the DSO is less exposed to risk when combining HEMS flexibility with its own controllable resources. Our analysis shows that each case has its particularities, therefore it is important to carry out dedicated studies to understand the best technical/economic options. The selection of the DSO resource greatly depends on the grid characteristics and the potential amount of technical problems arising (intranational replicability), since this is what truly impacts the economic interest of this cluster. Moreover, the number of networks covered by this group of InteGrid solutions seems to be relevant as its application was not economically viable in the conditions of scenario S24 in Slovenia, but it was in Portugal, attending to the dimension of both DSOs concessions.

3.7.3. Cluster 3

To visualize the variations in the pool size and average DER capacity, the NPVs obtained are displayed in matrices. For the sake of illustration, the most relevant figures were added in body of the report. All the results and complete matrices can be found in attach.

3.7.3.1. Commercial VPP in Slovenia

The pools comprised by flexibility providers with an average capacity of 0.5 MW with a negative overall NPV are presented in Table 19. In 35 pools out of 961, the revenues coming from the market participation do not cover the costs with all the solutions and would result as economically unattractive from an overall perspective. Located in the top-left corner of the matrix, these pools have essentially the smallest sizes.

Table 19: Cluster 03. Pools (MW) with a negative overall NPV (EUR) in case the average DER capacity is 0.5 MW. Slovenian mFRR market.

Down \ Up	0	1	2	3	4	5	6
0	-447182	-465957	-374423	-282890	-191356	-99823	-8289
1	-465957	-484732	-393198	-301665	-210131	-118597	-27064
2	-386389	-405163	-313630	-222096	-130563	-39029	52504
3	-306820	-325595	-234062	-142528	-50994	40539	132073
4	-227252	-246027	-154493	-62960	28574	120107	211641
5	-147684	-166459	-74925	16608	108142	199676	291209
6	-68116	-86891	4643	96177	187710	279244	370777
7	11452	-7322	84211	175745	267278	358812	450346

Regarding the average DER capacity, this exactly the situation among the studied ones where the costs of aggregation are greater for the commercial VPP as more clients need to be pooled to achieve a given pool size in the upward and downward direction. These costs relate to integration of DER, acquisition and installation of equipment (RTUs) and communication. As the average DER capacity increases, these costs are lower which translates into better overall and FO's NPVs.

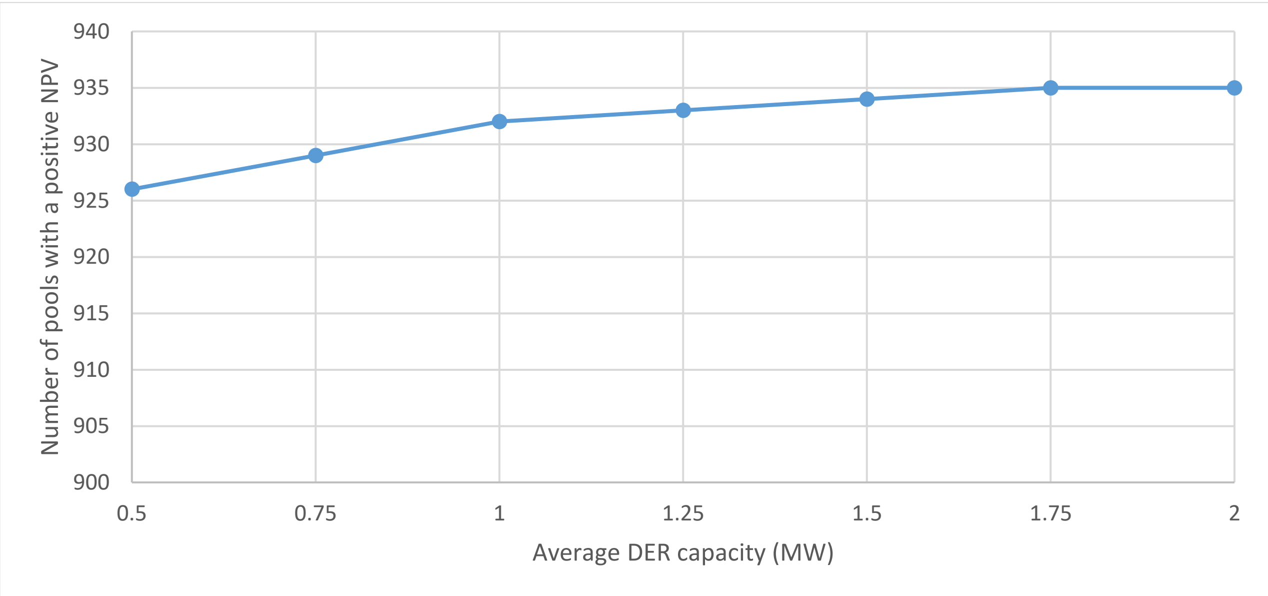


Figure 19: Cluster 03. Number of pools with a positive overall NPV as a function of the average DER capacity. Slovenian mFRR market.

The number of pools with an overall positive NPV as a function of the average flexibility providers capacity is shown in Figure 19. The greater is the average DER flexibility of the pools, the results do not change considerably. In fact, it stabilizes in 935 pools with a positive overall NPV after an average DER capacity of 1.5 MW. Therefore, for a market player such as the commercial VPP operator providing tertiary reserve services in Slovenia, this variable seems to be not that relevant.

3.7.3.2. Commercial VPP in Portugal

In the Portuguese case, the DSO's costs seem to have a more significant weight in the overall NPV as the earnings from market participation are much lower, impacting the economic worthiness of implementing Cluster 03 solutions as a group. In fact, no pool with an average DER capacity up to 2 MW, considering the different pool sizes ranging from 0 to 30 MW, had an overall positive NPV. This indicates that this cluster of solutions is not profitable when pooling flexibility providers with limited flexibility, in this country. The first overall positive results appeared for 44 pools with an average DER capacity of 2 MW, as depicted in the next table.

Table 20: Cluster 03. Pools (MW) with a positive overall NPV (EUR) for an average DER capacity of 2 MW. Portuguese mFRR market.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
29	-7317	-7317	-11020	-5336	-9039	-3354	-7058	-1373	-5076	608	-3095	-3095	-6798	-1114	-4817	867
30	15017	5629	11314	7611	13295	9592	15276	11573	17257	13554	19239	9851	15536	11832	17517	13814
Down \ Up	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
29	-2836	2849	-855	4830	1127	1127	-2576	3108	-595	5089	1386	7070	3367	9052	5349	
30	19498	15795	21479	17776	23460	14073	19757	16054	21739	18035	23720	20017	25701	21998	27682	

Regardless of the pools' characteristics, the DSO's NPV has always a fixed negative value since no benefits are foreseen for this stakeholder from the commercial VPP business model, only costs. The DSO must be equipped with the TLS - since it is a necessary tool to prevent voltage problems and congestion in the distribution network due to the provision of flexibility to the TSO - and the gm-hub. Consequently, one provides a closer look at the economic interest of the commercial VPP in the perspective of the flexibility provider (i.e., FO's NPV).

In case the commercial VPP is comprised by DER with an average capacity of 0.5 MW or 0.75 MW, the FO's NPV still is negative for all pools. Only for an average DER capacity of 1 MW, the NPV results positive in 12 cases, as shown in Table 21. These values are concentrated on the bottom left side of the matrix, where the pool size on the upward direction have the lower values and the downward direction have the greater. By looking at these results, one can understand that is more economically interesting for a commercial VPP to participate in the downward than in the upward tertiary reserve market. This can be justified by the lower offer of the first product in comparison with second, in Portugal.

Table 21: Cluster 03. Pools with positive FO's NPV (EUR) for an average DER capacity of 1 MW. Portuguese mFRR market.

Down \ Up	0	1	2	3	4	5	6
28	4333	-5055	-8758	-12461	-16164	-19867	-23570
29	17279	7892	4189	486	-3218	-6921	-10624
30	30225	20838	17135	13432	9729	6026	2323

When the average DER capacity increases to 1.25 MW, much more possible pool sizes (107) become economically viable to the commercial VPP. As can be seen below, the cases with a positive NPV can be found in the last rows of the matrix, reflecting the importance for the flexibility operator to building pool with a strong participation in the Portuguese downward mFRR.

Table 22: Cluster 03. Pools with positive FO's NPV (EUR) for an average DER capacity of 1.25 MW. Portuguese mFRR market.

Up / Down	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
25	12431	3044	-659	-4363	-8066	-2381	-6084	-9788	-13491	-17194	-11509	-20897	-24600	-28303	-32006	-26322
26	25377	15990	12287	8584	14268	10565	6862	3159	-544	5140	1437	-7950	-11654	-15357	-9672	-13375
27	38324	28936	25233	30917	27214	23511	19808	16105	21789	18086	14383	4996	1293	6977	3274	-429
28	51270	41883	47567	43864	40161	36458	32754	38439	34736	31033	27330	17942	23626	19923	16220	12517
29	64216	64216	60513	56810	53107	49404	55088	51385	47682	43979	40276	40276	36573	32870	29167	25463
30	86550	77163	73459	69756	66053	71738	68034	64331	60628	56925	62610	53222	49519	45816	42113	47797

Up / Down	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
25	-30025	-33728	-37431	-41134	-35450	-44837	-48540	-52243	-55946	-50262	-53965	-57668	-61371	-65075	-59390
26	-17079	-20782	-24485	-18800	-22504	-31891	-35594	-39297	-33613	-37316	-41019	-44722	-48425	-42741	-46444
27	-4132	-7835	-2151	-5854	-9557	-18945	-22648	-16963	-20666	-24370	-28073	-31776	-26091	-29795	-33498
28	8814	14498	10795	7092	3389	-5998	-314	-4017	-7720	-11423	-15126	-9442	-13145	-16848	-20551
29	31148	27445	23742	20038	16335	16335	12632	8929	5226	1523	7207	3504	-199	-3902	-7605
30	44094	40391	36688	32985	38669	29282	25579	21875	18172	23857	20154	16451	12747	9044	14729

The number of different pools with a FO's positive NPV when considering an increasing average DER capacity is shown in the following figure. The results get even better the greater is the average DER capacity of the pools. For a market player such as the commercial VPP operator providing tertiary regulation reserve services in Portugal, this variable seems to be relevant.

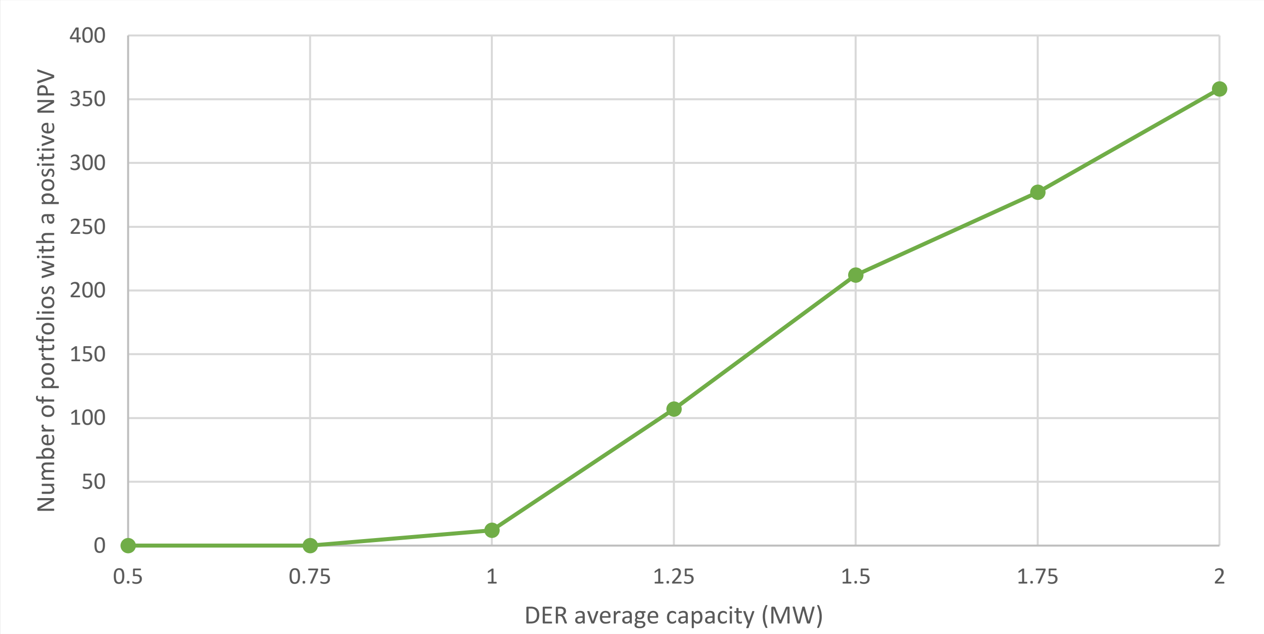


Figure 20: Cluster 03. Number of pools with a positive FO's NPV as a function of the average DER capacity. Portuguese mFRR market.

3.7.3.3. Wastewater treatment plants (HLUC08)

Mafra plant comprises four main processes which are preliminary treatment, biological treatment, filtration and dewatering, summing up to about 100 kW. In the case of Alcântara, the largest WWT plant in Portugal, the maximum power consumption is about 3500 kW with five major processes, namely preliminary treatment, biological treatment, UV disinfection, sludge treatment and odour control. The daily potential revenues of participating in the mFRR over 2018 for 100 flexibility scenarios of each WWT plant are displayed in the next figures. They have been calculated based on the average daily energy price and the total daily ratio in the same year, which profiles are provided in from Figure 52 to Figure 55 (Appendix section).

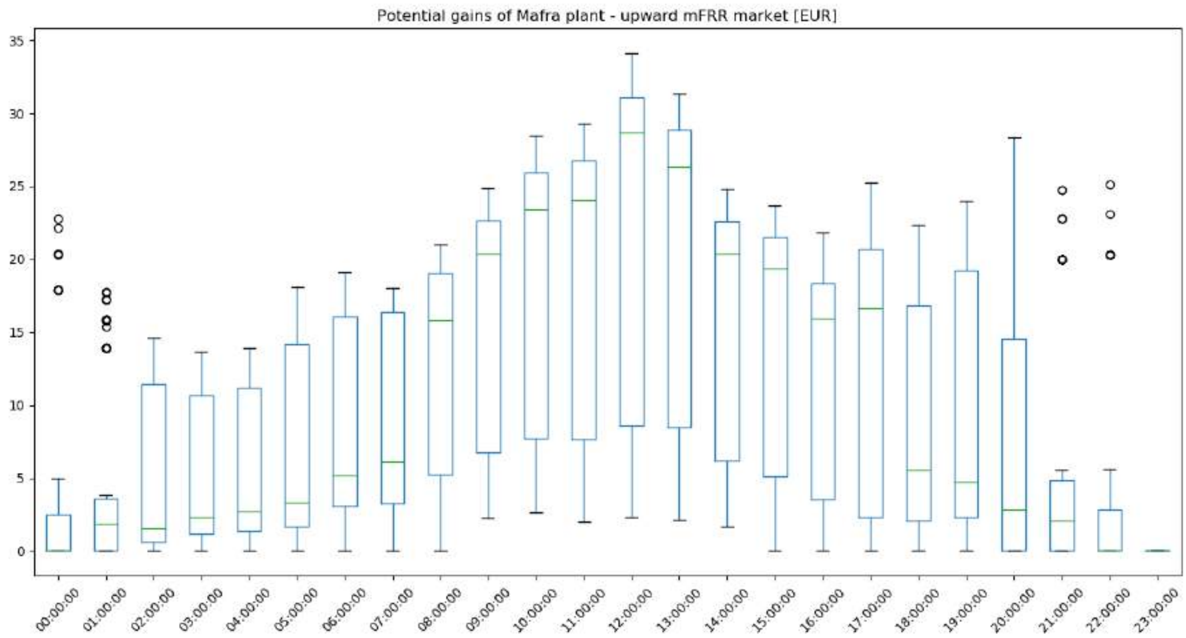


Figure 21: Cluster 03. Potential gains achieved by Mafra WWT plant over 2018 in the upward tertiary reserve market in Portugal as per the 100 flexibility scenarios.

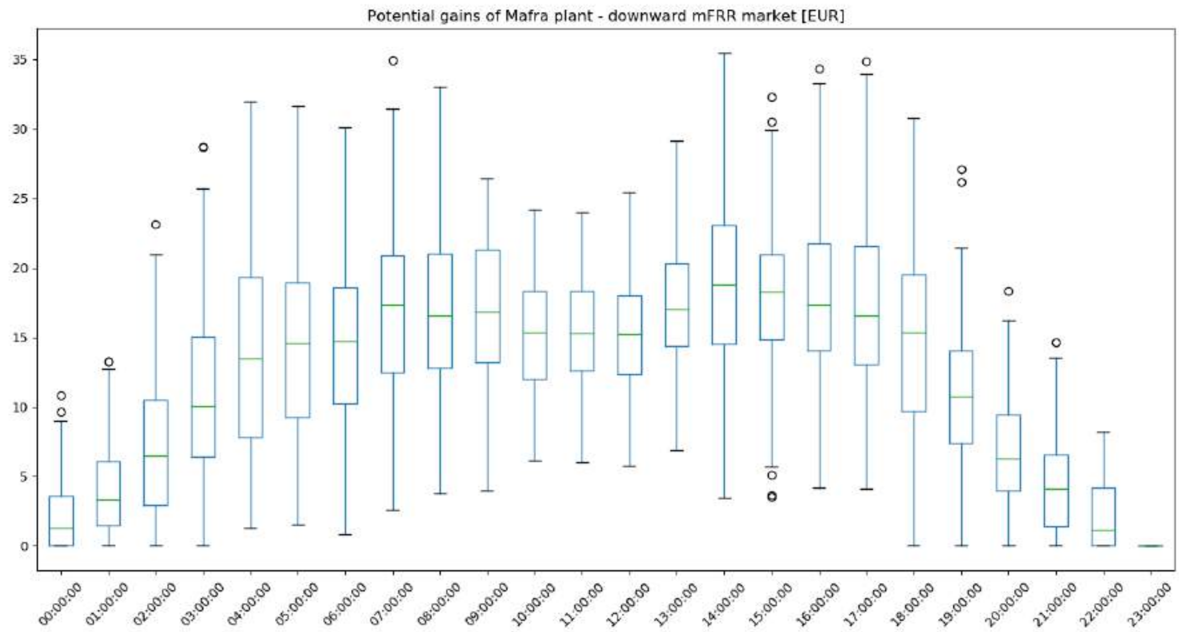


Figure 22: Potential gains achieved by Mafra WWT plant over 2018 in the downward tertiary reserve market in Portugal as per the 100 flexibility scenarios.

The potential gains of Mafra plant in both upward and downward direction range between 0 and around 35 euros. For Alcantâra WWT plant, the earnings on the upward mFRR are distributed between 0 and 1.000 euros, while on the downward mFRR are lower, ranging from 0 to about 400 euros. For both plants, one highlights that at 12 h on the upward mFRR, not only the mode assumes much higher values in comparison with the other hours but also the daily maximum values.

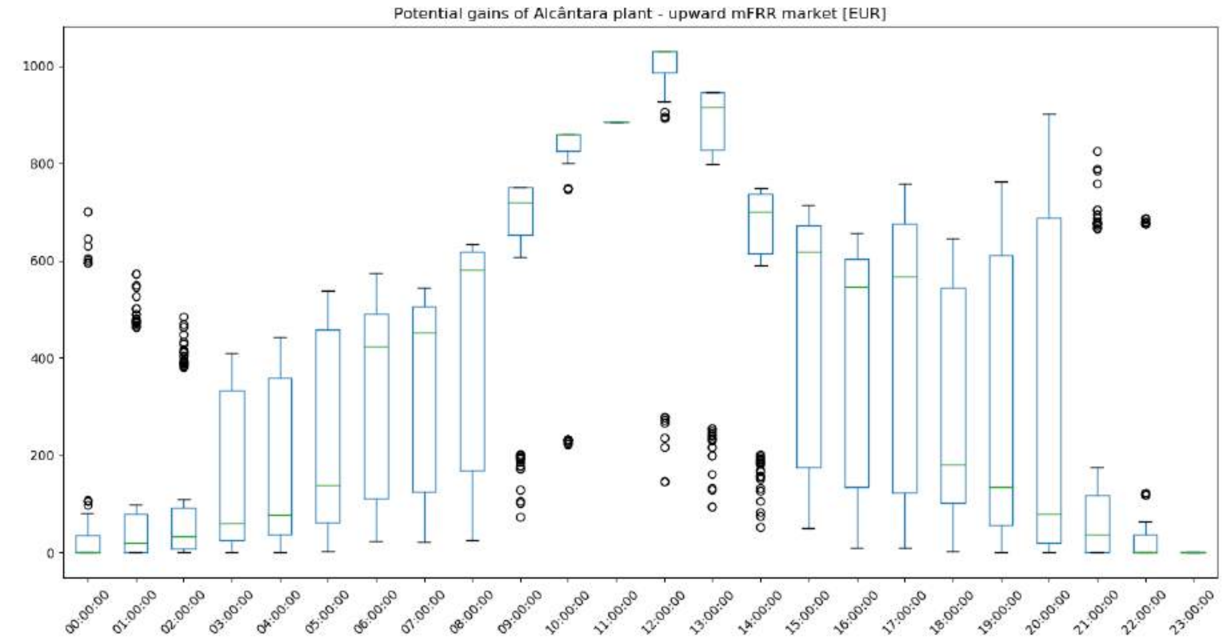


Figure 23: Potential gains achieved by Alcântara WWT plant over 2018 in the upward tertiary reserve market in Portugal as per the 100 flexibility scenarios.

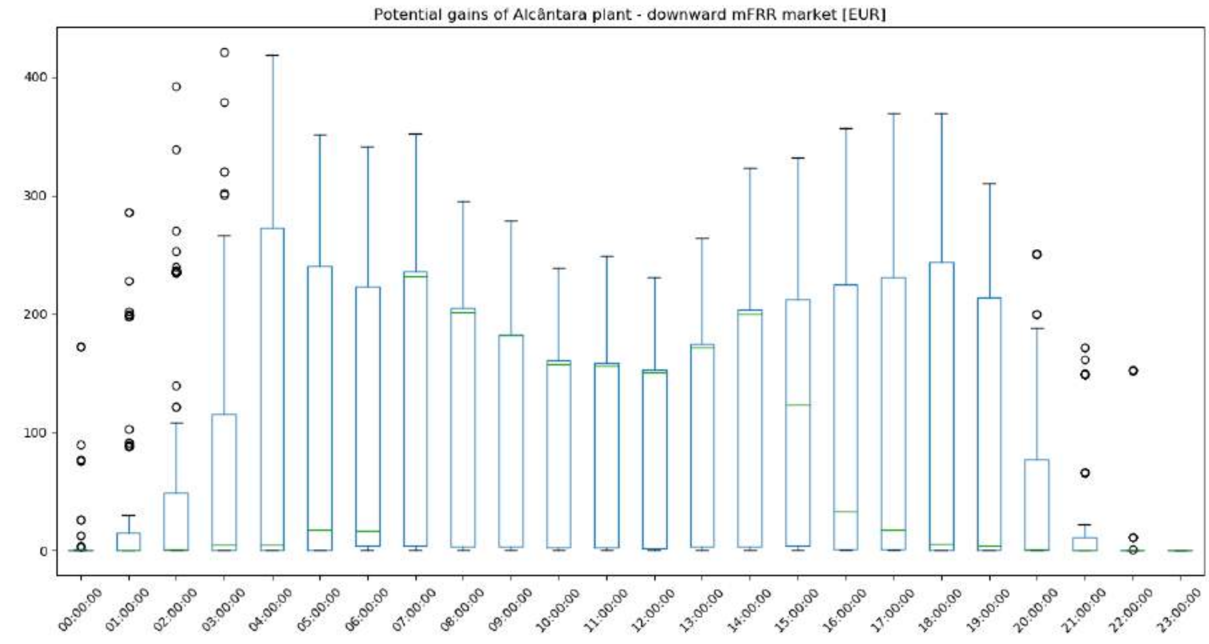


Figure 24: Potential gains achieved by Alcântara WWT plant over 2018 in the downward tertiary reserve market in Portugal as per the 100 flexibility scenarios.

Looking at the modest gains achieved by the WTT plants in the Portuguese mFRR market and the simulations performed in 3.7.3.1 and 3.7.3.2, it is evident that a commercial VPP aggregating only these two plants would not be profitable. In other words, more WTTs along with other large MV clients (with a more significant amount of flexibility) would need to integrate the VPP's portfolio for it to be economically feasible. Therefore, this analysis will be narrowed to AdTA perspective. Assuming these plants are part of a pool and are remunerated accordingly to its own mobilized flexibility for tertiary reserve, one investigates if the revenues would pay the costs related to the tools enabling the WTT plants participation, which are WATER2FLEX and AQUASAFE. As mentioned in the scenarios' description, the total revenues are share between the aggregator and the WWT plants: AdTA will receive 40% of the earnings minus 60% of the penalties for underperformance, which are 10% of the revenues for the flexibility operator.

Amongst the 100 scenarios, three scenarios have been selected; those with the maximum, most likely (central scenario) and minimum achievable revenues. The results are depicted in Figure 25. As can be seen, even the best case would not be economically interesting for AdTA. Having more plants providing flexibility would allow to scatter the AQUASAFE platform costs in several applications, improving the business case for this customer. A sensitivity analysis to the revenue share of AdTA, alongside the financial discount rate, is performed in section 3.8.1 for the best (less negative) scenario.

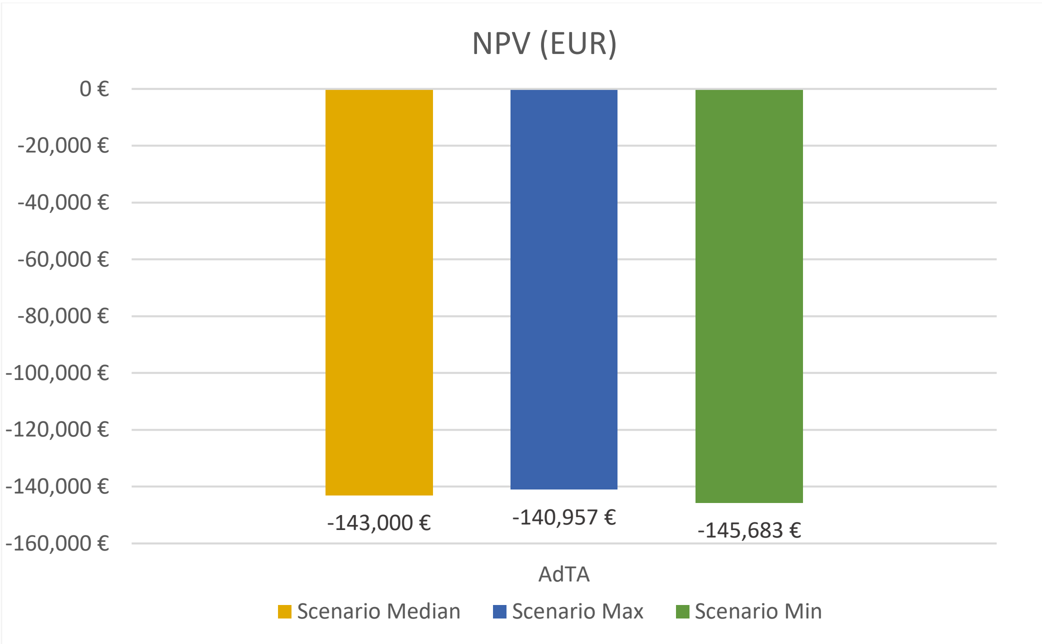


Figure 25: AdTA's NPV for scenarios with the maximum, most likely and minimum achievable revenues.

3.7.3.4. Conclusions

The earnings on the tertiary reserve market are lower in Portugal than in Slovenia when comparing pools with the same characteristics. This can be justified by fact that in Portugal only the energy activated is remunerated, while in Slovenia, mFRR products are compensated both on availability and activation. Therefore, in countries where mFRR capacity provision is mandatory and receives no payment, the economic replicability could be limited.

In general, it was possible to observe: 1) in Slovenia, pools with a small size are not economically feasible, regardless of the DER capacity aggregated; 2) while in the case of Portugal, pools with limited flexibility, regardless of their size, are not economically interesting. In the latter, it only becomes feasible, for a given pool size, when aggregating clients with a significant amount of flexibility as their number and, consequently, the costs associated to DER are lower (scalability in density constrain).

Another barrier to the economic profitability of aggregators and DER relates to a low annual ratio. Particularly in the case of Portugal, there is a large availability of tertiary reserve as conventional generators and pumped storage consumption units are obliged to provide their capacity. This situation translates into a reduced mobilization opportunity for flexibility and may create a distorted market environment, not in line with the "level playing field" spirit promoted by the EU Target Model. Moreover, as can be seen in Figure 26, in the same country, more flexibility is offered to the TSO upward than downward. Considering that demand response will offer mostly upward regulation, it is also a limitation on the portfolio's feasibility.

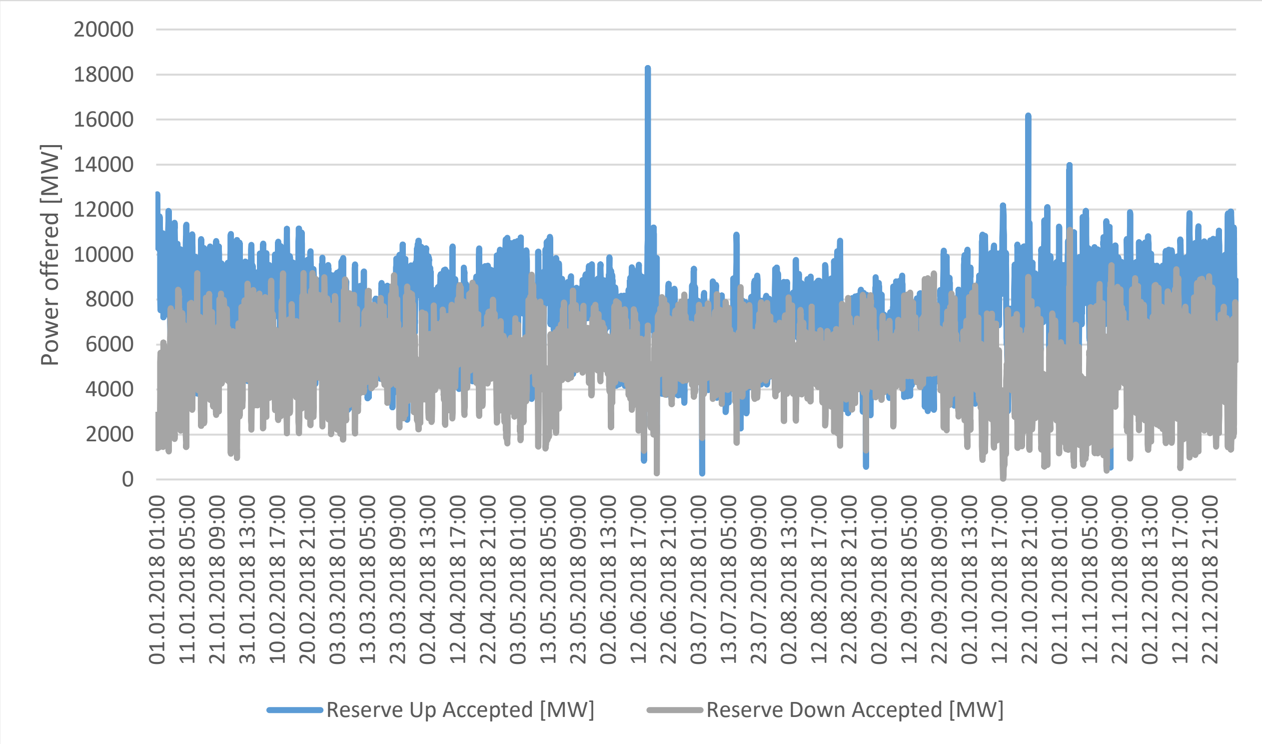


Figure 26: Tertiary reserve availability during 2018.

3.7.4. Cluster 4

All the technical simulations performed to determine the flexibility of one building and a pool of one-hundred buildings went up to 27th of July. Since the economic SRA is performed in an annual basis, the data was extended to a full year by mirroring the flexibility for the remaining 157 days.

3.7.4.1. Tertiary reserve market

The annual gains of 100 office buildings' pool achieved in the balancing market for tertiary reserve are presented in Figure 27.

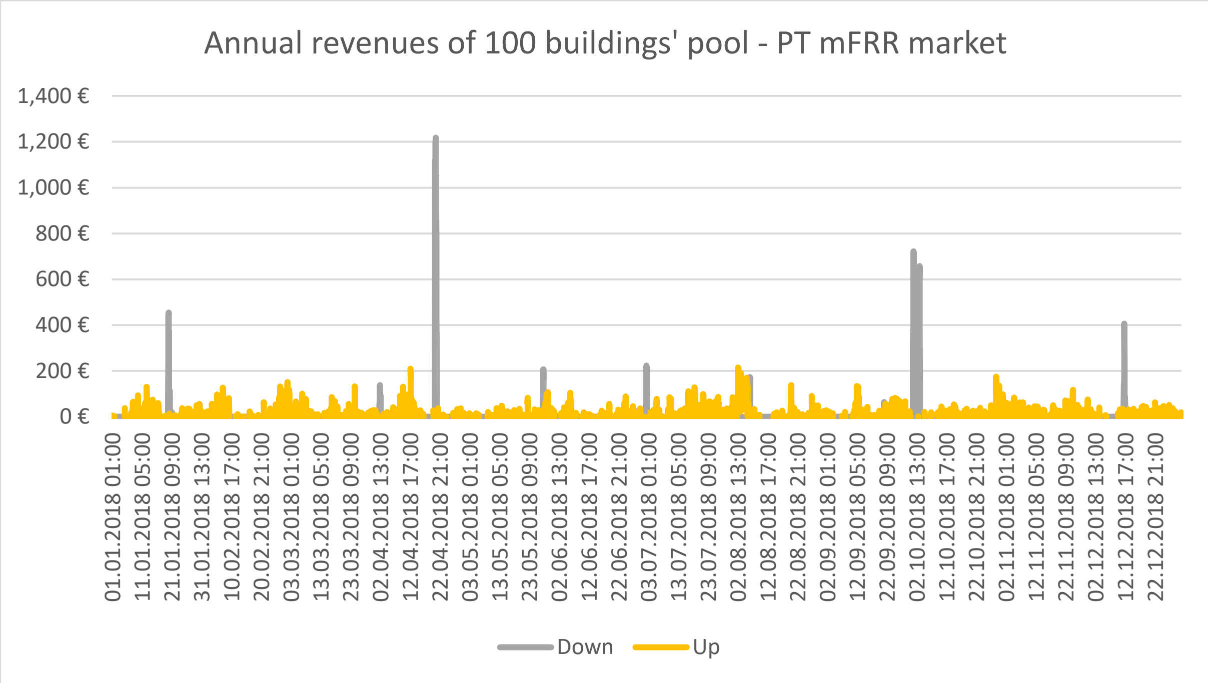


Figure 27: Annual revenues possibly achieved by a pool of 100 buildings in the Portuguese mFRR in 2018.

The NPV results are depicted in Figure 28. As observed for the commercial VPP, the project for the aggregator is not economically interesting from an overall and individual stakeholders' viewpoint. We would like to emphasize that if it was not for the costs related with hardware (i.e. RTUs), the aggregator would be profitable.

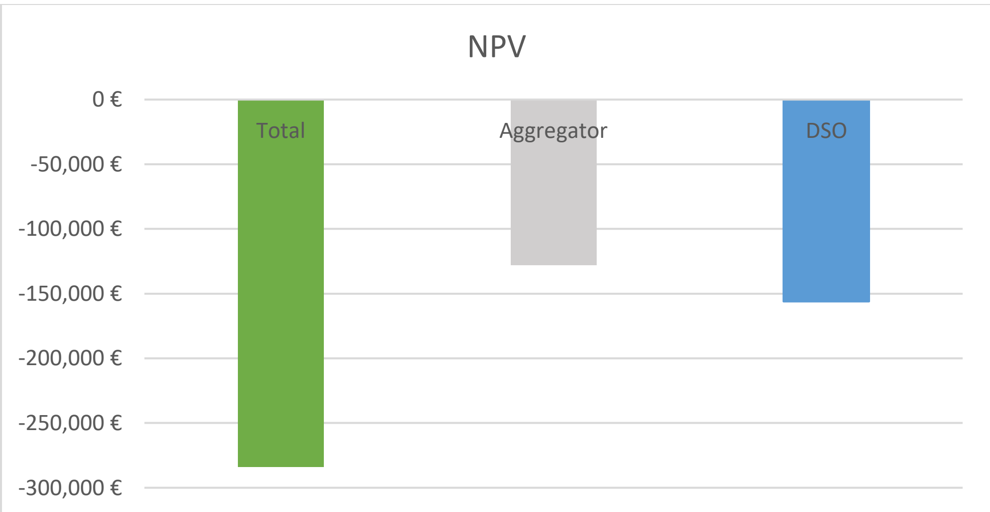


Figure 28: Cluster 04. Tertiary reserve market. NPV results.

3.7.4.2. Secondary reserve market

Since the units pre-qualified to provide aFRR services are not that many at the present day, the volume of capacity offered is in line with the required by the TSO and thus, there is a high likelihood of being contracted. A comparison between the volume offered and the one contracted for the regulation band is provided in Figure 29. In the hours with a value above 100%, the offers were not enough to tackle the needs of the system. Neglecting the actual bidding relation between up and down capacity on the regulation band, which is not fulfil by the pool, two cases have been studied: 1) the volume of capacity offered (which corresponds to all the flexibility simulated) was always accepted (100% chance) due to, for instance, a low bid price and 2) there is a 50% chance of being contracted and, therefore, the volume of capacity offered is reduced in 50% at a small price. For the sake of clarification, the price of the last offer accepted determines the price of the regulation band (e.g. marginal pricing).

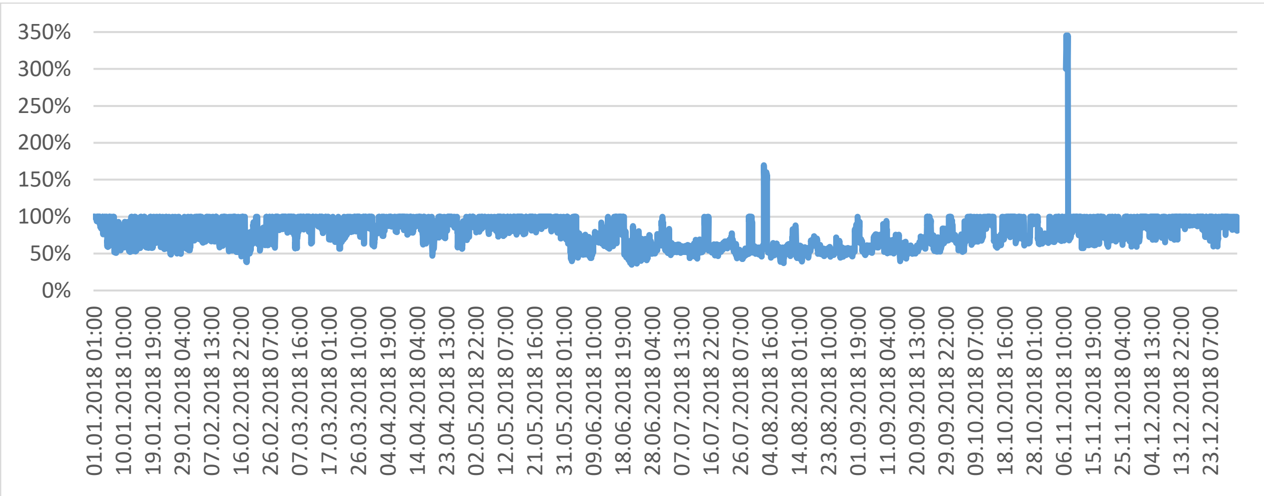


Figure 29: Volume contracted divided by the volume offered for the regulation band along 2018.

The figures below show the potential annual gains on both capacity and energy provision in the Portuguese secondary reserve market of a pool comprised by 100 office buildings (100% chance).

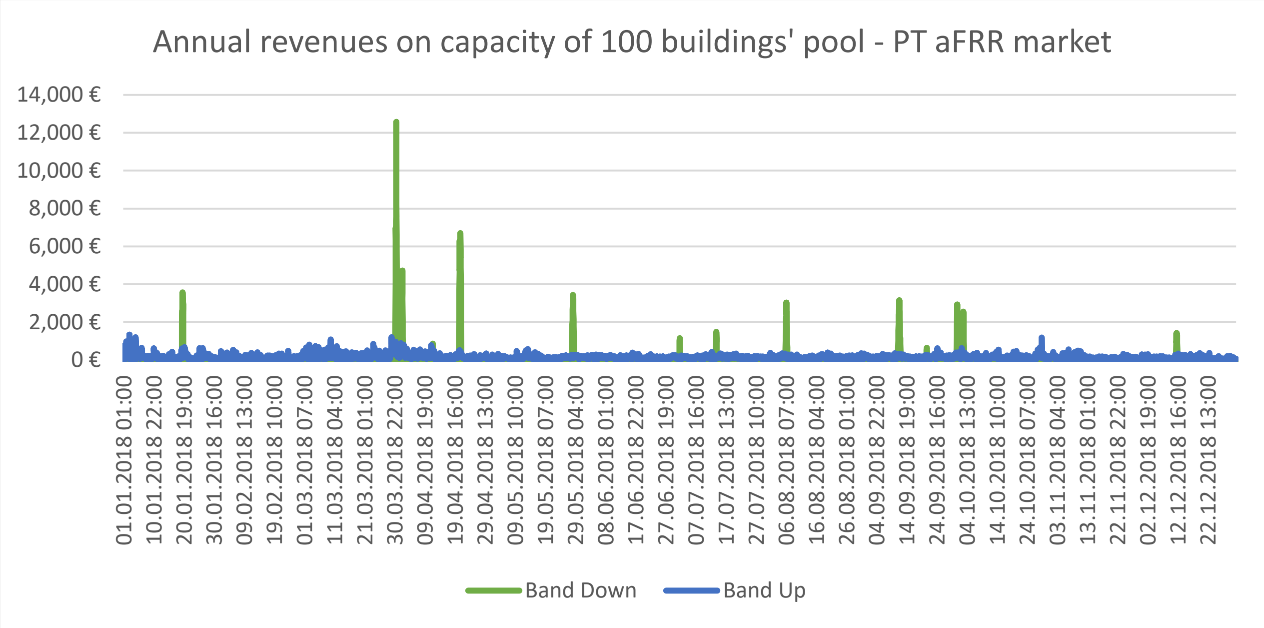


Figure 30: Annual revenues (on capacity) possibly achieved by a pool of 100 office buildings in the Portuguese aFRR market in the year of 2018.

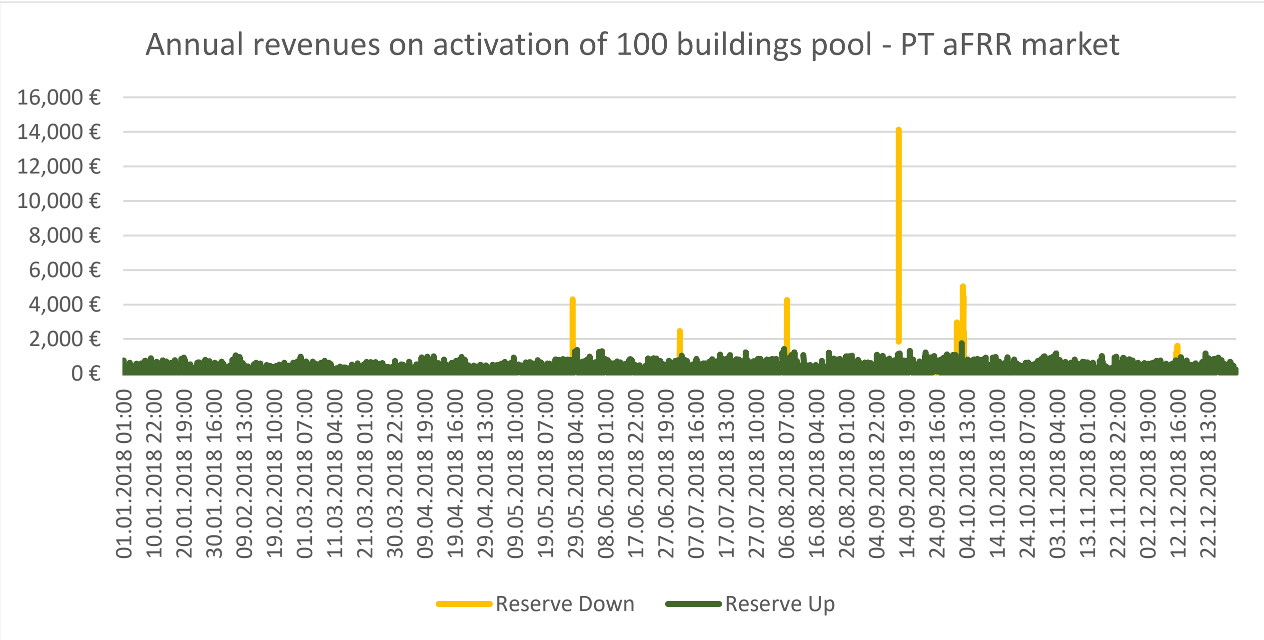


Figure 31: Annual revenues (on energy activation) achieved by a pool of 100 buildings in the Portuguese aFRR market in the year of 2018.

As can be seen in Figure 32, the participation in the secondary reserve market is profitable from an overall and aggregator's viewpoints in both cases (100% and 50% chances).

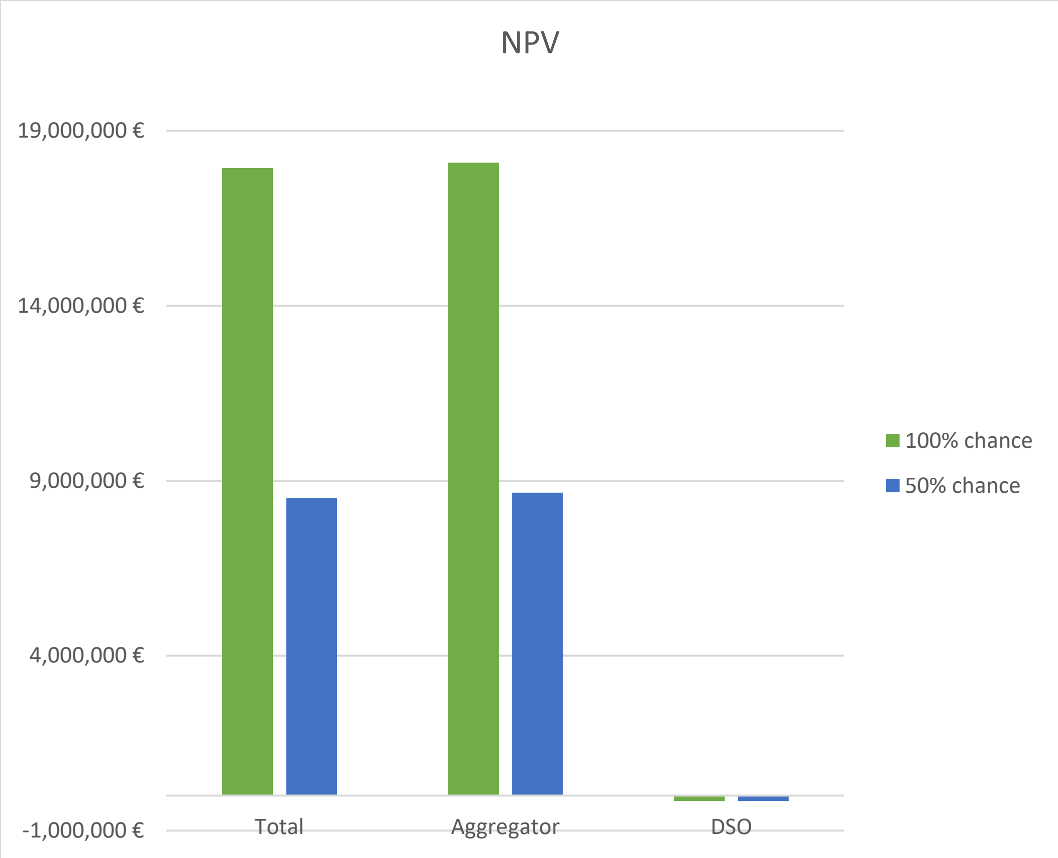


Figure 32: Cluster 04. Secondary reserve market. NPV results.

3.7.4.3. Conclusions

The results observed by the economic SRA for the secondary reserve market participation are considerably better when compared against the tertiary reserve market. This can be mainly justified by the following:

1) aFRR products are paid on capacity, which represented around 45% of the total revenues in the conditions simulated. This replicability analysis, with different markets within the same country, came to reinforce and support what we have been mentioning about the importance of the remuneration scheme employed to enable these new market players.
2) The ratio between the activated balancing energy and the capacity is much higher, meaning that, once contracted to provide regulation band, the uncertainty around being activated is significantly lower.

Nevertheless, main regulatory aspects of the design of this balancing market have been disregarded for the purpose of this analysis because are currently not well-suited for DER. Besides the technical pre-qualification requirements which have not been considered, the actual bidding portion between up and down capacity (i.e. 2/3 and 1/3, respectively) on the regulation band could not be fulfil by the pool since much more flexibility was offered up than down. Indeed, this requirement imposes a barrier on the participation of demand response since the provision of downward capacity by consumers implies that whenever aFRR is activated downwards, they have to increase consumption – something which is challenging for many loads, and can be expensive, depending on the network tariff that applies during the delivery period.

3.8. Sensitivity and Monte Carlo Analysis

A sensitivity analysis determines how different values of an input independent variable affect the outcome under a given set of assumptions. In other words, it studies how various sources of uncertainty contribute to the financial model's overall uncertainty.

Most input financial/macroeconomic variables used in the discounted cash flow analysis are established based on best available information and may change over time, introducing uncertainty. Therefore, they were subject to a sensitivity analysis to evaluate its impact on the total NPV of a given scenario considering the minimum and maximum values they can hypothetically assume. These values were chosen based on references and experts' opinion.

We are also mindful that the software and hardware costs introduced in the model are sources of uncertainty. However, due to their confidential nature – it would not be possible to show the results in the report – and lack of knowledge of their range of variation, the analysis was narrowed to information publicly available.

In the cases where the sensitivity analysis shows a higher variability of the project's outcome in both positive and negative fields, a Monte Carlo Simulation has been carried out. Monte Carlo simulation performs risk analysis, furnishing the decision-maker with a range of possible outcomes and their probabilities of occurrence. First, values are sampled at random from the input probability distributions. Each set of samples is called an iteration, and the resulting outcome from that sample is recorded. Monte Carlo simulation does it repeatedly (we considered 10 000 samples in our simulations), providing a probability distribution of possible outcoming results.

In the scope of work, a triangular distribution was chosen as the input probability distribution of all variables, for the sake of coherence. A triangular distribution is a continuous probability distribution with probability density function shaped like a triangle and it is defined by three values: (a) the minimum value; (b) the maximum value b and (c) the peak value, which is the most likely value (mode). This distribution is convenient to use in real-life situations where one does not know the mean or the standard deviation but can estimate the maximum and minimum values, and the most likely outcome, which is precisely the case. The formula for the probability density function is:

$$\begin{cases} 0, \qquad x < a \; or \; x > b \\ \dfrac{2(x-a)}{(b-a)(c-a)}, a \leq x \leq c \\ \dfrac{2(b-x)}{(b-a)(b-c)}, c \leq x \leq b \end{cases}$$

Where,

x is a random value; a is the minimum value; b is the maximum value; c is the mode.

The minimum, maximum and most likely values (base value) are the same used in the sensitivity analysis as well as the chosen scenarios.

3.8.1. Cluster 1

3.8.1.1. Slovenia

Recalling the information provided in 3.5 section, Table 23 summarizes the variables at stake and its range of variation.

Table 23: Cluster 01. Slovenia. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Social discount rate	%	5,00	4,00	6,00
Average day-ahead market price	EUR/MWh	43,67	33,67	53,67
CO_2 emission factors	tonnes/MWh	0,56	0	0,60
Non-Domestic VoLL	EUR/MWh	4320	1600	16 100

For this purpose, scenario 32 was chosen. The criteria behind its selection were both to:

1) activate all the benefits (above zero) since the input data that has been considered mainly affects them; and
2) to have an NPV circa zero. This allows understanding if any individual parameter change can make the conclusion on the feasibility of the project change.

The tornado plot below provides a graphical representation of the degree to which the total NPV of scenario is sensitive to the selected parameters. While the average day-ahead market price and the non-domestic VoLL stand out as the most relevant factors, no parameter variation within the considered ranges was able to drive the scenario's NPV in the positive field. Therefore, we can conclude it is more a matter of project's scale. Indeed, we could observe that a small-scale implementation is not economically interesting, and it only becomes feasible after being a larger scale.

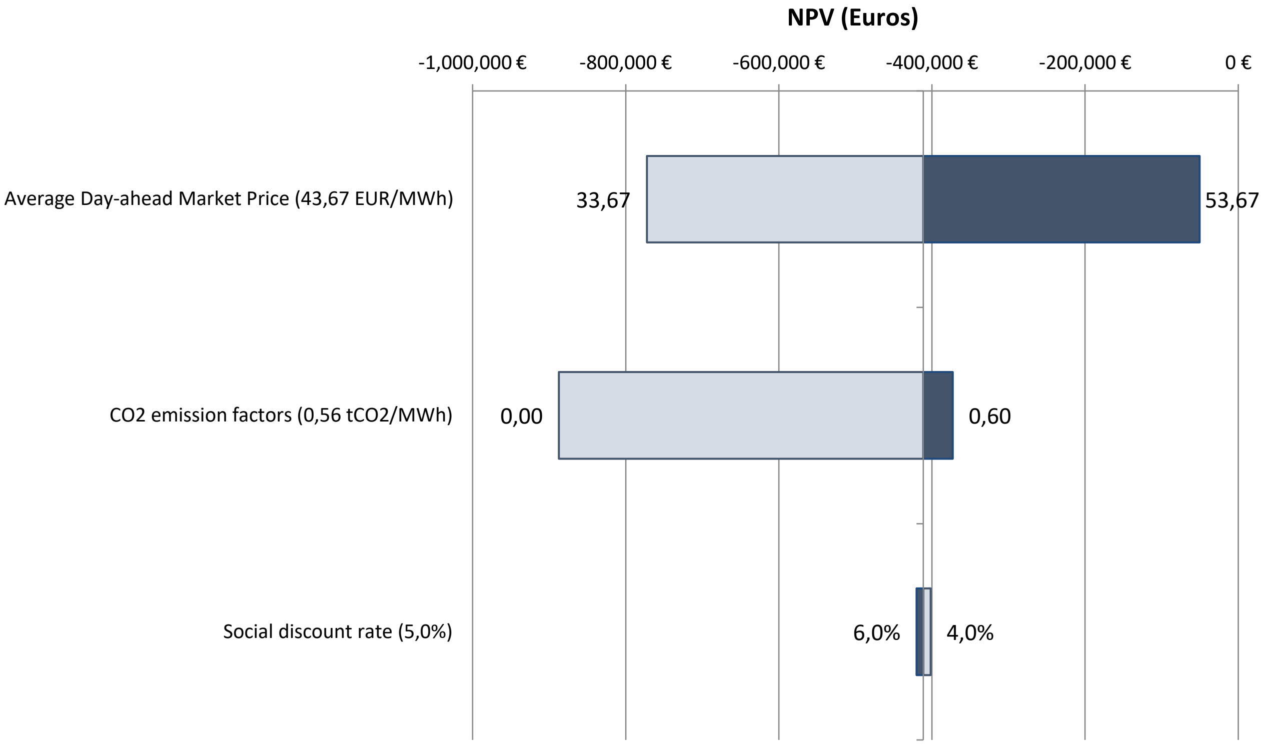


Figure 33: Cluster 01. Slovenia. Scenario 32. Tornado.

3.8.1.2. Portugal

Recalling the information provided in the Boundary Conditions section, the table below summarizes the two variables at stake and its range of variation.

Table 24: Cluster 01. Portugal. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Social discount rate	%	5,00	4,00	6,00
Average day-ahead market price	EUR/MWh	43,67	33,67	53,67

For this analysis, scenario 12 was chosen for the same reasons presented in Slovenia. The most relevant parameter is the social discount rate. Nevertheless, no parameter variation within the considered ranges was able to drive the scenario's NPV in the positive field.

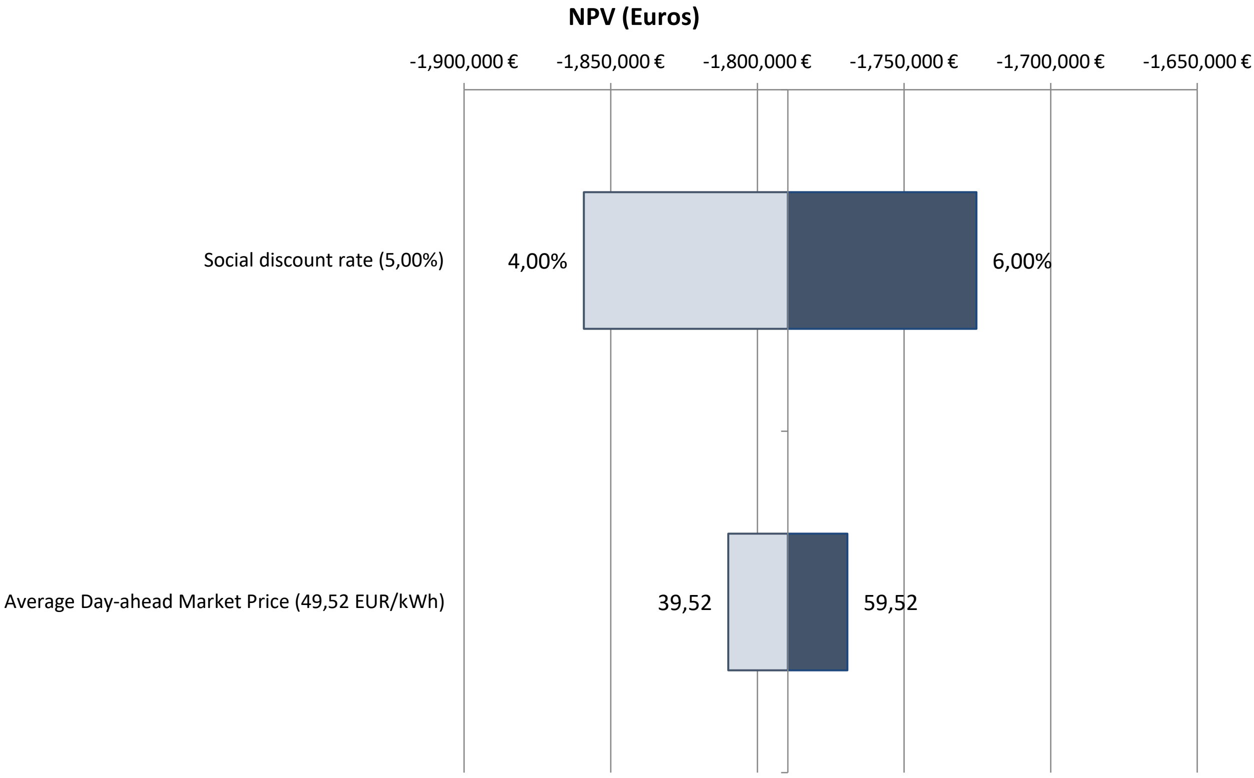


Figure 34: Cluster 01. Portugal. Scenario 12. Tornado.

3.8.2. Cluster 2

Table 25 summarizes the variables subject to sensitivity analysis and its range of variation in the case of Portugal.

Table 25: Cluster 02. Portugal. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Social discount rate	%	5	4	6
Active power losses cost	EUR/kWh	0,50	0,40	0,60
CO_2 emission factors	tonnes/MWh	0,37	0	0,75
Domestic VoLL	EUR/kWh	5,89	5,78	6
Natural gas Price	EUR/kWh	0,2	0,1	0,3
HEMS cost savings	%	10	7	13

For this purpose, scenario 35 was chosen. The criteria behind its selection were both to:

1) activate all the benefits (above zero) since the input data that has been considered mainly affects them; and
2) to have an NPV circa zero. This allows understanding if any individual parameter change can make the conclusion on the feasibility of the project change.

The tornado plot below shows that the discount rate and the HEMS energy cost savings stand out as the most relevant factors followed by the domestic VoLL. Variations in the first are leading to about 60 000 euros changes (both positive and negative directions) in the NPV of scenario S35. However, no parameter variation within the considered ranges was able to drive the scenario's NPV in the negative field, meaning that the project's feasibility is not affected by those.

Since the NPV results for Slovenia are very much alike, no sensitivity analysis was carried out for this country.

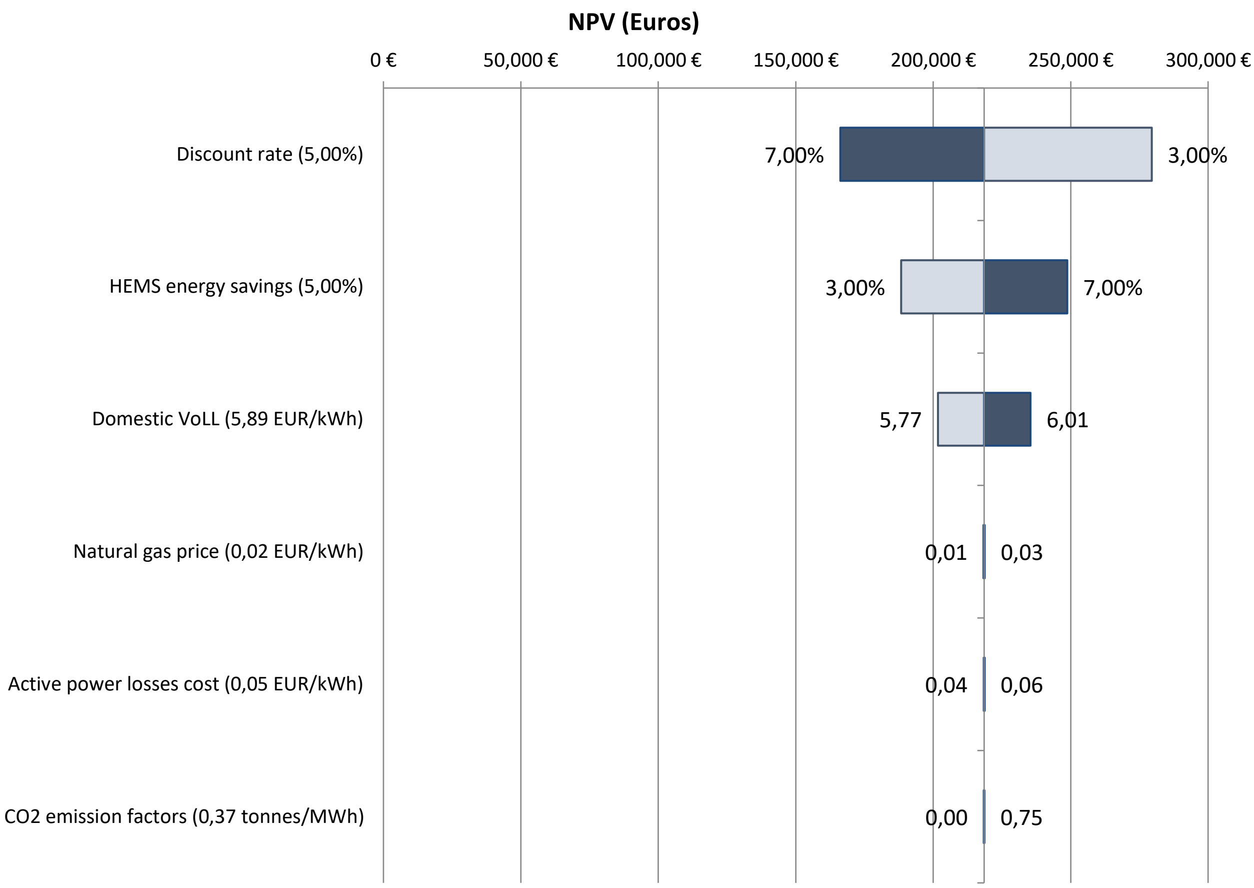


Figure 35: Cluster 02. Portugal. Scenario 35. Tornado.

3.8.1. Cluster 3

3.8.1.1. Slovenia

The table below summarizes the variables subject to sensitivity analysis and its range of variation in the case of Slovenia.

Table 26: Cluster 03. Commercial VPP in Slovenia. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Discount rate	%	15	13	17
Capacity fee mFRR+	EUR/MW	38 982	34 602	39 332
Energy fee mFRR+	EUR/MWh	250	240	260
Capacity fee mFRR-	EUR/MW	38 018	37 493	38 982

As per the tables of the Annex section, most of the pools if participating in the Slovenian mFRR would result as profitable from an overall viewpoint (NPV>0). For this analysis, a small pool with a positive NPV but close to zero (174 euros) was chosen since, in our experience, it is where the uncertainty associated to theses variables can change the project's feasibility. The size of this pool is 2 MW upward, 5 MW downward and has an average DER flexibility of 1.25 MW. Figure 36 below provides a graphical representation of the degree to which the total NPV of scenario is sensitive to the selected parameters.

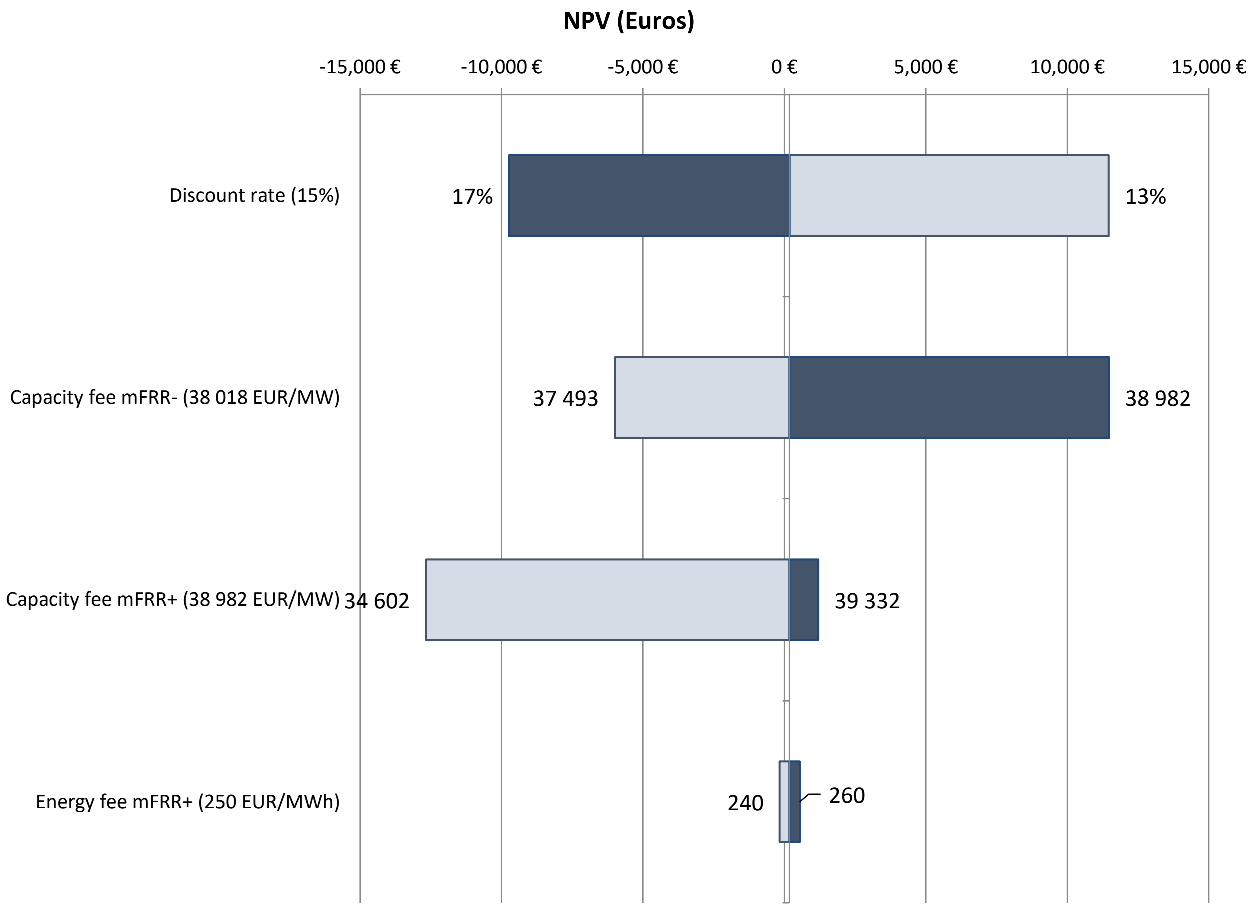


Figure 36: Cluster 03. Commercial VPP in Slovenia. Tornado.

As can be seen, although the variations on the most relevant factors lead up to only a maximum of 14 000 euros change, all of them within the considerable ranges were able to drive the scenario's NPV into the negative field. This means that, in the pools with a small NPV, the discount rate of the project and the market variables can easily change the outcome. What one can conclude is that small pool sizes should be avoided by the flexibility operator as it only becomes economically interesting and robust when aggregating and selling more flexibility to the TSO in both directions.

3.8.1.2. Portugal

Table 27 summarizes the variables at stake and its range of variation in the case of Portugal.

Table 27: Cluster 03. Commercial VPP in Portugal. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Discount rate	%	15	13	17
Energy fee mFRR+	EUR/MWh	73,1	18	180,3
Energy fee mFRR-	EUR/MW	39,9	0	70

As per the tables of the Annex section, only a few pools would result as economically interesting (NPV>0) from an overall viewpoint if participating in the Portuguese mFRR. For this analysis, the pool with the greatest NPV (27 682 euros) was chosen. This pool has a size of 30 MW upward, 30 MW downward and an average DER flexibility of 2 MW. If, in this case, any individual parameter change can turn the project's feasibility negative, it means that the other pools with a positive NPV are also affected by that.

From Figure 37, it is possible to observe that the energy fees stand out as key. Variations on the downward activation price lead up to approximately 750 000 euros change in the positive direction and up to about 1 million euros change in the negative direction. Variations on the upward activation price lead to less significant changes of around 113 000 euros in the positive direction and of circa 60 000 euros in the negative direction. Moreover, all parameter variation within the considered ranges were able to drive the scenario's NPV in the negative field. For a commercial VPP participating the Portuguese tertiary reserve market, these parameters are critical.

Since the sensitivity analysis shows a great variability of the project's outcome in Portugal, a Monte Carlo Simulation has been carried out to assess it in further detail. The histogram and cumulative distribution figures are provided below. These allow the user to understand that the likelihood that the project turns out a positive or a negative NPV are essentially balanced. This means that there is a high risk around the application of the cluster in Portugal, even if the central value of the distribution is positive (around 40 000 euros).

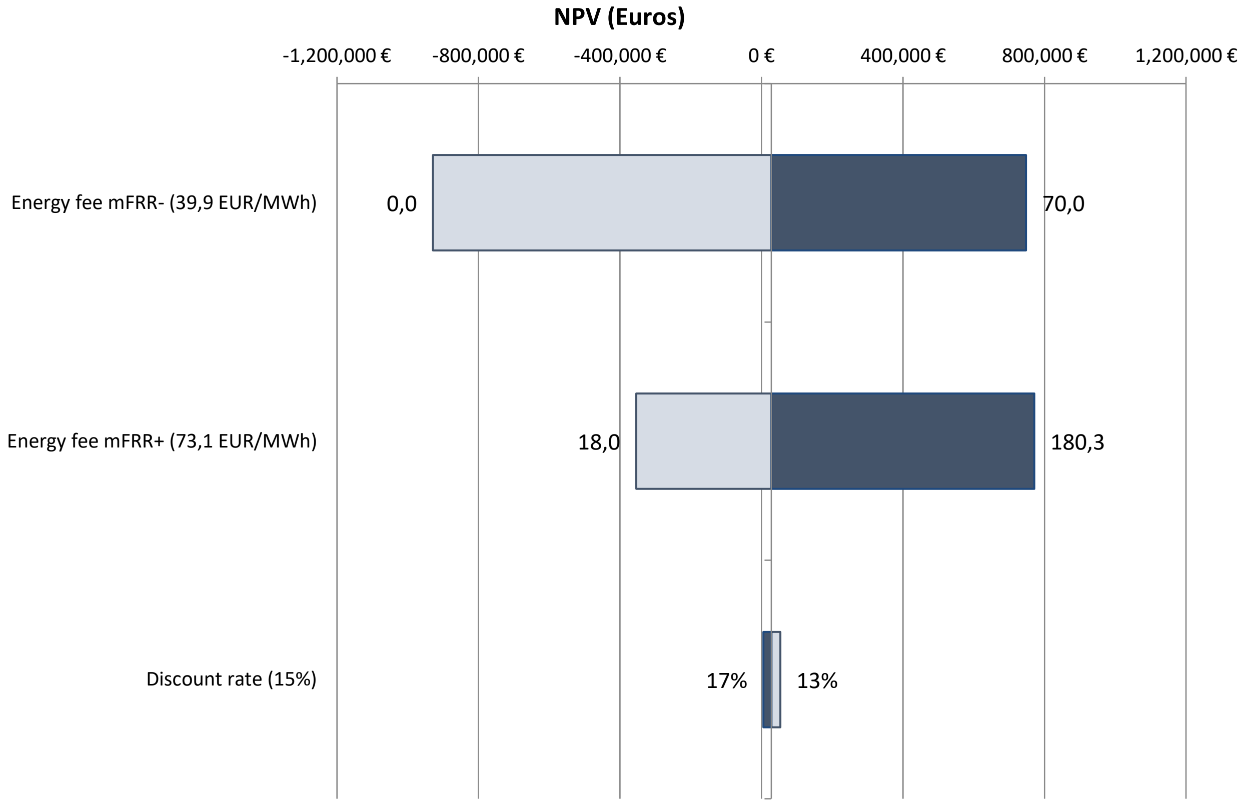


Figure 37: Cluster 03. Commercial VPP in Portugal. Tornado.

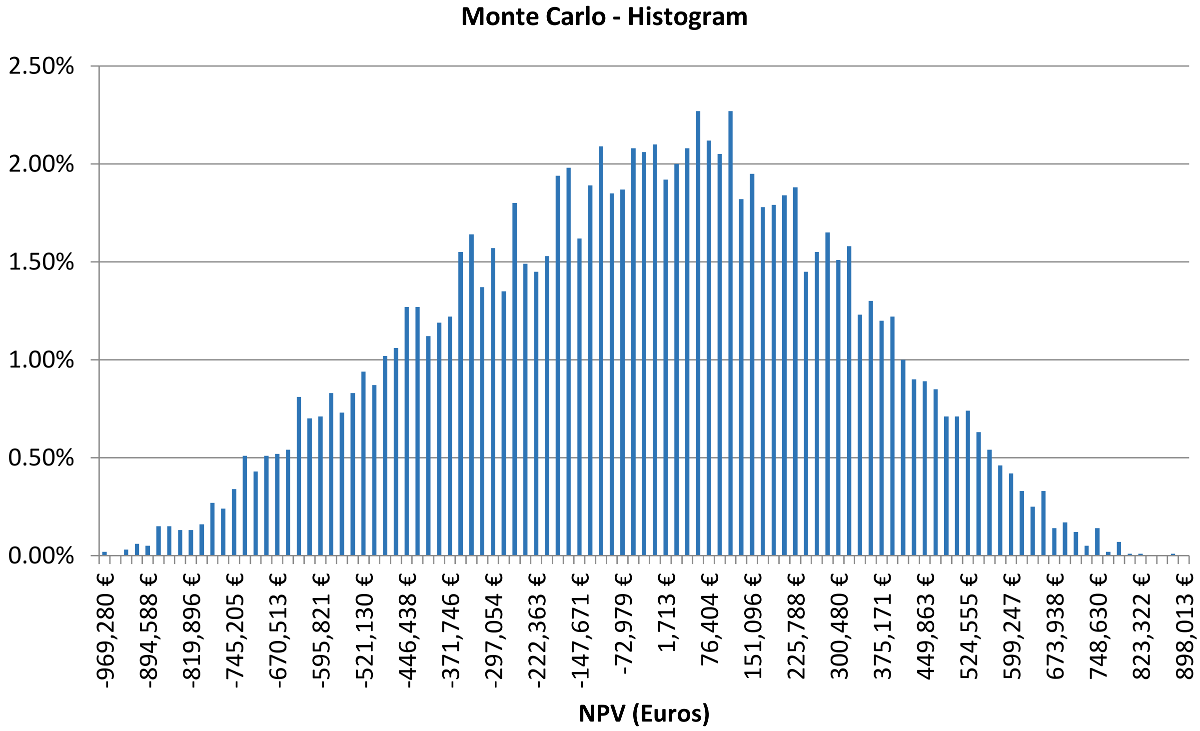


Figure 38: Cluster 03. Commercial VPP in Portugal. Monte Carlo - Histogram.

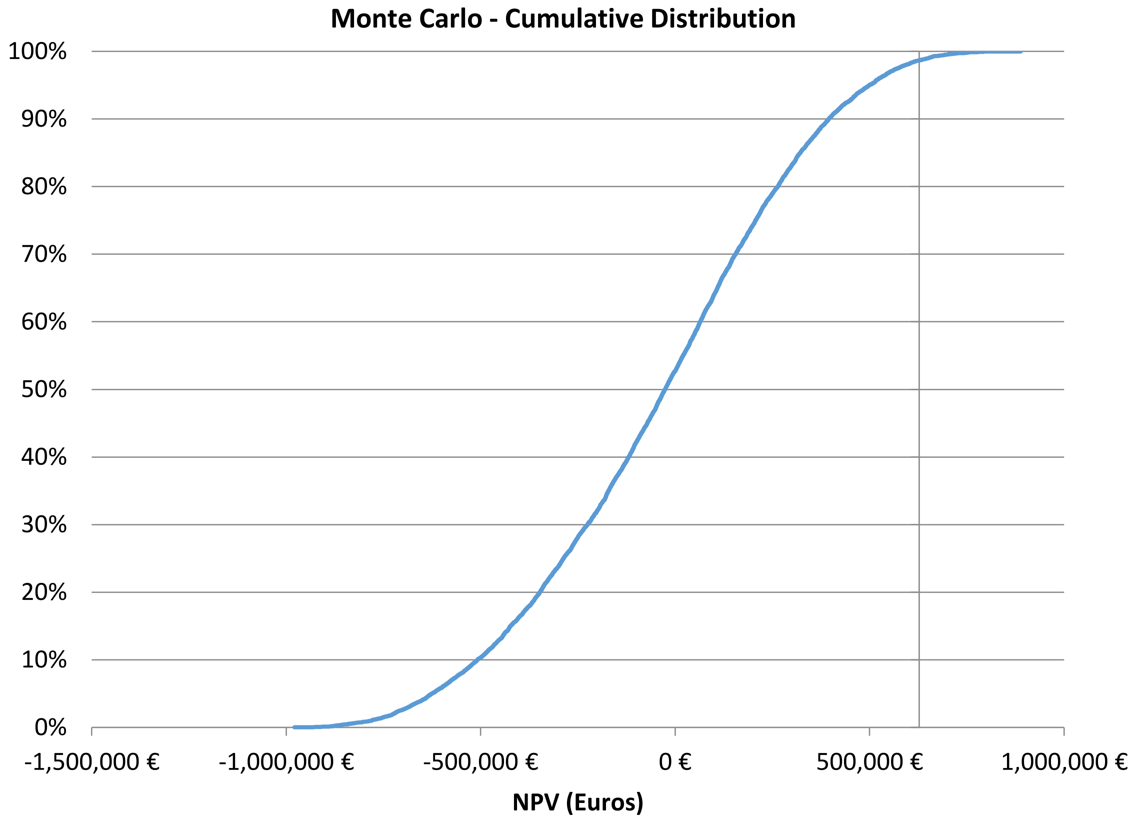


Figure 39: Cluster 03. Commercial VPP in Portugal. Monte Carlo – Cumulative distribution.

3.8.1.3. Wastewater plants

The table below summarizes the variables at stake and its range of variation.

Table 28: Cluster 03. Wastewater treatment plants. Sensitivity analysis.

Parameters/variables	Units	Base Value	Minimum	Maximum
Discount rate	%	15	13	17
Energy share	%	40	30	50
Penalties share	%	60	50	70

The changes on the best scenarios NPV are depicted in Figure 40. The energy share revealed as more relevant than the financial discount rate. However, no parameter variation within the considered ranges was able to drive the scenario's NPV in the negative field, meaning that project's feasibility change is not affected by those. Variations on the energy share lead up to 7 000 euros.

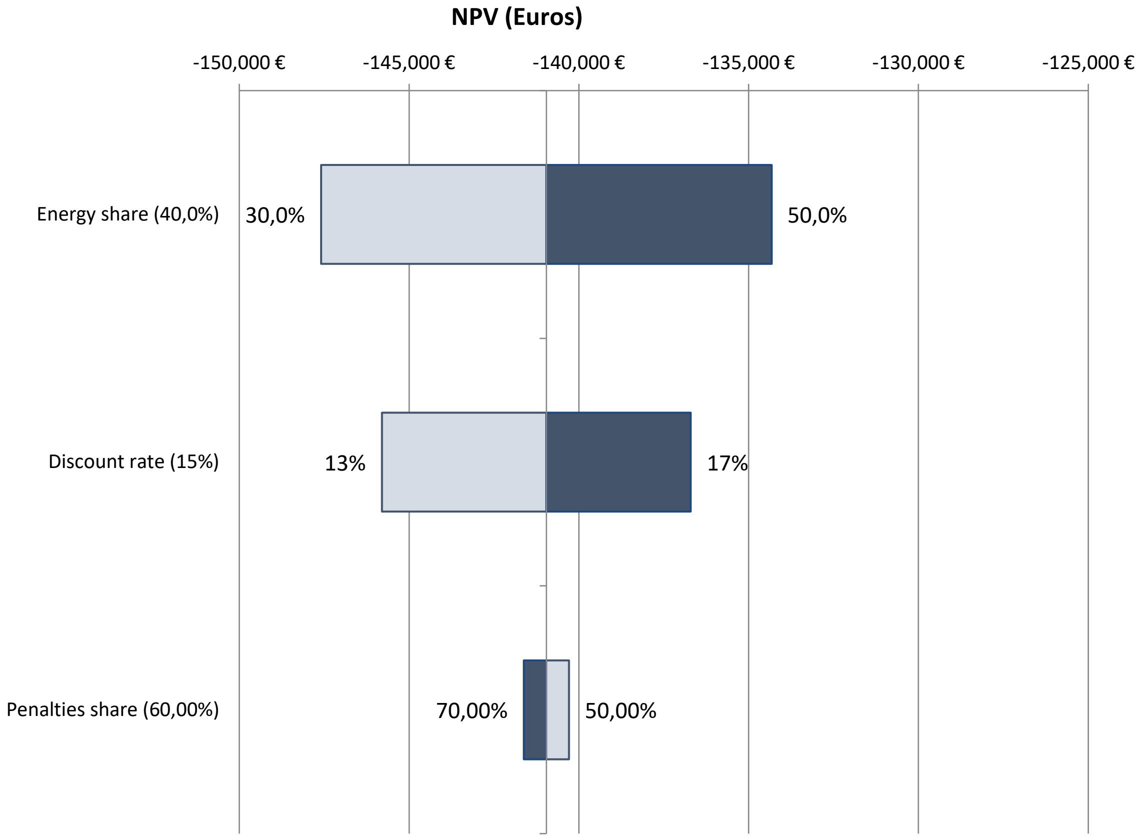


Figure 40: Cluster 03. Wastewater plants. Tornado.

3.8.2. Cluster 4

The only parameter subjected to sensitivity analysis in this cluster was the discount rate in a range of 13% to 17%. In the base case, the value applied was 15%. In the aFRR market, the pessimistic scenario of 50% chance was chosen. The results of the sensitivity analysis are displayed in Table 29.

Table 29: Cluster 04. Sensitivity analysis.

	Base case	Minimum	Maximum
Discount rate	15%	13%	17%
NPV mFRR market	-284 010 €	-287 437 €	-281 969 €
NPV aFRR market (50% chance)	8 504 600 €	9 271 037 €	7 831 782 €

For an aggregator participating in the mFRR market, the overall NPV change was around 1%, while, in the aFRR market, the outcome change is much more significant and was about 9% for a discount rate of 13% and 7% for a discount rate of 17%. However, no parameter variation within the considered ranges was able to drive the scenario’s NPV in the opposite side.

4. Regulatory replicability

Following the Economic SRA, this section explores how regulation will impact the possibilities for InteGrid solutions to be implemented in different countries, in and out of the project consortium countries. Regulation will mainly impose barriers or provide drivers for the different solutions at a national scale, i.e. the focus is placed on the regulatory replicability conditions.

It is worth noticing that this regulatory replicability analysis is not isolated in the InteGrid project and connects to a broader regulatory study carried out within the project. In Deliverable D1.3, a preliminary regulatory and market conditions assessment is done in four focus countries (Portugal, Slovenia, Sweden, and Spain) [REF D1.3]. Following that report, Deliverable D7.1 presents an update on the regulation in the selected countries, with the addition of Austria, as well as a first assessment of the possible regulatory barriers that InteGrid solutions may face [REF D7.1]. Finally, Deliverable D7.2 will focus on the regulatory barriers in each of the five target countries (Portugal, Slovenia, Sweden, Spain and Austria) and will provide recommendations on how to overcome them.

In this Deliverable D8.2, the focus is on the identification of the main barriers not only for the five focus countries, but also for other selected EU-28 Member States. The objective of this report is not to provide recommendations on how to overcome these barriers, but rather evaluate how compatible national regulatory frameworks are to the implementation of InteGrid solutions.

This regulatory replicability analysis chapter is divided in 4 sections. In section 4.1, a description of the regulatory barriers is presented together with a mapping of these barriers against the four clusters considered in this deliverable D8.2. Section 4.2 enumerates the EU countries whose regulation has been analysed and describes the reasons for this selection. Next, section 4.3 presents the SRA analysis itself, where the replicability of the clusters across countries is discussed. Finally, section 4.4 concludes with a maturity or compatibility analysis which aims to assess how far current regulation is from enabling the InteGrid functionalities considered in this report.

4.1. Mapping regulatory barriers to clusters

In order to evaluate how compatible the different clusters are, firstly a mapping of key regulatory barriers per cluster is conducted. Different clusters will be impacted differently by certain characteristics of national regulation in different countries. For example, Cluster 3 is centred in the idea of large consumers providing mainly balancing services to TSOs. Therefore, a certain country will most probably be compatible with the Cluster 3 if balancing markets are open to demand units, if balancing products are non-symmetrical, and, on a lesser degree, if aggregation is allowed. In this context, for each Cluster, key regulatory characteristics may indicate how compatible clusters are to countries.

The mapping carried out in this section is organized by regulatory topic, and sub-topic under which each regulatory barrier is classified. The list of regulatory barriers presented below has its origins in the assessment carried in WP7, that will provide recommendations on how to overcome them in the InteGrid target countries. In the regulatory replicability analysis, however, we derive a more compact and representative list of barriers in order to extend to analysis to the wider country selection presented in section 4.2.

Table 30: List of Regulatory Barriers by Cluster (0 no relevance, 1 small relevance, 2 relevant, 3 very relevant).

Topic	Sub-Topic	Identified Barrier	Cluster 1: Flex for MV	Cluster 2: Flex for LV	Cluster 3: Large Consumers cVPP	Cluster 4: Buildings Aggregation
DSO regulation	Revenue Regulation	Lack of incentives for DER flexibility procurement due to asymmetries between the treatment of CAPEX and OPEX which favour the former over the latter	3	3	0	0
		DSO revenue regulation does not remunerate the cost of new "distribution services" i.e. management of the grid using flexibility	3	3	0	0
		New smart grid technologies are not incentivized or not considered in the remuneration of DSOs	3	3	0	0
		Allowed revenues based in past investment/costs only, without considering future investment needs, including DER	3	3	0	0
		DSO are not required to submit long-term investment plans and/or it is not clear how these are reflected into their allowed revenues	3	3	0	0
	Other output-based incentives	Incentives for the reduction of energy losses are not in place or provide weak incentives (low-powered incentive, dead-bands, non-symmetric designs, cap and floors)	2	2	0	0
		Energy losses incentives do not consider the impact of DER and smart grid technologies	2	2	0	0
Local flexibility market/services	Mechanism to provide local flexibility	Mechanisms for local flexibility procurement and provision (local markets, non-firm access, agreements DSO-DER) are not implemented	3	3	0	0
		Lack of regulation for the coordination between TSO and DSO for the provision of ancillary services by DER	2	1	3	2
Balancing markets	Balancing services	Balancing markets not open to demand, included the one connected at distribution level, or balancing products not suited for demand-side resources	0	0	3	3
		Balancing market access and product definition not suited for DER (minimum sizes, design of deviation penalties, upwards/downwards allocated together, dual imbalance pricing)	0	0	3	3
		Barriers to the development of the aggregation activity	1	0	3	3
		Barriers to independent aggregation (e.g. balancing responsibility)	0	0	3	3
Retail tariff design (regulated charges)		Regulated charges show no or little time discrimination; structure inappropriate to promote flexibility	1	3	1	1
		Tariff design: high share of taxes and other regulated costs may kill other price signals	1	3	1	1

Each cluster may be affected by different regulatory barriers, as shown in Table 30. The concept of DER flexibility procurement by the DSO is at the heart of **Clusters 1 and 2.** From a regulatory perspective, besides the provisions allowing DSOs to use flexibility (through market-based mechanisms of other form of agreement between DSOs and grid users), the key issue is the economic incentives for DSOs to do so**.** Thus, these clusters are mainly affected by regulatory barriers related to the economic regulation of DSOs.

The reason for this is that these clusters ultimately aim at reducing conventional grid investment costs (or emergency RES curtailment)[4] at the expense of new types of expenditures such as compensations to flexibility providers or grid monitoring/automation technologies; therefore, DSO revenue regulation ought to account for this change in the network operation cost structure. In spite of the provisions in Article 32 of Directive (EU) 2019-944, as of today, most regulatory frameworks do not accommodate incentives for DER flexibility use. RPI-X regulation focusing on short-term cost reductions, usually remunerating conventional grid investments (CAPEX) and incentivizing the reduction in operational expenditures (OPEX), is widespread (CEER, 2019). Some regulatory proposals advocate for a TOTEX approach or for strengthening the focus on output-based regulation, among others.

This change in paradigm may also be hampered by outdated grid planning approaches that do not acknowledge DER flexibility potential. Despite the fact that, in the context of InteGrid, clusters 1 and 2 are mainly focused on the operational planning and real-time stages, these functionalities would be useless unless considered as well at the network planning stage. Traditional planning approaches, given the fact that a passive operation is normally assumed, tend to result in very robust distribution grids with enough spare capacity to face adverse operation scenarios.

On the one hand, at the networking planning, DSOs are not always required to submit long-term investments to the regulator, and/or it is not clear how these investments will be taken into account in the future remuneration of DSOs. On the other hand, at the periodic revision of allowed revenues[5], the typical approach is to consider only past (realized) investments and costs, oftentimes as an input to benchmarking analysis. In the scenario of increasing usage of DER flexibility for network management purposes (considering that nowadays this is rare), some predictive approach to the use of flexibility could be needed.

A last topic related to the regulation of DSOs affecting the costs and benefits considered in the economic SRA is the design of economic incentives to reduce energy losses in the distribution grid[6]. The reduction in energy losses may be an added benefit of the active grid operation tested in clusters 1 and 2 (albeit, in some circumstances, network losses may also increase as grid assets may be operated closer to their rate thermal limits). However, in order for DSOs to reap such benefit (or not be penalized for what may actually be a

[4] The reduction in bus voltage deviations may be seen as a proxy for investment deferral, as such deviations would conventionally be solved through grid reinforcement.

[5] A typical RPI-X regulation is based on regulatory periods for which dedicated price reviews are performed and allowed revenues are set ex-ante. Such regulatory periods have a length of several years (usually 3 to 6 years). Additionally, some countries include intra-period revenue adjustments.

[6] The discussion will focus on technical losses, i.e. those caused by physical phenomena in electrical components, since these are the most relevant regarding the impact of DER and InteGrid functionalities.

more efficient operation), the associated economic incentives should be in place and account for the impact of DER and the use of flexibilities.

On the consumer/prosumer side, there may be also important regulatory barriers for the deployment of these clusters, particularly for cluster 2 involving residential consumers, relate to the retail tariff structure and design. More specifically, the level and structure of regulated charges[7] can be a major barrier to the promotion of flexibility from end users, especially where regulated charges (or taxes) account for an important share of the final electricity costs seen by end consumers. For instance, in countries where retail tariffs show no time discrimination or fixed charges amount to a large proportion of the bill, DER flexibility, especially demand response connected at the LV network, will have little incentive to shift its demand.

Moreover, a high share of regulated costs in the retail tariffs would weaken price signals coming from energy prices or dynamic network tariffs. At the same time, if charged through a volumetric charge, high regulated charges can in fact incentivize new solutions like self-consumption or batteries. However, since this type of cost allocation is not considered as cost-reflective (policy and most of network costs generally do not depend on the volume of energy consumed), this incentive for flexibility of self-generation may not be economically efficient and potentially expose end-users to a regulatory risk in case regulated charges are re-designed after they have invested in the new equipment.

Turning to **Clusters 3 and 4**, the main regulatory topic to be considered is the design of balancing markets and services, with a focus on secondary and tertiary reserve markets (aFRR/mFRR according to the EU-wide nomenclature). These are well-stablished services run by TSOs. However, these services have been conventionally provided almost exclusively by large generators connected to the transmission grid. The implementation of clusters 3 and 4 would involve some deep changes to this new paradigm, namely the participation of demand-side resources and the participation of flexibility providers connected at distribution level. In cluster 3, large consumers are expected to provided services through the cVPP, that will bid into tertiary regulation markets. In cluster 4, the aggregation of building demand is being explored, possibly resulting in the provision of secondary and tertiary regulation.

Therefore, the main barriers identified for these two clusters are related to these changes. Balancing markets today may still be closed for the participation of demand response and, even if markets are formally open for demand response, certain characteristics may impose practical barriers for their participation. These may include high minimum bid sizes, required symmetrical bidding for upwards and downwards reserves, or dual imbalance pricing, among others. Hence, a redesign of balancing market products, design and criteria may be needed.

Aggregation is also at the core of these clusters. Therefore, barriers for the development of aggregation are also barriers for these clusters. Two main barriers regarding aggregation were identified. The first one considers barriers for aggregation in general, including participation of aggregated resources in balancing markets, whereas the second is specifically on independent aggregators. As already discussed in deliverable

[7] The term "regulated charges" refers to the share of the retail tariff paid by end users that aims to recover the costs related to regulated activities (transmission, distribution, system operation, market operation, regulator fees) and policy decisions (RES additional remuneration, tariff deficit annuities, cross-subsidies among regions), in case these costs are partly or completely passed-through to the electricity tariff.

D7.1, independent aggregators still face many challenges such as uncertainties regarding balancing responsibility.

Lastly, there is one regulatory barrier identified as being largely crosscutting to all four clusters, i.e. the TSO-DSO coordination. Even if this barrier does not show the highest importance in the context of InteGrid, it will indeed affect all clusters to some extent. DSOs using DER flexibility may need to compete with the TSO also procuring DER flexibility for balancing purposes or other ancillary services, or TSO driven activations of DER may cause problem in the distribution grid. Therefore, for regulatory replicability purposes, it is important to assess how TSO-DSO coordination is being enhanced in the analysed countries. This discussion will be mostly made for cluster 3 where the TLS tool is used specifically to tackle this problem.

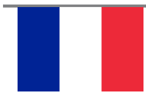
4.2. Selection of countries to analyse

This regulatory replicability analyses how compatible the InteGrid clusters are to the regulation in different countries. Therefore, a set of countries was selected for this analysis. Naturally, the three demo countries in InteGrid were the first countries to be included in this set, namely Portugal, Slovenia and Sweden. Additionally, other two countries from the InteGrid consortium were included, namely Austria and Spain. These countries are included as partners of the InteGrid consortium and can provide precise information on their national regulation.

Besides the five InteGrid target countries, five additional countries were selected to complete the set of countries analysed in this regulatory replicability report, namely Belgium, France, Germany, UK[8], and Italy. These countries were chosen among EU Member States and were selected based on different aspects from their national regulatory frameworks that were deemed advanced or innovative. Thus, each one of them can provide interesting experiences regarding the topics listed in the previous section 4.1. Therefore, not only this replicability analysis serves to check compatibility among countries, but it also identifies good practices for many regulatory topics.

[8] This report generally refers to the UK as comparisons are made among countries. However, the power system regulation (markets, networks, tariffs, etc.) of Great Britain and North Ireland are independent and present distinct NRAs (OFGEM and CRU respectively). It must be noted that all the discussions in this report actually applies to the regulation in GB.

Table 31: EU countries considered in the regulatory SRA and justification.

Country	Abbreviation[9]	Reason for selection
	PT	InteGrid Demo Country
	SI	InteGrid Demo Country
	SE	InteGrid Demo Country
	AT	InteGrid Target Country
	ES	InteGrid Target Country
	BE	Several different DSO regulatory frameworks (Flanders and Wallonia), but some of the most advanced regulation on independent aggregation, including ways to solve the balancing responsibility allocation problem.
	FR	Balancing markets potentially very favourable to demand-side and DER participation.
	DE	Remarkably different TSO-DSO landscape (four TSOs, 800+ DSOs). Innovative market-based platform for flexibility procurement being tested (Enera). Balancing markets quite open to demand-side participation
	UK[10]	Innovative output network regulation (RIIO). Innovative incentives for flexibility procurement, including local market initiatives (Piclo Flex). Balancing markets open to demand-side participation, but complex market design
	IT	DSO regulation presents several innovative features promoting smart grid deployment and DG-RES integration.

Broadly speaking, the four clusters can be categorized into a subgroup focused on active grid operation using flexibilities (clusters 1 and 2) and another subgroup addressing demand-side participation in balancing markets (cluster 3 for industrial demand and cluster 4 for commercial demand). Accordingly, as shown as well by Table 30, most of the relevant regulatory issues may be classified into three categories, i.e. DSO regulation, local flexibility markets/services, and balancing market design.

Table 31 enumerates the set of additional countries included in the assessment as well as a brief description of the reasons why each country was selected. As mentioned above, the main goal was to identify, based on a literature review and desk research, a few countries that could bring interesting regulatory experiences

[9] ISO 3166-1 alpha-2 country code
[10] UK is used instead of GB. See footnote 8.

or best practices into the regulatory SRA regarding one or more of the three categories mentioned in the previous paragraph. These relevant features are the following:

- DSO regulation: UK and Italy are forerunners in the implementation of innovative approaches to grid regulation, including features such as menu regulation, shift to output regulation or incentives for innovation.
- Local flexibility markets/services: these regulatory mechanisms are generally poorly developed yet, with only a few experiences being operated at commercial scale yet. Among these experiences, Piclo Flex (UK) and Enera (Germany) may be considered among the most advanced ones. Moreover, both Germany and UK have implemented in the past different mechanisms to use DER flexibility for alleviating grid constraints through agreements between DSO and DER (e.g. non-firm access contracts in the UK) or through mandated curtailment (e.g. curtailment rules under emergency conditions for solar PV in Germany).
- Balancing market design: on the one hand, demand-side participation in balancing markets is a necessary precondition for clusters 3 and 4. France and Germany are among the countries that present better regulatory conditions for this to happen. UK was also considered interesting in this regard given that several specific balancing products have been created specifically for demand, although this may have led to a very complex balancing market design. On the other hand, the emergence of independent aggregators can be deemed as a facilitator for the entry of demand in balancing markets. However, this requires clear definitions for the allocation of balancing responsibility between independent aggregators and retailers (who are the conventional BRPs). Belgium was seen as having an advanced regulation in this regard and thus included in the regulatory SRA.

All relevant regulatory topics will be discussed in detail for the five target countries (Portugal, Slovenia, Sweden, Spain and Austria). However, since some of the additional EU countries included for this report present interesting features only for some of the regulatory topics, in some cases not all of these countries will be discussed in detail for all clusters, but only in those where their inclusions are deemed significant.

4.3. Assessment of barriers by cluster and country

As mentioned previously in Section 4.1, the four clusters can be broadly divided into two groups, characterized by the core goal of each cluster. Likewise, the regulatory barriers deemed relevant to each cluster are quite similar within these two groups. Therefore, in order to avoid repetitions, the analysis presented in this section is divided by these two categories, namely active grid operation using flexibilities (encompassing clusters 1 and 2), and demand-side participation in balancing markets (comprising clusters 3 and 4).

4.3.1. Clusters 1 and 2: Active Grid Operation Using Flexibilities

Section 4.1 showed that the use of flexibilities[11] to support distribution grid operation may face several regulatory barriers related to the economic regulation of DSOs, the existence of mechanisms enabling DSOs to access these flexibilities and the structure of regulated charges and retail tariffs. Up to 10 different regulatory barriers mostly relevant to these two clusters were enumerated in Table 30. In order to guide the analysis for the countries considered, the aforementioned barriers have been translated into a reduced set of questions. These are shown in Table 32.

Table 32: Key regulatory question for active grid operation using flexibilities.

Key regulatory question for active grid operation using flexibilities	
DSO revenue regulation	Would DSOs benefit from using flexibility to defer or avoid grid investments?
	Would DSOs recover the costs associated with the use of flexibility?
	Do DSOs and regulators adopt a long-term vision for grid development/regulation, including the use of flexibilities?
Local flexibility mechanisms	Are DSOs enabled by regulation to procure flexibility from grid users to support grid operation?
Incentives for the reduction of energy losses	Do DSOs receive (strong) economic incentives to reduce energy losses?
	Is the impact of DER and smart grid solutions considered when setting baseline/target levels for losses?
Regulated charges and retail tariffs	Does the structure of regulated charges allow or promote end-user flexibility?
	Are taxes and/or other regulated charges distorting flexibility incentives embedded in the tariffs?

This section sheds light on the questions formulated above for most of the ten countries listed in section 4.2 using information from different several sources. In the case of the five InteGrid target countries, the main sources of information were the questionnaires used for deliverables D1.3 and D7.1 [REF D1.3, D7.1]. Where necessary, updates driven by recent changes in national regulation were identified. For instance, in Portugal, recent regulation introduced several new dispositions related to the operation and metering in

[11] (CEER, 2017b) defines flexibility as "... the capacity of the electricity system to respond to changes that may affect the balance of supply and demand at all times.", stating also that the use of flexibility services by the DSO "could support more efficient network use and system operation".

The Smart Grid Task Force defines flexibility as "...the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. The parameters used to characterize flexibility include the amount of power modulation, the duration, the rate of change, the response time, the location etc." (European Smart Grids Task Force, Expert Group 3, 2015).

LV distribution systems to account for high penetration of small-scale RES[12]. Likewise, the Spanish regulator introduced several changes in the revenue regulation of DSOs and the calculation of the regulatory rate of return for the period 2020-2025[13]. For the additional countries, information was gathered mainly from reports and surveys from recognized European institutions, such as ACER or CEER.

4.3.1.1. DSO revenue regulation

Clusters 1 and 2 aim demonstrating the use of flexibility to support distribution grid operation. This is in line with the recently adopted Clean Energy Package, which states that distribution system operators shall procure flexibility services in a market-based manner from resources such as distributed generation, demand response or storage, when such services are less costly than grid expansion (Directive (EU) 2019/944). The main goal is therefore to achieve lower grid costs by reducing expansion expenditures in the long-term.

However, it will not be possible to replace network expansion (reinforcement) by flexibility completely. In some cases, network expansion/reinforcement will be necessary to ensure security of supply, whereas, in other situations, temporary procurement of flexibility could help to overcome existing constraints during the time required to complete expansions/reinforcements. Therefore, DSO regulation should create the necessary conditions for DSOs to decide on what is the most suitable solution for each case, including long-term costs and reliability. By incentivizing DSOs to operate efficiently, regulation would thus benefit end consumers through, for instance, lower network charges.

Nowadays, most European countries have implemented some form of incentive regulation, which intends to promote cost reductions whilst ensuring adequate levels of security of supply. In spite of the many differences in the details of the national regulatory frameworks that can be found, some general features that discourage the use of flexibilities are widespread. These create a situation where, as discussed in section 4.1, current regulation is generally still ill adapted to this upcoming paradigm.

Firstly, many countries place stronger incentives for cost reduction on OPEX as compared to CAPEX; as stated in (CEER, 2019), "*The survey revealed that a majority of the regulators in electricity and gas alike require the cost saving mainly on the OPEX side*." Moreover, the RAB is frequently updated in order to reflect actual investments carried out by DSOs, being some key differences how often the RAB is updated

[12] Regulation No. 610/2019 that Approves the Regulations for Intelligent Electricity Distribution Services. In Portuguese: *Regulamento Nº 610/2019 Aprova o Regulamento dos Serviços das Redes Inteligentes de Distribuição de Energia Elétrica.*

[13] Agreement approving the proposed methodology for the calculation of the financial rate of return applied to the electric power transmission and distribution activities for the second regulatory period 2020-2025. In Spanish: A*cuerdo por el que se aprueba la propuesta de metodología de cálculo de la tasa de retribución financiera de las actividades de transporte y distribución de energía eléctrica para el segundo periodo regulatorio 2020-2025.*

Circular 6/2019, of December 5, of the National Commission of Markets and Competition, which establishes the methodology for the calculation of the remuneration of the electricity distribution activity. In Spanish: *Circular 6/2019, de 5 de diciembre, de la Comisión Nacional de los Mercados y la Competencia, por la que se establece la metodología para el cálculo de la retribución de la actividad de distribución de energía eléctrica.*

(time lag between investment and inclusion in the RAB) or the economic value given to new RAB additions. These two characteristics lead to a situation in which DSOs see little incentive to reduce grid investments, especially if this implies an increase in OPEX, e.g. to remunerate the flexibility provision.

A regulatory mechanism that can be relevant to support the required changes are the investment plans that grid operators have to submit periodically to NRAs for evaluation. In fact, Article 32 of Directive 2019/944 acknowledges this by stating the following:

> *"the distribution system operator shall publish at least every two years and shall submit to the regulatory authority. The network development plan shall provide transparency on the medium and long-term flexibility services needed, and shall set out the planned investments for the next five-to-ten years, […]. The network development plan shall also include the use of demand response, energy efficiency, energy storage facilities or other resources that the distribution system operator is to use as an alternative to system expansion."*

Therefore, it is relevant to assess to what extent current DSO investment plans comply with this future requirement, going beyond a conventional grid expansion analysis estimating the load growth and the reinforcements (largely copper-and-iron investments) that would be necessary to supply the peak load.

Overall, as shown in Table 30, current DSO regulation would therefore present the following barriers for the development of clusters 1 and 2:

1. Lack of incentives for DER flexibility procurement due to asymmetries between the treatment of CAPEX and OPEX which favour the former over the latter
2. DSO revenue regulation does not remunerate the cost of new "distribution services" i.e. management of the grid using flexibility
3. New smart grid technologies are not incentivized or not considered in the remuneration of DSOs
4. Allowed revenues based in past investment/costs only, without taking into account future investment needs, including DER
5. DSO are still not required to submit long-term investment plans and/or it is not clear how these are reflected into their allowed revenues

The aforementioned barriers can be translated into several questions that will be explored for the selected countries throughout the remainder of this section. The first question would be whether, based on existing regulation, DSOs would benefit from using flexibility to defer or avoid grid investments or, on the contrary, a reduction in grid investments would result in an economic loss for the DSO. A second related question is whether DSOs may recover the costs associated with the use of flexibility; these may include communication systems and economic compensations to flexibility providers. Lastly, we shall analyse whether DSOs and regulators adopt a long-term vision for grid development/regulation, including the use of flexibilities.

The review of national regulation performed reveals that the regulatory framework for DSOs are widely different across countries. Nonetheless, it may be said that, in general, flexibility is not clearly incorporated into grid regulation. None of the NRAs currently contemplates explicitly the use of flexibility for the development of the network, even when investment plans are used for regulatory purposes. Moreover, a separate treatment of CAPEX and OPEX with asymmetric incentives among them is widespread, being the regulation of LV grids in Portugal the only instance of a TOTEX regulation among the target countries, as well as the UK and Italy (planned) among the additional countries. On the other hand, some countries (e.g.

Portugal, Slovenia and Spain) present some type of incentive for innovation that could potentially allow DSOs to cover the costs of new technologies or flexibility services in pilot projects or small areas.

On the ensuing, a more detailed description of the situation country by country is provided:

- **Portugal**: the Portuguese regulatory framework in the last regulatory period for HV and MV distribution is based on a rate of return regulation for CAPEX and a price cap regulation for OPEX, i.e. cost reduction targets are set on OPEX whilst a cost of service approach is retained for CAPEX. The path of allowed OPEX is set every three years, being the efficiency requirements determined through a DEA benchmarking and complemented with the Malmquist Index. On the contrary, CAPEX is updated annually according to actual investments. In the case of the LV grid, a TOTEX approach is followed, by which all costs (except concession rents and workforce restructuring plans) are subject to an efficiency target.

  Regarding the inclusion of new investments in the RAB, in addition to the values sent by the companies each year, the NRA also takes into account the Development and Investment Plan prepared by the DSO, which is focused on the HV/MV distribution networks. The DSO must submit a 5-year HV and MV investment plan, every two years, to DGEG (technical regulatory body dependent on the government) and ERSE for evaluation and subsequent approval by the Portuguese parliament and the Portuguese government. In the case of the LV grid, the DSO submits a LV plan every year to the regulator.

  The impact of DER penetration on grid costs is taken into account when investment plans are made. Additionally, the Portuguese regulation includes an incentive for the DSO to deploy innovation projects. In case these projects are approved by the regulator, the DSO would receive 50% of their annual benefits up to 1,5% of their investment, during 6 years. This type of incentive is enabled when CAPEX is regulated under a cost of service regulation.

  It is important to notice that in Portugal the Law 8/2012 forbids utilities from applying consumers any charge related to meters. This is an important barrier to the definition and stabilization of a clear incentive mechanism to the deployment of smart metering in Portugal.

- **Slovenia**: a revenue cap methodology is allegedly in force for OPEX and CAPEX. However, both cost components are calculated and regulated separately. A benchmarking analysis is used to determine DSOs eligible costs.

  CAPEX allowances are based on the investment plans submitted by DSOs. For every year, the deviations between approved investment plans and actual investments must be explained, including the causes for these deviations e.g. insufficient financial resources, long procedures for the preparation and collection of the investment documentation, etc. The Ministry of Infrastructure is the institution that accepts and confirms the plans.

  The Slovenian regulation includes financial incentives for the deployment of smart grid solutions, provided the corresponding projects comply with a set of criteria defined in the regulation. Eligible projects include investment projects that aim to promote an efficient development of networks whose total investment value exceeds 200.000 €, as well as pilot addressing the integration of new technologies and services in the area of smart grids and related market mechanisms. A project that is included under this scheme is credited with a one-off incentive of 3% of the carrying amount of the asset as at 31 December of the year in which the asset entered in operation. The sum of the incentives is capped to 10% of the reported net benefits of the whole project.

- **Sweden:** the regulatory model of Sweden is structured on the different cost items. First, a separate assessment of CAPEX and OPEX is made, being in turn the latter divided into controllable and non-controllable cost. An efficiency target reduces the controllable cost year by year. This requirement on higher productivity is not applied for the non-controllable cost. The RAB is computed as the replacement value of existing assets. The allowed revenue is adjusted after the 4-year regulation period due to deviations between prognoses and realized values for investments, disposal and non-controllable costs. The regulatory rate of return is determined as the WACC[14].

  DSOs periodically submit investment plans to the regulator. However, these are just indicative as the RAB is updated based on actual investments and depreciation after each 4-year regulatory period by the regulator.

  The Swedish regulation does not include specific incentives for the deployment of smart grid solutions, although ICT-related CAPEX is handled as any other cost with a depreciation time of 12 years. Related OPEX costs can be recovered in the next regulatory period, although efficiency requirements would apply to these.

- **Spain:** DSOs in Spain are under a revenue cap regulation with six-year periods, being the current one 2020-2025[15]. CAPEX and OPEX remuneration are calculated separately considering the information reported by DSOs and a set of tables of standard costs for different asset categories. Deviations between standard and actual costs are capped and these must be justified if they exceed a certain threshold. The remuneration is therefore largely proportional to the volume of investments made by the DSO. New distribution investments are included into the RAB and start to be remunerated with a delay of two years, i.e. assets put into service in year n-2 start are included in the remuneration of year n. The rate of return is determined following the WACC approach.

  DSOs must submit every year an investment plan for the next 4 years, which are reviewed and eventually approved by the NRA and other authorities. A cap on the overall volume of investments is set according to the finally approved investment plan; upwards deviations may result in a lower CAPEX remuneration for the investment costs that exceed the allowed investment cap. This reduced remuneration applies throughout the whole useful life of the assets. Compliance with the investment plans and the corresponding investment limits is checked every three years, i.e. twice during each regulatory period.

  The recently passed regulation introduces two mechanisms to promote smart grid solutions. Firstly, the regulation defines the category of “type 2” investments, which correspond to investments in network automation and digitalization required to support the energy transition. These

[14] In the regulatory period starting in 2020, CAPEX remuneration is expected to decline significantly due to the introduction of longer depreciation times and a lower regulatory WACC.

[15] A set of amendments to the DSO revenue regulation was approved at the end of 2019 (Circular 1/2019) and it will be applied for the first time in the period 2020-2025. Despite the fact that the overall revenue regulation model was not changed, this piece of regulation modified several aspects of DSO regulation that are relevant to InteGrid.

investments are added to the RAB at their actual cost provided that they fall within one of the smart grid asset categories defined by the regulator. Additionally, DSOs are entitled to passed-through to their allowed revenues the cost of pilot projects, both CAPEX and OPEX, subject to the submission of a CBA and the approval of the regulator. The cost of these pilot projects will not be considered within the abovementioned investment limits.

In Spain utilities can apply consumers monthly rents on the meters during the lifetime of such equipment. Spanish utilities were offered an incentive for them to ensure the roll-out of smart metering until the end of 2018. Such incentive consisted in an increased value of such monthly rent applied to the meters.

- **Austria:** Austrian DSOs are subject to an incentive regulation scheme for OPEX and a hybrid scheme for CAPEX. Allowed OPEX in the base year, i.e. the one considered for the price review, are adjusted according to a cost path determined taking into account both general and individual benchmarking-based productivity targets, as well as inflation. Regarding CAPEX, investments within a regulatory period are added to the RAB with a two-year delay, without any assessments about cost efficiency or usefulness. However, investments will be part of the TOTEX cost base considered in the benchmarking studies performed in the subsequent price review. The results of this analysis will affect the individual productivity factor and the opening RAB of the next regulatory period. Thus, this may be considered a hybrid regulatory scheme between cost of service and incentive regulation.

  DSOs do not submit investment plans. Excessive investments are prevented through the continuous TOTEX benchmarking process described above.

  The Austria regulation does not present any specific incentives for the deployment of smart grids. Nonetheless, investments are not distinguished between innovative or conventional solutions; thus, DSOs, in principle, could include them in their declared costs to the regulator.

- **UK:** the ex-ante allowed revenues of DSOs[16] are calculated before the beginning of every regulatory period (the current one is 2015-2023) following a building blocks approach. Distribution costs[17] are subject to a TOTEX regulation, under which allowed TOTEX are computed as a weighted average of the DSO expenditure forecast included in their business plan and the regulator's estimate, obtained through a modelling toolkit including several cost assessment or benchmarking models.

  The RAB[18] is updated on an annual basis based on the ex-ante allowances and the actual TOTEX reported by the DSOs. A pre-defined capitalization rate, i.e. the share of TOTEX that will be added to the RAB, is applied to each DSO. Additionally, ex-ante allowances are modified ex-post based on a menu-of-contracts regulation known as information quality incentive (IQI).

  DSOs must submit a business plans the NRA during the price review, and they are a central element in the determination of allowed revenues. The business plans must make a strong emphasis on how

[16] Despite the fact that distribution companies in the UK are referred to as DNOs (Distribution Network Operators), the term DSO is used for the sake of consistency and in line with EU terminology.

[17] Excluding non-controllable costs, costs outside the price control, or expenditures to address specific investment projects driven by particular circumstances of some DSOs.

[18] British regulation refers to the RAB as regulatory asset value or RAV.

DSOs plan on complying with a set of outputs (reliability, DER integration, losses, safety, end-user satisfaction) in a cost-efficient manner, justifying it through technical studies and CBAs, and manage the risks and uncertainty in their operations.

These business plans should cover the length of the regulatory period. Eight-year regulatory periods were introduced after 2015 to promote a long-term thinking. However, this came with it challenges, which led to the introduction of several uncertainty management mechanisms such as reopeners in case of significant deviations with respect to the base ex-ante allowances in topics such as load-related expenditures, innovation roll-out, etc., or a mid-period review. In fact, the regulator is proposing to reduce the length to five years for the next regulatory period.

Regarding innovative grid solutions, DSO regulation in the UK comprises three promotion mechanisms. Firstly, the annual Network Innovation Competition (NIC) funds up to 90% of the cost of large-scale innovative projects that are awarded. Second, the Network Innovation Allowance allows DSOs to spend between 0.5% and 1% of their base allowance on small-scale innovation projects (90% of the costs may be passed-through). Lastly, the Innovation Roll-out Mechanism gives DSOs the possibility to request a revenue adjustment to fund the roll-out of proven innovative solutions after the regulatory period has started in two pre-defined time windows.

- **Italy:** the current regulatory period corresponds to the term 2016-2023, which is in turn divided into two sub-periods of four years each. Italy has traditionally applied a hybrid regulatory model, with a price-cap mechanism applied to OPEX, which were accordingly subject to an efficiency requirement, and a rate of return (WACC) regulation on CAPEX. The RAB was thus updated on an annual basis to include new investments and deduct the corresponding depreciation.

  The approach remained in place for the first sub-period 2016-2019. However, the regulator expressed her willingness to adopt a TOTEX approach for the sub-period 2020-2023 similar to the one described above for the UK, based on the evaluation of DSO business plans and a menu of regulatory contracts. Therefore, DSOs would be obliged to submit forward-looking long-tern (5-10 years) business plans demonstrating the effectiveness of proposed expenditures on a set of outputs as well as their efficiency through CBA studies. However, in order to ensure a progressive implementation of the TOTEX approach, ARERA (2019) states that the TOTEX regulation will be applied to transmission regulation in the last year of the current regulatory period, whereas it will only start to be applied in the next regulatory period (after 2023) for distribution.

  In 2010, the Italian regulator implemented an incentive to promote smart grid projects with a focus on DG integration in the medium-voltage network, whereby investments approved by the regulator were awarded an additional 2% in their allowed WACC for 12 years. This input-oriented approach was followed by an output-based incentive mechanism to promote investments in certain smart grid functionalities that had proven positive cost-benefit ratios[19]. This consisted in an additional payment (no penalty) for each MVA of transformation capacity that presented this capability. The main functionalities included under this scheme is voltage control in MV networks with high shares of DG causing frequent reverse power flows.

[19] The regulation also introduced incentives for the modernization of the distribution grid in urban areas.

4.3.1.2. Local flexibility mechanisms

From a DSO perspective, there are two main regulatory requirements for the deployment of the solutions related to clusters 1 and 2. On the one hand, as discussed in the previous section, DSO revenue regulation should encourage DSOs to use flexibility as an alternative to grid reinforcement. On the other hand, certain regulatory mechanism allowing the DSO to actually access this flexibility are necessary, i.e. whether DSOs are enabled by regulation to procure flexibility from grid users to support grid operation. The latter type of scheme is what we generically refer to as local flexibility mechanisms in this report.

These local flexibility mechanisms can take different forms depending on the procurement method, the participating technologies, whether participation is mandatory or voluntary, etc. According to (CEER, 2018), four general types of flexibility mechanisms can be found:

i. Rule-based: Mandatory requirements set by regulation.
ii. Network Tariffs: incorporating flexibility incentives (ToU, dynamic charges, etc.)[20].
iii. Connection Agreements: DSOs reach an agreement with new grid users who provide flexibility in exchange for some sort of compensation (e.g. lower connection charges).
iv. Market-Based Procurement: DSOs explicitly procure flexibility from local markets.

Conventionally, the use of flexibility mechanisms has been limited, as shown by the country review performed. Slovenia and Sweden reported that these mechanisms are not used at distribution level, whilst in Italy the use of distribution flexibility is limited to pilot projects and in France a limited use of flexible connection contracts for generators may be found. Their use in the remaining countries is mostly limited to a rule-based approach under emergency conditions or based on flexible connection agreements[21]. The following examples were found:

- **Portugal:** the DSO may only manage the injection/withdrawal of grid users in case or emergency under grid congestion. The recently approved DL nº 162/2019, which establishes the new regime for self-consumption in Portugal, introduced the possibility to limit the capacity of self-generators connected to the grid or temporarily curtail them under emergency conditions where the operational limits of the grid quality of service indicators may be violated. In any case, affected users would not be entitled to an economic compensation.

- **Spain:** in principle, DSOs are enabled by regulation to request the RES Control Centre (CECRE) run by TSO to curtail RES generation units larger than 5MW connected to their grids in case grid constraints are foreseen or under emergency conditions. In these cases, the DSO ought to identify the units able to solve this congestion as well as the amount of generation that must be curtailed to solve the congestion, and notify the TSO. The TSO, via the CECRE, wold solve the congestion by

[20] Note that network tariffs incorporating some form of discrimination by voltage level of period are common. However, these tariffs are normally the same for the whole country or DSO area and do not normally take into account the specific conditions of a given part of the grid at a specific time, which is the scope of these InteGrid clusters.

[21] Network users, especially DG units, commonly need to comply with certain technical requirements, such as limits of the power factor or voltage magnitude at the point of common coupling, in order to be allowed to connect to the grid. However, these requirements tend to be fixed and common to all grid users, thus they do not consider the actual conditions the grid in each area and period. Therefore, this section specifically addresses mechanisms providing DSOs with some degree of controllability over the DER connected to their grids.

limiting and, if necessary, redispatching the corresponding RES units in the same way as if the congestion were located in the transmission network. The DG units affected would be paid according to the rules set in the technical constraint management market run by the TSO. However, in practice, due to the lack of well-developed procedures and regulation, DSOs rarely ask the TSO to perform such curtailment actions.

- **Austria:** distribution-connected generation participates in voltage control services according to existing grid codes. Despite the fact that generators should maintain a unity power factor by default, the grid operator may require a different setting if grid conditions require it. The provision of this service is subject to non-remunerated mandatory requirements that depend on the type (inverter-based or other) and size of the generator as well as the voltage level (MV or LV). The fulfilment of these requirements has priority over the injection of active power. Regarding congestion management services, current regulation does not explicitly prevent it, but it is not done in practice due to the lack of incentives for network operators.
- **Germany:** the German Renewable Energy Sources Act, or EEG, enable DSOs to modify remotely the injection of generation units connected to their grids. All units above 100kW, including CHP units, must allow DSOs to remotely reduce or increase the feed-in by remote control in the event of grid overload. In the case of solar PV units, this obligation applies to all units above 30 kW. Smaller units may choose to permanently limit their power injection to 70% of the nameplate capacity or to install the same communication system as larger plants. In all cases, DG units are entitled to economic compensation. Nonetheless, this mechanism should be applied only on a temporary basis in case of an emergency and the DSO is still expected to reinforce the grid in order to avoid curtailment.
- **UK:** the use of flexibility at distribution level has been usually limited to the use of non-firm access contracts for large consumers and generators signed with the DSO. These grid users would benefit from a faster grid connection and lower connection charges. Nonetheless, they would face the risk of open-ended curtailment without additional compensation. In most cases, DSOs provide these users with an estimated curtailment rate, but no formal cap on the amount of curtailment is set. Small consumers may not access these contracts, as they do not have an explicit capacity limit (in practice, the size of the upstream fuse would be the only limit). At the moment, access options are being evaluated in the framework of a significant code review[22].

Even though the InteGrid functionalities are not tied to specific mechanisms for flexibility provision, existing schemes, as the ones described above, may be still ill adapted for the InteGrid functionalities. In cluster 1, it is assumed that DSOs may book flexibilities in the operational planning horizon; not as an emergency condition. Moreover, the types of grid users are limited to some technologies regardless of the willingness of grid users to contribute. Hence, a full implementation of these clusters may make more sense in a context where flexibility mechanisms are more advanced, including the possibility to procure them through local markets.

These advanced market-based mechanisms are still scarcely developed. Even if DSOs are not legally prevented from using flexibility, there is generally no specific regulation either, thus this is still largely a grey

[22] https://www.ofgem.gov.uk/electricity/transmission-networks/charging/reform-network-access-and-forward-looking-charges

area. However, there are already a few market-based platforms becoming active at commercial level (sometimes under a regulatory sandbox condition), such as the ones present in UK and Germany (Schittekatte & Meeus, 2020; Smart Energy Europe, 2019):

- **UK:** the Piclo Flex platform[23], launched by an independent software company, went into full operation in 2019 after a piloting phase. This platform allows DSOs[24] to purchase flexibility from any resource connected within a given geographical area through a tendering procedure and for different contracting periods, defined by the DSO according to its needs. Three DSOs are currently acquiring flexibility through this platform, i.e. UK Power Networks[25], SP Networks[26], and Western Power Distribution[27].
- **Germany:** the Enera platform[28] is a joint project promoted by several German companies (Market Operator, TSO and DSOs) and supported by the German Federal Ministry of Economic Affairs and Energy enjoying a regulatory sandbox. So far, Enera is running a pilot project to facilitate wind power integration in Northwest Germany reducing the cost of wind curtailment forced by grid conditions. In this platform, both TSOs and DSOs may buy flexibility services on an intraday horizon to solve grid congestions in pre-defined locations.

4.3.1.3. Incentives for energy losses reduction

The use of flexibility to support MV or LV grid operation mainly aims at solving potential or detected grid constraints and, in the long-term, defer or avoid new grid reinforcements. However, these functionalities will also affect technical network losses as a result of changes in the active and reactive power flows through the network. Therefore, it was deemed relevant to quantify such impact in the economic SRA presented in section 3. However, the financial exposure of DSOs to changes in network losses depends on the regulatory framework. DSO regulation, particularly after the implementation of incentive-based regulation schemes, frequently presents ad-hoc incentive mechanisms to encourage DSOs to reduce network losses.

Thus, the first question on this topic affecting replicability is whether adequate economic incentives to reduce network losses are in place in each country and whether these incentives are strong enough. Across the countries analysed, it can be seen that this type of incentives is widespread, being loss reductions generally valued at wholesale market prices. Nonetheless, wide deadbands, tight caps/floors on the value of the incentive or valuing losses well below market prices may dilute its power. The situation in the relevant countries is as follows:

[23] https://picloflex.com/

[24] Despite the fact that distribution companies in the UK are referred to as DNOs (Distribution Network Operators), the term DSO is used for the sake of consistency and in line with EU terminology.

[25] https://www.ukpowernetworks.co.uk/internet/en/have-your-say/listening-to-our-connections-customers/flexibility-services.HTML

[26] https://www.spenergynetworks.co.uk/pages/flexibility.aspx

[27] https://www.flexiblepower.co.uk/

[28] https://projekt-enera.de/

- **Portugal:** a symmetric bonus-malus scheme with a deadband around the reference value is in place. The value of this incentive is also subject to a cap and floor values. The regulator sets for every year within a regulatory period the economic value of losses, the reference level and the cap/floor values. In the period 2018-2020, the value of losses was set to a third of the annual average price in the day-ahead market.
- **Slovenia:** the DSO has to compensate actual network losses by purchasing the corresponding amount of electricity. However, DSO allowed revenues only recover a certain amount of pre-defined allowed losses, expressed as a share of the energy distributed annually. Thus, DSOs see an incentive to reduce network losses, under which these are valued at market prices.
- **Sweden:** DSOs have to purchase the energy necessary to cover actual losses. The cost of this energy is added to the allowed revenue. In addition to this, there are incentives to reduce losses through norm costs determined by comparison with other electricity grid companies depending on customer density.
- **Spain:** Spanish DSOs are encouraged to reduce network losses by an incentive scheme that is added on top of their base allowed revenues. The design of this mechanism has been recently modified as described in Article 24 of Circular 6/2019 from the regulator. According to this scheme, DSOs whose level of losses are above standard loss factors, set in the regulation and common to all DSOs, would have to pay a penalty, whereas those DSOs performing better than this standard value would receive an incentive. The amount paid or perceived by each DSO would depend on their own historical evolution; being the incentive (penalty) larger for those DSOs whose own losses decrease (increase) over time and vice versa. The incentive is designed in such a way that the amount of money paid by all the DSOs that are penalized is generally equal to the amount paid to all the DSOs that receive an incentive. The total value of the individual incentive or penalty is capped by the NRA to ±5% of the base allowed revenues of each DSO.
- **Austria:** the cost of energy losses is part of the TOTEX used in regulatory benchmarking in which they are compared to other DSOs in the country. Hence, DSOs have an incentive to reduce losses, as their benchmarking score will otherwise be distorted. Losses are bought via the electricity TSO for all electricity DSOs in a competitive manner on power exchanges or OTC markets.
- **UK:** DSOs are not directly incentivised to reduce losses through a financial mechanism as in other countries, because the quality of available data is deemed too poor. Instead, this topic is controlled through monitoring and reporting obligations set on the DSOs as well as mandating them to justify in their forward-looking investment plans the measures that they plan to implement in order to reduce network losses, adequately justified with CBA calculations. Moreover, DSOs may be awarded a discretionary reward by the regulator if they prove they carried out exceptional and innovative measures to reduce network losses. In the future, as smart metering improves the quality of data available, loss reduction incentive mechanisms may be reintroduced.
- **Italy:** the mechanisms to promote loss reduction is similar to those in Slovenia or Sweden, i.e. DSOs have to purchase actual losses, whereas their allowed revenues only cover a pre-defined reference level.

However, the existence of this type of incentives is not enough to support the clusters 1 and 2. Reference levels of losses, sometimes referred to in regulation as target levels or allowed level of losses, do not generally account for the impact of DER as they are usually based on historical values or cross-industry benchmarks. However, the impact of DER may not be adequately reflected in past values nor affect equally all DSOs. This can be either beneficial or detrimental to the DSO, but in any case, outside of their control. Therefore, another relevant question to pose is whether the impact of DER and smart grid solutions considered when setting baseline/target levels for losses. The approach followed in different countries is as follows:

- **Portugal:** the reference level of losses is set by the regulator, supposedly based on the national climate change mitigation plan. In practice, the reference percentage value for losses (shown as "*Perdas"* in Figure 41) has remained constant in the last ten years.

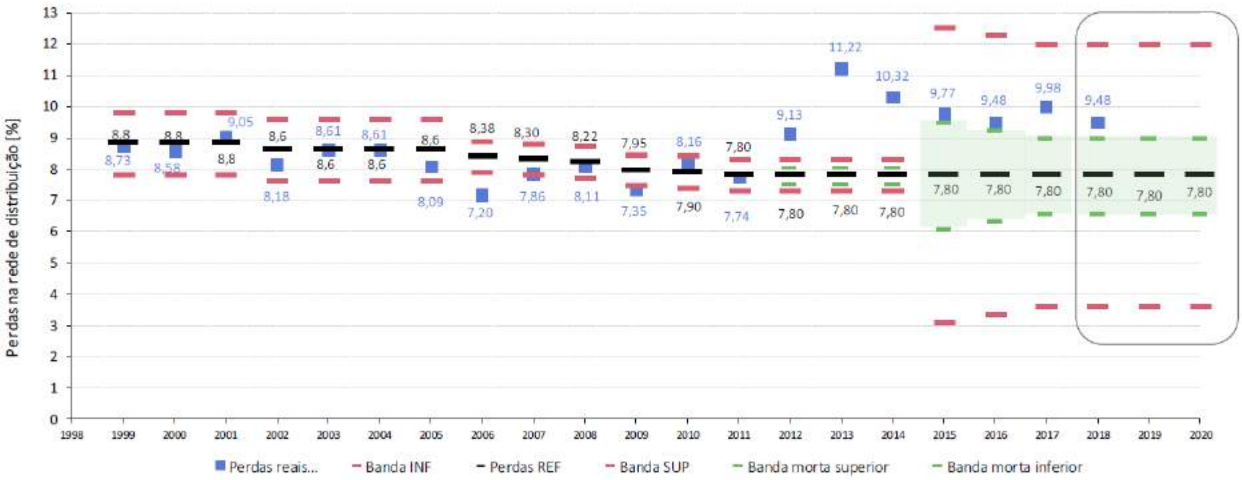


Figure 41: Evolution of distribution network losses in Portugal and the associated incentive scheme over 1998-2020. Source: (ERSE, 2019b)

- **Slovenia:** the allowed level of losses is determined every three-year regulatory period by the NRA based on the actual losses in the previous year and the expected reduction over the next period.

- **Sweden:** reference levels of losses are calculated individually for each DSO in such a way that they are encouraged to progressively decrease the losses compared to historical values. However, these norm losses are calculated by the regulator considering the density of customers of each DSO.

- **Spain:** actual losses of each DSO are compared against an industry wide standard, defined as a share of network losses different for each time period and voltage level as well as its own historical performance. Therefore, this approach does not consider differential aspects of the distribution area, although the energy injection in each DSO area is considered in the energy balance to compute grid losses.

- **Austria:** the cost of losses is used as an input variable in frontier benchmarking analyses. Thus, there is no reference level of losses as such. However, under this approach, the losses of each DSO are indirectly compared to those of the other DSOs included in the sample without necessarily considering whether differences in the cost of losses among DSOs is driven by exogenous factors (orography, DER penetration, etc.) rather than by inefficiencies.

- **Italy:** distinct reference values of losses are calculated for different load-density areas (high, medium or low concentration), but these are common to all DSOs. However, a DSO-specific correction is made in order to ensure that the incentive considers the actual operating conditions of the networks and avoids unjustified excessive rewards to DSOs[29]. This latter correction is non-symmetrical as it only reduces the incentives for those DSOs beating the reference values but does not reduce the penalties otherwise.

Ideally, DSOs should be subject to cost-reflective incentives to reduce losses where reference values reflect the conditions faced by each DSO, including the presence of DER and smart grid solutions. However, in practice, this may be very hard to achieve. In a context where the impact of DER and smart grid solutions on network losses is uncertain, a relatively weak incentive to reduce losses may be preferable over a strong incentive with wrongly set reference value that may unfairly penalize or reward some DSOs.

4.3.1.4. Regulated charges and retail tariffs

All the clusters analysed in this report require, in one way or another, changes in the normal behaviour of end consumers in order to provide grid support or participate in balancing services. Naturally, these changes in the consumption profile will have an impact on the electricity bill of these consumers, which depend on the design of the tariffs they have contracted. Additionally, this tariff can promote or hamper the adoption of HEMS or self-generation, which are key enablers for the provision of flexibility in cluster 2. In particular, it is relevant to analyse the level and structure of regulated charges (or taxes) as they can significantly distort other economic signals.

Furthermore, whilst this topic may be relevant to all types of consumers, it is particularly relevant to cluster 2, which affects residential consumers/prosumers, because LV consumers normally bear the highest share of the regulated costs[30]. Hence, the discussion will focus on this consumer segment.

The two key questions that need to be addressed are whether the structure of regulated charges promotes end-user flexibility, and what share of the final electricity bill corresponds to regulated charges and/or taxes[31]. Broadly speaking, flat charges without time discrimination tend to discourage flexible behaviour and the incentives of end users for adopting HEMS will be poor[32]. Likewise, large shares of regulated costs would weaken the price signals coming from energy prices or dynamic network tariffs.

On the other hand, these conditions may be deemed, in principle, favourable for the promotion of self-generation. High volumetric charges, for instance driven by high regulated costs included in this term, would

[29] As stablished in the document “Delibera 377/2015/R/eel” from ARERA.

[30] There are several reasons for this, such as:

1. Network costs are usually allocated in a cascading manner, thus being LV consumers made responsible for the costs of all voltage levels as well as the most numerous.
2. LV consumers are usually considered less elastic to price and therefore they are allocated the highest share of policy costs (Ramsey pricing).
3. According to EU legislation industrial consumers can be subject to exemptions from the payment of several policy costs (e.g. extra costs of RES) without this being considered unfair State aid.

[31] Although flexibility procurement could be enough to provide incentives for the adoption of the HEMS (explicit flexibility), in this analysis we also consider the incentives given by tariff price signals (implicit flexibility). As shown by the economic SRA, this may be the biggest benefit for the adoption of the HEMS.

[32] Whilst it may be acknowledged that economic savings are not necessarily the only driver for end-users to deploy HEMS, they are still relevant.

result in high benefits for prosumers, especially if net-metering is in place. However, this tariff design can be considered as an over-incentive for self-generation that ought to be avoided as it fails to appropriately reflect the underlying cost drivers, ultimately potentially leading to cross-subsidies and cost recovery problems (CEER, 2017a).

In order to assess the current status in the countries analysed, this section first reviews the weight regulated costs, particularly non-network related ones, and taxes have on the final bill of residential consumers. However, direct comparisons are usually hard to perform due to different legal definitions and data reporting across countries. For the sake of comparability, the data published by ACER in their annual retail market monitoring report has been used as reference. On average, in the year 2018, energy costs amounted to 37% of the total, network costs (transmission and distribution) to 25%, RES costs to 13%, and taxes to another 25%. Moreover, over the period 2012-2018, the weight of RES costs has doubled at the expense of network and energy costs. This reveals that the amount of regulated costs allocated to residential consumers has become quite a relevant topic in Europe.

Turning to the situation in individual countries, Figure 42 shows the cost breakdown of the electricity bill of residential consumers in capital cities in the year 2018 in Europe countries. It can be seen that the share of regulated costs and taxes in the final bill costs varies greatly across European countries, although in most of them these represent more than half of total costs[33].

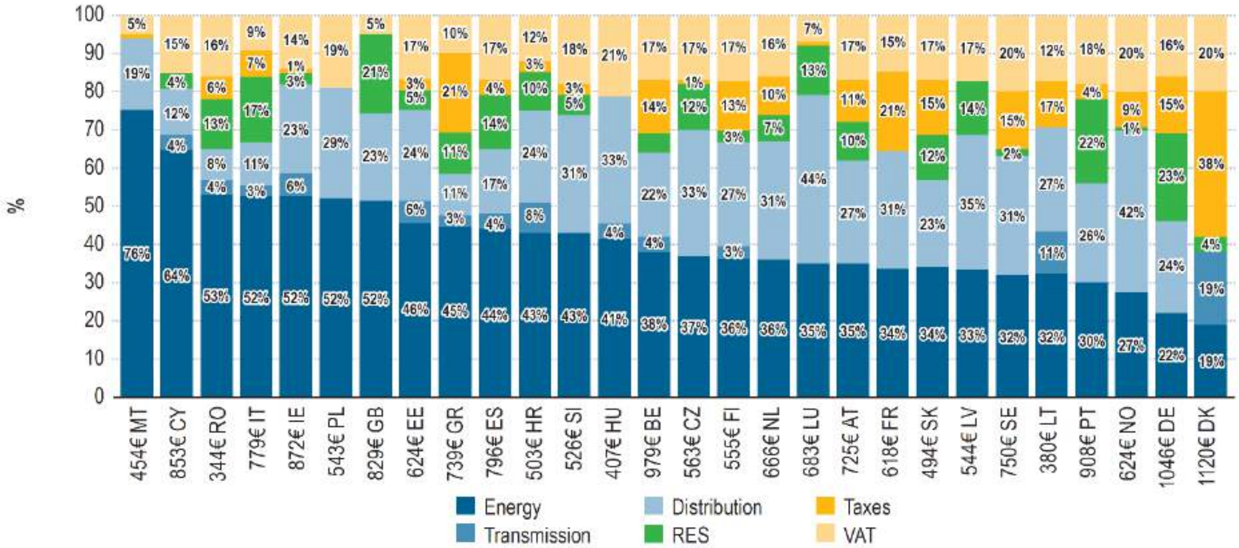


Figure 42: Breakdown of electricity tariff offers for residential consumers in capital cities. Source: (ACER, 2019)

Concerning the subset of countries selected for this analysis, a similar variability can be found as shown in Figure 43. The weight of regulated costs (network plus RES) ranges from 31% to 52% (in Italy/Belgium and France respectively) and, including taxes, non-energy costs amount to between 47% and 78% (Italy and Germany respectively).

[33] The countries where the weight of energy costs is the largest usually correspond to small insular systems with abnormally large marginal energy costs driven by their particular conditions (inability to exploit economies of scale, need for back-up generation due to the lack of interconnection, etc.).

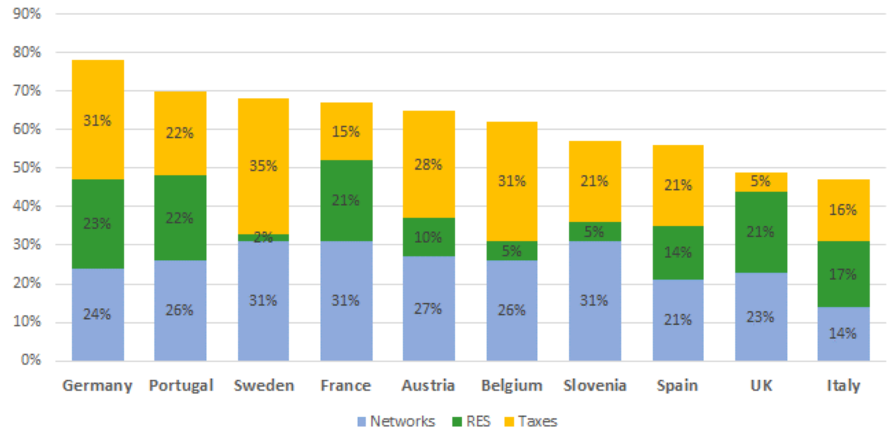


Figure 43: Share of taxes, network and other regulated costs in residential bills in selected countries.

The second relevant topic to consider is the structure of the regulated tariff, i.e. how these costs are passed-through to end users. The most common terms are:

- Energy charge (€/kWh): this term may present or not some form of time discrimination[34]. A high volumetric charge would encourage the adoption of self-generation; however, if this term does not present time discrimination, end-users would see little incentive to install HEMS for load management (or a storage system). Additionally, large volumetric charges may distort other efficiency signals from market prices or dynamic network rates. Likewise, large energy charges can be a barrier for new flexible technologies such as electric vehicles or heat pumps.

- Capacity charge (€/kW): this term may be charged based on a pre-defined amount such as a contracted capacity or based on the size of the fuse or based on a metered peak demand in a given period. Capacity charges may lower the incentives for self-generation as this usually implies a lower volumetric component. However, especially if they incorporate time discrimination, they may encourage the adoption of HEMS since end-users would have an incentive to manage their loads in order to reduce their peak consumption. On the other hand, high capacity charges can be a barrier for the adoption of EVs[35] or heat pumps too.

- Fixed charge (€/month): this term is independent of the consumption of end users although it may vary across consumer categories. In principle, fixed charges per se should not distort the response from end-users as they may be seen as a sunk cost. However, they may result in end-users perceiving little benefit from being flexible, as compared to their electricity bill, and thus opting out of such solutions.

It is not straightforward to gather comparable information about the structure of the overall regulated tariff due to several practical complexities, e.g. different definitions of consumer categories definition across countries, the responsibilities for the calculation of different regulated components may be allocated to different stakeholders (NRA, TSO, DSO, ministries, etc.), etc. Nonetheless, in order to obtain some indication

[34] Note that a ToU energy charge with becomes similar to a capacity charge as the length of the time blocks becomes smaller.

[35] Barriers to EVs may be reduced by introducing time discrimination in the capacity charges, e.g. to encourage night charging.

of how this structure may differ across countries, the structure of the distribution network tariff, shown in Figure 44, may be used as a reference[36].

It can be seen that, in most European countries, distribution costs are mostly charged through a volumetric component. The weight of the fixed or capacity-based components only exceeds 40% in three countries, two of which are within the InteGrid target countries, i.e. Sweden and Spain, whereas this value is 79% and 84% respectively. In the remaining countries of interest, three of them present values around 30% (Portugal, Italy and Slovenia), whereas in the remaining ones the value is below 20%.

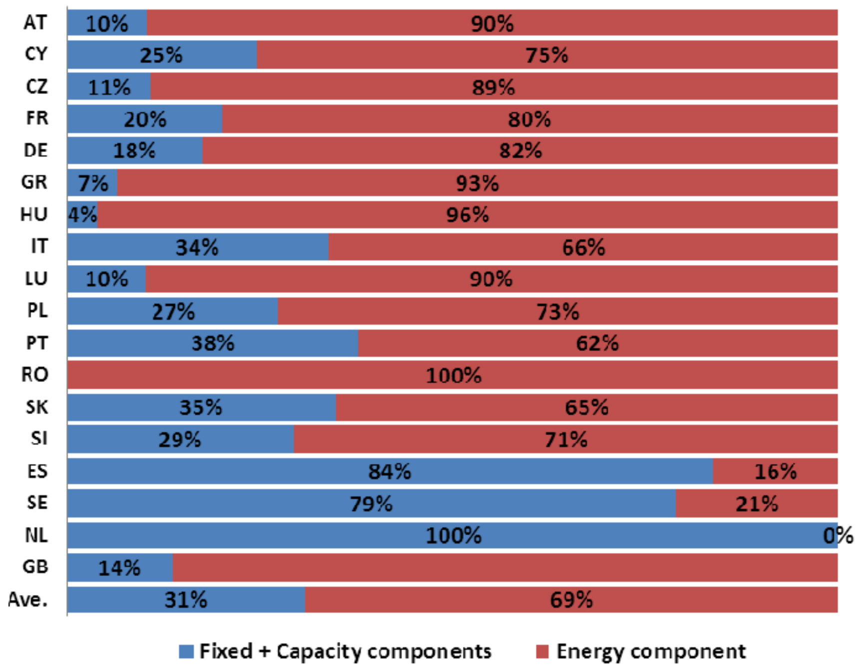


Figure 44: Weight of different distribution tariff components in European countries. Source: (REF-E et al., 2015)[37]

4.3.2. Clusters 3 and 4: Demand-side participation in balancing markets

In the context of the InteGrid project, demonstrations are mainly testing the use of flexibility by DSOs for grid management purpose, as discussed above for clusters 1 and 2. Nevertheless, the participation of demand-side response and other types of DER in balancing markets is also being researched in the InteGrid

[36] Distribution costs are largely fixed or dependent on the peak demand of end users rather than on the volume of energy distributed. Thus, countries where these costs are largely charged through a volumetric component may indicate that other regulated costs independent of the volume of energy consumption may also be charged in a similar fashion (and vice versa).

[37] Note that these values may have changed over the last few years as many countries are revisiting their tariff design methodologies, as smart meters and DER are being deployed at large scale.

project, mostly from the DER and aggregators' perspective. These solutions correspond to InteGrid HLUC10 and HLUC12, which in the context of the SRA are included within clusters 3 and 4.

As discussed in section 4.1, the participation of demand response in balancing markets may face several barriers as of today. Table 30 lists five relevant[38] regulatory barrier, namely:

- Lack of regulation for the coordination between TSO and DSO for the provision of ancillary services by DER
- Balancing markets not open to demand, included the one connected at distribution level, or balancing products not suited for demand-side resources
- Balancing market access and product definition not suited for DER (minimum sizes, design of deviation penalties, upwards/downwards allocated together, dual imbalance pricing)
- Barriers to the development of the aggregation activity
- Barriers to independent aggregation (e.g. balancing responsibility)

In order to check if these barriers exit in the analysed countries, the abovementioned barriers can be translated into different research questions, organized into three main blocks, namely balancing market design, aggregation and TSO-DSO coordination.

Firstly, the design of balancing markets is important in enabling the participation of demand response, both by explicitly allowing this participation, and by setting appropriate products and market rules for this kind of distributed energy resource. For cluster 3, we focus on the analysis of mFRR market design, while for cluster 4 the aFRR is the centre of the analysis.

Secondly, aggregation is analysed, as it is also at the core of cluster's 3 and 4 concepts. For cluster 3, we research aggregation on a broader sense, considering that in this cluster the retailer is aggregating demand response for participation in the aFRR market. For cluster 4 though, two additional concepts are also relevant. On one hand, the aggregation of multiple types of DER should be allowed, considering the VPP concept employed in this cluster. On the other hand, independent aggregation rules may also play an important role, as VPPs may be operated by independent agents.

Table 33 presents the guiding questions under each category, as well as the relevance for each cluster.

Table 33: Key regulatory question for demand participation in balancing markets.

Key regulatory questions for demand participation in balancing markets		Relevant Clusters
Balancing Market Design	Are balancing markets open for demand-response participation?	Cluster 3 and 4
	Are products and conditions suitable for demand/DER participation?	Cluster 3 and 4
Aggregation	Are there barriers for the aggregation of resources in balancing markets?	Cluster 3 and 4
	Is the independent aggregation allowed? Is it viable?	Cluster 3
	Is different type of DER aggregation (VPP concept) possible?	Cluster 3
TSO-DSO coordination	Is TSO-DSO coordination mature enough for DER to provide balancing services?	Cluster 3 and 4

[38] Graded as "2" or "3".

In order to answer the questions formulated in Table 33 for the ten analysed countries, information from different sources were considered. For the five InteGrid countries, questionnaire used for deliverables D1.3 and D7.1 were consulted. Nevertheless, updates were necessary in relation with these previous reports, as national regulations going through an adaptation period, due to the requirements brought by the Clean Energy Package. This is the case in Portugal, for instance, where a pilot project has been testing the participation of the demand in balancing markets (ERSE, 2018), and in Spain, where a very recent regulation changes the balancing provision rules in order to allow the participation of demand and storage sources[39].

For the five additional countries, information was gathered mainly from reports and surveys from recognized European institutions. Regarding balancing markets, three main report were used, namely the "Survey on Ancillary Services Procurement, Balancing Market Design 2018" from ENTSO-E (ENTSO-E, 2019b), the "smartEn Map: European Balancing Markets Editions" (Smart Energy Europe, 2018), and the "Demand Response status in EU Member States" (Bertoldi et al., 2016).

4.3.2.1. Balancing market design

In cluster 3, the key concept is the aggregation of large consumers through the cVPP concept. The cVPP is then expected to provide the aggregated flexibility into the TSO's markets. In the case of InteGrid, the main market being considered is the tertiary regulation market, or more specifically, the manual frequency restoration reserve (mFRR), according to the European network codes.

On one hand, this balancing product can be considered a liquid and well-implemented product in most countries, and therefore suitable for possible participation of DER. Other types of balancing products may have additional challenges. The FCR, or frequency containment reserve, is the fastest type of reserve, and therefore critical for the system. For this reason, several countries do not trade this service in an organized market, but rather consider it as a mandatory service for generation units able to provide it. The automatic frequency restoration reserve (aFRR) is the second reserve to be activated. It is a fast reserve, and therefore units have to comply with more complex requirements to be prequalified for the provision of this service. Despite the increased complexity, this product is being addressed in cluster 4. Finally, the replacement reserve (RR) product, intended to serve as a replacement for the mFRR, is not in place in all countries. Therefore, it is not considered in this regulatory replicability analysis. Therefore, the focus of this section will be placed on the design of balancing markets for the provision of aFRR and mFRR products.

As of today, balancing markets across Europe are not harmonized, and therefore, specificities in every country matter in terms of replicability. Nevertheless, a harmonization effort is taking place as consequence of the implementation of the Network Codes and Guidelines. The Electricity Balancing Guideline (EBGL) calls for standardization of balancing products to a certain extent. The main goal of the EB GL is to reach an integration of balancing markets across Europe. Within the scope of the EB GL are the pan-European balancing platforms that will trade the balancing products across borders, namely the PICASSO (for aFRR trading), the MARI (mFRR), and TERRE (RR) (ENTSO-E, 2019a). It is important to note though, that the standardization proposed by the EB GL does not aim to be complete, but rather sufficient to allow cross-

[39] Resolution from 11 of December of 2019 from the CNMC. In Spanish: Resolución de 11 de diciembre de 2019, de la Comisión Nacional de los Mercados y la Competencia.

country of the different balancing markets. In practice, balancing markets will still differ among countries, and therefore, this regulatory replicability analysis is still relevant for the future scenario in which the EBGL will be fully implemented.

In addition to the definition of product harmonization, the EBGL also provides additional instructions on market design aspects that are relevant for the replicability of clusters 3 and 4. More precisely, the EBGL provides important guidelines for the participation of resources connected to the distribution grid in balancing markets. Schittekatte et al. (2019) shows that the in recital (8) of the EBGL calls for a level-playing field for all market participants, including demand-response aggregators and assets connected to the distribution grid in the provision of balancing services. These two are precisely the two key open questions regarding the balancing market design affecting the replicability of clusters 3 and 4, namely:

- Are balancing markets open for demand-response participation?
- Are balancing products and conditions suitable for demand/DER participation?

The review of the current situation in the abovementioned countries shows that some relevant steps have been taken in order to adapt national balancing markets. However, it is also revealed that further efforts would be required to ensure a level playing field for all potential participants in these markets. This review shows that simply enabling DER and demand response to participate is not enough unless additional requirements are market conditions change as well. On the ensuing, a summary of the current situation in these countries is provided:

- **Portugal:** balancing markets are not yet open for demand-response participation (Smart Energy Europe, 2018). As of today, FCR[40] is a mandatory and non-remunerated product, and must be provided by agents connected at the transmission network only (ERSE, 2019a). For the aFRR, the market is, in principle, open to all prequalified agents. Nevertheless, the prequalification process involves the testing of generation capabilities. Even more importantly, participating units have to provide both upwards and downwards bids. These bids do not have to be exactly the same, but they have to respect a certain ratio established by the system operator. These conditions make the participation of demand-response, in practice, not possible. Regarding the tertiary regulation, or the mFRR in the terms of the EBGL, the Portuguese regulation also impose restrictions to the participation of the distributed-connected resources. Among the requirements for an agent to provide tertiary regulation, two are especially restrictive namely the necessity for being a generator and being connected to the transmission grid (ERSE, 2019a).

  Despite the lack of an already open balancing market for the participation of demand response, important initiatives are ongoing in Portugal that may enable the participation of distributed resources in the near future. The first and more predictable is the implementation of the EBGL. But besides that, the Portuguese regulator started in 2019 a pilot project for the participation of large demand response in the tertiary reserve market (Diretiva n.º 4/2019. Aprovação das Regras do Projeto-Piloto de participação do consumo no mercado de reserva de regulação, 2019). In this Pilot Project, the abovementioned constraints for demand participation are relaxed for the participating

[40] In Portugal, the current framework still treats the balancing services as primary, secondary and reserve regulation. For the sake of simplicity, we assume the primary regulation as equivalent to the EBGL's FCR, the secondary as the aFRR and the reserve regulation as the mFRR.

agents. The offers are submitted only for downwards reserves and are non-mandatory (differently than the mandatory bids in the case of generation). This project is still on-going, as it was set to last for one period. By the end of the project, a report stating the results of the project will be published by the regulatory authority ERSE[41].

It is important to notice though, that participants on this pilot project must bid over 1MW, and therefore it is aimed at large consumers. Aggregation is not permitted in this pilot, although it is expected to be allowed in future balancing markets, based on a recently published regulation[42]. Therefore, this pilot project is a step forward towards the implementation of cluster 3, but it would not allow fully using the cVPP concept.

Table 34: DR participation in balancing - Portugal on a nutshell.

	*Demand-response participation in balancing provision is still not possible. A pilot project is testing the participation of large consumers in the tertiary reserve market. Aggregation is not allowed in this pilot though.*

- **Slovenia:** in principle, load is able to provide balancing services. According to the last survey on ancillary services published by ENTSO-E, Slovenian loads use the same market mechanisms as others participants (ENTSO-E, 2019b). Regarding the services that demand resources can provide, the survey mentions that only the mFRR is applicable for this type of agent. FCR is only open to generators, while aFRR is open to generators and pump storage units. In fact, in Slovenia the TSO already procures mFRR bilaterally from industrial consumers (Smart Energy Europe, 2018)[43].

  Despite the fact that the Slovenian balancing market is somehow open to the participation of demand-response, the smartEn (2018) report is sceptical about the potential and openness of balancing markets for load participation. On one hand, the Slovenian balancing market is said to be limited for the participation of several types of resources. In fact, the contracted reserves are rather small, summing up +-60MW for aFRR in 2015, and +348 MW and -180 MW for mFRR for the same year [REF D1.3]. DER account for roughly 10% and 6% of these for upward and downward mFRR, respectively. However, these resources are rarely activated (Smart Energy Europe, 2018). On the other hand, the participation of DER is bilaterally contracted, and therefore suffers from lack of transparency. In this context, the Slovenia balancing services seem to be open for demand-side participation and the Slovenian TSO seem to proactively look for the participation of these resources. Nevertheless, questions on the (1) transparency of the mechanism, and (2) the possibility for a business model for demand participation in balancing markets, given the size and concentration of the market, remain open.

[41] Considering the time-line for the end of the project, results will be available before the end of the regulatory analysis in InteGrid. Therefore, results on this pilot project are expected to be discussed in deliverable D7.1.

[42] Decreto-Lei n.º 162/2019

[43] The reader may notice that the smartEn report mentions that aFRR is procured bilaterally by the TSO from industrial consumers. This information however is divergent from the ENTSO-E survey and also from the field experience in InteGrid. Within the stakeholder consultation, industrial consumers providing balancing to the TSO were interviewed, and they were clearly providing a manually activated reserve.

Table 35: DR participation in balancing - Slovenia on a nutshell.

	*Participation of demand in mFRR is possible and currently done in Slovenia. Nevertheless, load resources are contracted bilaterally by the TSO, on non-transparent basis. Additionally, the market seems to be small and concentrated, which poses challenges for the deployment of clusters 3, and especially 4.*

- **Sweden:** the Swedish regulatory framework is very much linked with the ones in Norway, Finland, and Denmark, as the Nordic countries share a single market and regulation (despite having different TSOs). In principle, in the Nordics allow the participation of demand response in ancillary service markets. Nevertheless, roles and responsibilities are not well defined, and retailers (the ones that can aggregate demand response and offer in balancing markets) have to incur relatively high costs in providing balancing (Bertoldi et al., 2016).

  Besides the lack of regulatory definition and the high costs for retailers to participate, other practical aspects of the balancing markets in Sweden may create additional barriers for the participation of demand response as of today. In Sweden, most of balancing services are provided by hydro generation, cheap and very flexible resource for this kind of product. This, however, may change in the future in favour of DR balancing opportunities, as more inflexible generation (such as wind) is being installed in Sweden. Additionally, demand response can contribute to alleviate north-to-south congestions. As of today, most of hydro generation is located in the north of the country, while the important urban centres are in the south, creating pricing differences between the five bidding zones in Sweden due to the limited transmission capacity. In this context, distributed-connected resources may become an important tool for balancing the system, as they are connected within, or very close to load centres.

Table 36: DR participation in balancing - Sweden on a nutshell.

	*In principle, all balancing services are open for demand-side participation. In practice, participation is still rather limited. Demand agents have to participate through retailers, which incur in important costs and face uncertain rules. Market conditions are also challenging, as balancing is mainly provided by the abundant hydro generation.*

- **Austria:** demand response and aggregation have progressively been accepted in balancing markets, starting in the year 2013. At the time, demand response was expected to bring balancing prices down. Although Austria had significant over installed capacity, prices in balancing markets were considered high (Bertoldi et al., 2016). Therefore, in theory, demand response can participate in all balancing markets, as long as they fulfil the prequalification process (Smart Energy Europe, 2018). In practice though, the prequalification process is still complex and imposes several limitations for certain types of demand response participation. Starting with FCR, this product has to be offered in a symmetrical way, and therefore is limited to generation. For aFRR, procured in weekly tenders, the minimum bid size is 1 MW. However, polling is allowed, provided that individual consumers maintain a communication (phone contact) with the TSO. Bertoldi et al. (2016) argues that this requirement alone excludes residential consumers from participation, together with the requirement of 4-hour activation block, in the case of mFRR provision. On the prequalification process, balancing service providers (BSPs) can perform the tests on a centralized way, but they need to measure and store data on individual users/consumers.

Despite the complex prequalification process and limiting conditions on product definition, the Austrian regulation is clearly proactive in trying to include demand-connected resources in balancing services provision. The network charges, for instance, are differentiated in case of balancing provision, being charged at a lower rate by DSOs. Also, consumers are not penalized for changing their consumption profile when providing demand response (Bertoldi et al., 2016). Moreover, Austria is actively participating in the implementation of the PICASSO and MARI platforms, which may help foster the inclusion of demand response in balancing markets not only in Austria, but also in other Member States.

Table 37: DR participation in balancing - Austria on a nutshell.

	*Austria is proactive country in opening balancing markets to demand response participation. Nevertheless, a lengthy and complex prequalification process, together with limiting conditions on their product definitions still represent a barrier for DR balancing provision.*

- **Spain:** until very recently, Spain could be considered a country closed for DR participation in balancing markets. The only exception was the “interruptible contract”, in which the TSO tenders a certain flexible capacity from large industrial consumers [REF D1.3]. The TSO then can use this flexibility when needed, also for balancing purposes. Regarding the actual balancing markets, FCR was always a mandatory and not remunerated service. The aFRR was traded in both capacity and energy auctions, but symmetrical bids were mandatory, excluding demand participation therefore. The mFRR equivalent (tertiary control) was not open to demand response, and was mandatory for all generators to bid in this capacity market.

These characteristics however are going through important changes at the time of writing this regulatory replicability analysis. In December 2019, a new resolution was approved by the regulatory authority as consequence of the directives established by the EBGL. The Resolution 18423/2019 now recognizes four types of balancing providers, namely generation units, demand agents, units with storage, and representative of the former three types (in other words, aggregators). Minimum bid is set to be 1MW, and the resolution also establishes that the prequalification requirements for demand response, aggregation and storage will be set in future regulation (Resolución 18423 de 11 de diciembre de 2019, de la Comisión Nacional de los Mercados y la Competencia, 2019).

Table 38: DR participation in balancing - Spain on a nutshell.

	*Until very recently, Spain did not allow the participation of demand response in balancing provision, with the exception of the “interruptible contract” product for industrial consumers. This is going through a complete change however, as Spain just approved a new regulation mandating the possibility for DR, storage and aggregation to be able to provide balancing services.*

- **Belgium:** Belgian balancing markets are friendly towards demand response, according to the smartEn report (2018). In this country, primary and tertiary balancing products are open for demand participation (FCR and mFRR). Even the fast FCR do not impose limitations to demand response participation, although its participation is still limited in practice. The aFRR is not open yet to demand response though, but it is going through changes in the regulation. A new market design is expected to be implemented in 2020, in which a level playing field will be pursued in this product. The mFRR is already open to demand response participation. Minimum bid size is 1MW, but aggregation is allowed, and therefore this requirement is not restrictive for DR participation. Nevertheless, only resources at the MV can participate, and this could be a barrier for cluster 4[44].

  Nevertheless, the openness of balancing markets for demand response in Belgium is noticeable, and can be seen through the participation of load units in the existing markets. For every product, the regulatory authority sets the maximum allowed capacity that can be procured from demand. Every year, this limit has been reached (Bertoldi et al., 2016).

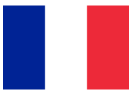
Table 39: DR participation in balancing - Belgium on a nutshell.

	*Belgium can be considered an open market for demand response participation. Some restrictions still exist however, like the aFRR market design – still not open for demand – and limitations for LV consumer participation.*

- **France:** this can be considered a very open country for demand response participation in balancing markets. The FCR market (weekly auctions) is open for demand response, and its participation can already be observed. Around 70 out 570 MW are provided by demand response in the FCR market (Bertoldi et al., 2016). The aFRR market though, is not open to demand response. This product is limited to large generators, which are obliged to provide this service. Nevertheless, this may change with the implementation of the PICASSO platform. The mFRR, on the contrary is open to demand participation with high participation of demand response. Close to half of the mFRR is provided by DR (Smart Energy Europe, 2018).

  Apart from the regular balancing markets, France also has a specific tender only for DR provision of flexibility, destined for balancing purposes as well. The AOE (in French “Appel d’Offres Effacement) offers capacity payments for DR for the contracted periods. Currently there 730 MW participating in the program and half of this capacity is destined to mFRR provision. This programme is open to all voltage levels and it is the main source of revenue for DR in France (Smart Energy Europe, 2018).

Table 40: DR participation in balancing - France on a nutshell.

	*French balancing markets are welcoming to demand response participation. Both FCR and mFRR markets have relevant DR participation, and a dedicated programme is placed to procure DR flexibility for balancing purposes – the AOE. Nevertheless, the aFRR is still closed for demand participation.*

[44] Cluster 4 considers the participation of commercial buildings in the secondary reserve market. Therefore, compatibility of cluster 4 in Belgium from the balancing market design perspective may depend on the voltage level in which the consumer is connected, provided that aFRR is open for DR.

- **Germany:** Germany has recently undergone a major regulatory review on several aspects, including demand response integration. A major market revision was approved in 2018, leading to higher integration of DR in markets such as balancing. Before that, the market regulation in Germany created significant barriers for DR provision of balancing services. For instance, DR could incur in high grid costs for deviation when providing secondary reserve. Also, units would have to be available to be dispatched for up to 12 hours (Bertoldi et al., 2016).

  After the market revision, DR became eligible to participate in the provision of FCR, aFRR and mFRR. The three products are procured in daily auctions of six four-hour blocks. The minimum bid size is 1MW for most cases, and pooling is allowed. There are not limitations for technologies[45], as long as they can go through the prequalification process, including low voltage connected resources. The prequalification process though, still misses some further developments (Bertoldi et al., 2016).

Table 41: DR participation in balancing - Germany on a nutshell.

	*Germany has just gone through a major regulatory revision that will benefit the participation of DR in balancing markets. In principle, the market is open but some aspects are still being implemented, such as definitions in the prequalification process.*

- **UK:** the British market is considered to be one of the first in Europe to initiate the process of integration of demand response in electricity markets. However, this process seemed to have lost momentum, and DR the possibility of balancing participation in balancing provision is mixed for the different products (Bertoldi et al., 2016; Smart Energy Europe, 2018). Additionally, balancing products in Great Britain are still very different from the ENTSO-E classification, and are procured by the British SO on pay-as-bid tenders and bilateral deals.

  Considering the several different balancing services in Great Britain, in principle DR can participate in most of them. However, product definitions and other market rules imposes barriers for participation. For instance, the equivalent of the aFRR[46] has a minimum bid size of 50 MW, representing a barrier even for aggregated demand. The mFRR equivalent has lower minimum bid size (3 MW), but is very complex for participation, and tenders are not all equal. A prove of that is the low participation of demand response in the provision of this services. Only 0.01% of the volume comes from DR, according to recent data (Bertoldi et al., 2016). From all products, the FCR seems to be the most open to DR participation. Minimum bid size is 1MW, delivered in four-hour blocks. All technologies are allowed, provided that they fulfil the technical requirements of the product.

Table 42: DR participation in balancing – Great Britain on a nutshell.

	*The British balancing market was one of the first to be open to demand response in Europe. However, this process was not fully completed yet, certain product definitions still impose important barriers for the participation of load units.*

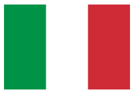
- **Italy:** it may be considered a virtually closed market for demand response participation in balancing provision. Several pilot projects are in place, but as of today, only the mFRR equivalent product is

[45] Some exceptions may exist. RES cannot be aggregated in the aFRR market for instance.

[46] Called Fast Reserve

open demand through aggregation. The FCR is not procured through a market, but is mandatory provision for generation plants with installed capacity of 10 MW or higher. aFRR is also closed to distributed connected resources and demand. The mFRR equivalent is traded on a market fashion, and is under a pilot-project that actually covers the whole tertiary reserve provision (Bertoldi et al., 2016). The participation of demand response in the tertiary reserve is allowed for demand response, under the condition that they have hourly metering. All consumers above 55kW comply with this condition, but consumers at the LV are still having the new second-generation smart meters installed.

Table 43: DR participation in balancing – Italy on a nutshell.

	*Italy is closed to demand response participation in balancing markets. Primary and secondary reserves are not traded in organized markets, and the tertiary reserve, although open to DR, is under a pilot-project, and is expected to evolve into a future stable regulation.*

Besides the general openness of the different balancing markets for the participation of demand response, another important aspect is how suitable the products and market rules are for the participation of demand response. Several of these aspects were already mentioned in the country analysis above. Nevertheless, we make an assessment of the different products and market characteristics, and some conclusions of their implications for the replicability of clusters 3 and 4.

The information presented in the following tables were extracted from the ENTSO-E's "Survey on ancillary services procurement and balancing market design 2018" (ENTSO-E, 2019b). Therefore, some methodological aspects should be considered. According to ENTSO-E, this survey captures concepts on a high-level, and fail to provide details on the different products. Additionally, not all countries use the same concepts for the same market characteristics, and therefore an approximation is made to fit products and services into a single nomenclature. Finally, this survey describes the state of the market in 2018, and therefore recent changes could not be reflected in this survey's results. Whenever any data has been updated by the authors of this deliverable, with respect to the original survey results, this will be acknowledged. Despite possible imprecisions included in the data, this survey provides an illustrative overview of the design of products and markets.

- **aFRR**: The procurement of aFRR can be done either in terms of capacity, energy or both. Considering that this product is usually activated in a short time frame (1 to 15min), the procurement of capacity and energy is the most common procurement scheme. Nevertheless, important differences exist on the way the capacity and the energy are procured. For several countries, the provision of the service is mandatory. This mandatory provision is usually restricted to large generation units, and often represents a barrier for the participation of DR. For other countries, a hybrid approach is mentioned. Those with a "market only" approach would be the most suitable for the replicability of Cluster 4.

Table 44: aFRR Procurement Scheme. Source: (ENTSO-E, 2019b)

Country	*aFRR Capacity Procurement*	*aFRR Energy Procurement*
Austria	Market only	Market only
Belgium	Market only	Market only
France	Hybrid	**Mandatory only**
Germany	Market only	Market only
Italy	**N/A**	Hybrid
Portugal	Market only	Market only[47]
Slovenia	Hybrid	Hybrid
Spain	Market only	Market only
Sweden	Market only	N/A
GB/United Kingdom	N/A	N/A

Another important characteristic of this product is the form in which it is priced. First and foremost, it is essential that non-symmetrical bidding is in place for the participation of demand response. On a symmetrical product, both upwards and downwards bids must be submitted, imposing a clear barrier for Cluster 4, in which demand only is being aggregated, and therefore no upward regulation can be offered. In addition to bidding symmetry, the form in which the product is prices and settled is also relevant. They could be pay-as-bid, marginal pricing (also known as pay-as-clear), or regulated prices.

Table 45: aFRR Bid Symmetry and Settlement Rules. Source: (ENTSO-E, 2019b)

Country	*aFRR Capacity Symmetry*	*aFRR Capacity Settlement*	*aFRR Energy Settlement*
Austria	Don't need to be symmetrical	Pay as bid	Pay as bid
Belgium	Don't need to be symmetrical	Pay as bid	Pay as bid
France	Don't need to be symmetrical	Regulated Price	N/A
Germany	Don't need to be symmetrical	Pay as bid	Pay as bid

[47] This information has also been changed with regards to the ENTSO-E survey, that showed “N/A”.

Italy	N/A	N/A	Pay as bid
Portugal	Don't need to be symmetrical[48]	Marginal Pricing	Marginal Pricing
Slovenia	**Has to be symmetrical**	Pay as bid	Pay as bid
Spain	Don't need to be symmetrical[49]	Marginal Pricing	Marginal Pricing
Sweden	Don't need to be symmetrical	Pay as bid	Marginal Pricing
GB/United Kingdom	N/A	N/A	N/A

Finally, another important characteristic to is the technical requirement for provision. The need for real-time monitoring may impose a technical challenge to balance suppliers, as they may have to comply with expensive ITC requirements. Moreover, the Full Activation Time (FAT)[50], may be more difficult to implement in countries with faster products (FAT < 5min).

Table 46: aFRR Bid Symmetry and Settlement Rules. Source: (ENTSO-E, 2019b)

Country	***aFRR Capacity Monitoring***	***aFRR Capacity Monitoring***	***aFRR FAT***
Austria	Ex-Post Check	Ex-Post Check	**90s < x <= 5 min**
Belgium	Ex-Post Check	Ex-Post Check	5min < x <= 15 min
France	Hybrid	Hybrid	5min < x <= 15 min
Germany	**Real-Time Monitoring**	**Real-Time Monitoring**	**90s < x <= 5 min**
Italy	N/A	**Real-Time Monitoring**	5min < x <= 15 min
Portugal	Hybrid	Hybrid	**90s < x <= 5 min**
Slovenia	**Real-Time Monitoring**	**Real-Time Monitoring**	5min < x <= 15 min
Spain	**Real-Time Monitoring**	**Real-Time Monitoring**	**90s < x <= 5 min**
Sweden	Hybrid	Hybrid	**90s < x <= 5 min**
GB/United Kingdom	N/A	N/A	N/A

[48] Does not have to be symmetrical, but have to respect a certain ratio

[49] Does not have to be symmetrical, but have to respect a certain ratio.

[50] The FAT is the maximum time for the balancing unit to go from zero provision (up or downwards) to the full dispatched balance power.

- **mFRR**: If the characteristics of aFRR may have an impact in the way cluster 4 is designed, the same characteristics for mFRR will impact the replicability of cluster 3. However, some characteristics may not represent as big of a challenge as for cluster 4. For instance, mFRR is in general a slower product (longer FAT), and monitoring requirements may not be as strict.

Table 47: mFRR Procurement Scheme. Source: (ENTSO-E, 2019b)

Country	*mFRR Capacity Procurement*	*mFRR Energy Procurement*
Austria	Market only	Market only
Belgium	Market only	Market only
France	Market only	Market only
Germany	Market only	Market only
Italy	**N/A**	Hybrid
Portugal	**N/A**[51]	**Mandatory only**
Slovenia	Hybrid	Hybrid
Spain	**Mandatory only**	Market only
Sweden	Market only	Market only
GB/United Kingdom	Market only	Market only

In general, the procurement of mFRR capacity (when applicable) and energy are market-driven for the analysed countries. Regarding bid symmetry, all countries reported that non-symmetrical bids are accepted, which is a positive characteristic considering the compatibility with cluster 4.

Table 48: mFRR Bid Symmetry and Settlement Rules. Source: (ENTSO-E, 2019b)

Country	*mFRR Capacity Symmetry*	*mFRR Capacity Settlement*	*mFRR Energy Settlement*
Austria	Don't need to be symmetrical	Pay as bid	Pay as bid
Belgium	Don't need to be symmetrical	Pay as bid	Pay as bid
France	Don't need to be symmetrical	Marginal Pricing	Pay as bid
Germany	Don't need to be symmetrical	Pay as bid	Pay as bid

[51] The ENTSO-E survey shows "market only" for capacity procurement of mFRR in Portugal. Therefore, this value was changed from the one in the survey, considering that no mFRR capacity is procured as of today.

Italy	N/A	N/A	N/A
Portugal	N/A	N/A	Marginal Pricing
Slovenia	Don't need to be symmetrical	Pay as bid	Pay as bid
Spain	N/A	N/A	Marginal Pricing
Sweden	Don't need to be symmetrical	Pay as bid	Marginal Pricing
GB/United Kingdom	Don't need to be symmetrical	Pay as bid	Pay as bid

The technical requirements for the provision of mFRR also seem less challenging than aFRR. Only Germany and Sweden reported the need for real-time monitoring. The FAT for all countries is higher than 5 minutes.

Table 49: mFRR Bid Symmetry and Settlement Rules. Source: (ENTSO-E, 2019b)

Country	***mFRR Capacity Monitoring***	***mFRR Capacity Monitoring***	***mFRR FAT***
Austria	Ex-Post Check	Ex-Post Check	5min < x <= 15 min
Belgium	Ex-Post Check	Ex-Post Check	5min < x <= 15 min
France	Ex-Post Check	Ex-Post Check	5min < x <= 15 min
Germany	**Real-Time Monitoring**	**Real-Time Monitoring**	5min < x <= 15 min
Italy	N/A	N/A	5min < x <= 15 min
Portugal	N/A	Hybrid	Depends on the unit
Slovenia	Ex-Post Check	Ex-Post Check	5min < x <= 15 min
Spain	Ex-Post Check	Hybrid	5min < x <= 15 min
Sweden	Hybrid	**Real-Time Monitoring**	5min < x <= 15 min
GB/United Kingdom	Hybrid	Hybrid	Depends on the unit

4.3.2.2. Aggregation rules

The regulatory compatibility of clusters 3 and 4 is mainly determined by two regulatory conditions. Firstly, balancing markets must be open and welcoming for demand response to provide its flexibility, as discussed in the previous section. Secondly, aggregation must be allowed, considering that in both cluster 3 and 4, demand response is aggregated and then offered in balancing markets. Cluster 4 explores the idea of retailers that can aggregate the flexibility from their customers and offer in specific balancing markets. More specifically, cluster 4 focuses on the aggregation of commercial buildings and offering their flexibility in the aFRR market. In this context, for cluster 4 to be compatible in the different countries, aggregation of resources must be allowed in the different balancing markets. In this section, we do not limit the analysis to aFRR, but also explore other products, expanding the scope of the cluster from the regulatory perspective.

The replicability of cluster 3 depends on characteristics even beyond the ones of cluster 4. Considering this cluster is based on the VPP concept, two additional challenges arise. Firstly, aggregation of different types of distributed resources must be allowed so the concept of the virtual power plant can be deployed. Additionally, enabling the development of independent aggregation through suitable regulatory conditions is deemed a relevant topic, particularly for cluster 3. The reason for this is that VPP operators could facilitate opening the market to new participants exploring innovative business models not necessarily constrained by the conventional retail business model, including independent aggregation.

The independent aggregator is a new agent defined by the Clean Energy Package (CEP) as a "market participant engaged in aggregation who is not affiliated to the customer's supplier" (CEP Electricity Directive, 2019). In this context, distributed energy resources, including demand response, can enter in an agreement with independent aggregator besides already having an agreement with a retailer. Moreover, the CEP also determines "the right for each market participant engaged in aggregation, including independent aggregators, to enter electricity markets without the consent of other market participants" (CEP Electricity Directive, 2019). That means that, in principle, an independent aggregator does not have to enter into an agreement with the consumers' retailer, and that can lead to distortive situations if a proper regulatory framework is not in place. For instance, the independent aggregator can create an imbalance on the retailer's portfolio by activating their customer's flexibility. If there is no compensation in place, the retailer is worse off. On the contrary, if there is a mandatory compensation in place, that may put the independent aggregator in a position of uncertainty regarding the retailer's profile and the base line for the deviations, leaving the independent aggregator business model[52] at risk (Lind et al., 2019).

On the ensuing, the questions of whether aggregation is permitted, particularly considering DER, and whether regulatory conditions are suitable for the development of independent aggregators will be explored for the countries considered in this report. Overall, it can be seen that, whilst there is still a long way to go, several countries have already made progress to facilitate aggregation, including independent aggregation and the rules to coordinate with BRPs.

- **Portugal:** Until very recently, aggregation in Portugal was not forbidden, but there was no specific legislation on this matter. In 2019, a new Decree[53] was published addressing self-generation, and partially transcribing the Renewables Regulation[54] of the Clean Energy Package. In this new regulation, important definitions are made towards the development of aggregation in Portugal. The decree recognizes aggregation and independent aggregation. Nevertheless, this decree is

[52] In this deliverable D8.2, we aim at addressing the impact of regulation on replicability only. Nevertheless, important market conditions created by regulatory characteristics have to be acknowledged. For a more in-depth analysis of the market conditions and other factor impacting the business models within the scope of InteGrid, we refer the reader to the deliverables D7.5 and D7.6.

[53] Decreto-Lei n.º 162/2019

[54] Directive (EU) 2018/2001 of the European Parliament and the Council of 11 December 2018

focused on regulating self-consumption and energy communities, and therefore does not provide definitions on the aggregation rules. Considering also the closed balancing market design, and the recent pilot-project on demand response for balancing that does not allow the participation of aggregation, we can conclude that additional definitions are still needed in Portugal.

- **Slovenia:** Aggregation in Slovenia is already a reality, as well as the concept of the VPP. The supplier Elektro Energija operates the VPP, with CyberGrid as the system provider and Elektro Ljubljana as the connecting DSO (Bertoldi et al., 2016). No official compensation scheme is defined to settle potential revenue losses of suppliers. The baseline used is based on the demand response unit schedule, set as the deviation between the "reduced" consumption and the "regular" scheduled consumption for the unit. Companies can use their own baselines, if accepted by the TSO (Bertoldi et al., 2016). Despite the proactivity of some agents in fostering the VPP concept in Slovenia, the country still lacks a comprehensive aggregation framework and standardised baseline methodology (Smart Energy Europe, 2018).

- **Sweden:** Retailers are allowed to become aggregators in Sweden. In principle, independent third-party aggregation is also possible if the agent registers as a BRP. In this case, besides paying an annual cost and installing the required electronic reporting system, the independent aggregator would have to sign an agreement with the consumer's BRP (Bertoldi et al., 2016). Independent aggregators can, however, act on behalf of retailers, acting as a subcontracted agent.

- **Austria:** Aggregation from the retailer's side is legal, as well as independent aggregation. However, independent aggregators have to inform and contract with the BRP/retailer in order to use the consumer's flexibility. Additionally, there are no compensation mechanisms in place for retailers to recover potential losses created by aggregation activity. Bertoldi et al. (2016) argues though that the energy potentially displaced by demand response participating in balancing markets would be low, and that the cost of measuring, communication and settling those imbalances could be higher than the imbalances themselves. Nevertheless, this situation shows that in Austria, the independent aggregator still lacks a framework that eliminates the need for contracting the consumer's BRP and that sets possible compensations between aggregator and retailer.

- **Spain:** As of today, aggregation of distributed resources in Spain is still a very immature activity. It is important to notice the concept of aggregation is already present in balancing markets in Spain. In the aFRR market, generating units of one technology from a same company are aggregated within a regulation zone. The aggregation of demand response of other types of distributed resources is, however, not in place yet. For instance, aggregation is not allowed in the interruptible contracts, the only way demand response provides flexibility to the TSO as of today. However, a new regulation has just been approved, introducing the aggregator as a possible provider of balancing services. According to the new regulation, aggregated demand, generation or storage will be allowed to offer balancing, but in a separated fashion[55]. In other words, demand and generation could not be aggregated together, potentially limiting the compatibility of the VPP concept.

- **Belgium:** Aggregation regulation is well developed in Belgium as compared to other EU Member States. Independent aggregation is allowed and already explored in Belgium. Prior to 2018, independent aggregators had to enter into an agreement with the customers BRP. However, the

[55] Resolution 18423 of December 11, 2019. Article 8(3).

"Energy Pact" removed this obligation in 2018 (Bray & Woodman, 2019). As of today, independent aggregators can participate in balancing independently from the BRP (Smart Energy Europe, 2018). In order to enable the participation of the independent aggregator, an innovative regulation was put in place, based on the concept of Transfer of Energy (ToE) (Elia, 2019). The independent aggregator and the supplier can enter in a bilateral agreement to decide how to settle possible costs from imbalances (the "out-out" arrangement). However, if not bilateral agreement is made, a standard ToE framework applies (Dam, 2019). This ToE is calculated by the Belgium TSO Elia. This mechanism provides a predictable framework for independent aggregators in Belgium, including VPPs, already present in the Belgium balancing markets (Next Kraftwerke, 2019).

- **France:** In France, the aggregation framework is also well developed, allowing independent aggregators to offer DER's flexibility without having to sign a parallel contract with the supplier. The framework enabling this was introduced in 2014, namely the "NEBEF" mechanism (Smart Energy Europe, 2018). This mechanism sets the compensation amounts that independent aggregators have to pay to BRPs (Bray & Woodman, 2019). In addition to that, the first VPP is being implemented in France, demonstrating a good compatibility with cluster 3 (European Utility Week, 2019).
- **Germany:** Until very recently, independent aggregation suffered with several barriers in Germany. Third-party aggregators had to enter into several bilateral agreements with the consumer, the TSO, the DSO and the consumers' BRP (Bray & Woodman, 2019). Since 2018, with the introduction of the new aggregation framework, these contracts are no longer required (Smart Energy Europe, 2018). The concept of the VPP is also already in use in Germany (Next Kraftwerke, 2017).
- **UK:** According to Bray & Woodman (2019), the UK still lacks a framework that solves the "BRP/aggregator" agreement and compensation issue. In principle, the independent aggregator should not need a prior consent from the supplier. However, not all markets can be accessed without a consent, and some others are closed to participation via the supplier, making it difficult for independent aggregators to participate in certain balancing markets (Smart Energy Europe, 2018). Nevertheless, this scenario is currently being changed. At the end of December 2019, the first independent aggregator, also operating a VPP[56], was allowed to become the equivalent to a BSP (ELEXON, 2019). This was possible due to currently ongoing implementation of the TERRE project in GB (Ofgem, 2018).
- **Italy:** According to the smartEn report (2018), aggregation takes place in Italy in the tertiary control market, equivalent to the mFRR. In this market, that is operated under a project called UVAM, aggregation demand response of mostly medium of large industrial consumers could be verified

4.3.2.3. TSO-DSO coordination

Enhanced coordination between TSOs and DSOs is an important element for the seamless participation of aggregated demand response in balancing markets. In this regard, this coordination is necessary to ensure that the activation of balancing offers coming from resources connected at the distribution grid will not

[56] In the UK referred as Virtual Lead Party

affect the operation of the DSO network. In a scenario in which the DSO may also procure flexibility from DER, this coordination becomes even more necessary. This is exactly the situation in which both the tVPP and the cVPP (InteGrid's HLUC12) are operated in the same area, or that the DSOs directly procures the flexibility from demand response (clusters 1 and 2).

In the InteGrid project, this coordination is achieved through the use of the TLS. The TLS can act as one possible "coordination schemes" between the TSO and DSO. Other coordination schemes are possible as well. In the absence of an interface such as the TLS that informs TSOs and DSOs of which resources can be activated, other market designs to ensure that the procurement and activation of flexibility by both system operators is done efficiently may be found (Lind et al., 2019). Several options were already proposed by academia, but in general terms, they can be summarized in three big groups:

1. Markets centralized on the TSO: one option would be to leave the TSO operate and dispatch all markets. This could lead to a more efficient optimization problem, but would reduce the possibility of an active DSO management of the grid.
2. TSO runs a central market, while the DSO runs a local market: In this way, each SO runs its market and they agree on a way to avoid problems in procurement and activation. For that, several alternatives were put forward. They could agree on certain limits on the interface of the two systems for instance. Alternatively, the DSO could run a local market for all products and send the unused bids to the upstream market of the TSO.
3. External platform: Other projects and research have focused on create "flexibility markets", in which both TSO and DSOs can buy the flexibility for their own needs. Tools such as the InteGrid TLS would be used as mechanisms to avoid congestions when activating resources.

In addition to the need for coordination schemes, system operators also have the necessity for enhanced information exchange between TSO and DSO. Examples of this information exchange may be found in Portugal with the ICCP (Inter Control Centre Protocol) (Bernardo & Dias, 2012) or Spain with the CECRE (Control Centre for RES) (Lind & Chaves Ávila, 2019).

However, as shown in deliverable D7.1, TSO-DSO interaction is still limited to a scenario of low DER flexibility procurement by the TSO, and no procurement of DER flexibility by the DSO in the focus countries of InteGrid [REF D7.1].

- **Portugal**: the main coordination effort happens for the elaboration of investment plans. There is also coordination with respect to the grid's operation and energy flows. Both in Portugal and in Spain, some enhanced coordination is need due to the interruptible contracts, which exist in both countries. In Portugal, in case the TSOs decides to use the flexibility of a consumer participating in the interruptible program, it can directly do it directly, in case of urgency, or through a request to the DSO (ERSE, 2019a).

- **Slovenia:** operational coordination takes place at the HV level, at the interface between TSO and the DSO. As in the case of Sweden discussed below, Slovenia presents an additional challenge regarding the TSO-DSO coordination. In these two countries, there is a "two-level" DSO. In Slovenia, the national DSO SODO participates in the planning of the network, while the regional electricity distribution companies (EDC) operate the distribution grids. This could lead to a higher complexity in information exchange between the now three stakeholders (TSO, National DSO, and Regional DSO)

- **Sweden:** coordination happens for both planning and operation. For network planning, the TSO informs the DSOs when the Ten-Year Network Plans are made. Regarding operation, the main coordination measures are described in Table 50.

Table 50: TSO-DSO Coordination measures in Sweden. Source: (Lind & Chaves Ávila, 2019)

Time-Step	Coordination Measures
Long term	Outage planning coordination: yearly communication between respective operational planning unit (TSO/DSO). TSO dialogue with DSO representatives about consequences for different operational modes and outages.
Medium term	Exchange of switching schedules of common interest.
DA, ID near real-time	TSO in dialogue with relevant DSO about consequences for various operational modes and outages, overloads and disturbances. In the short-term, there is communication between grid control centers.

The organizational arrangements for grid operation in Sweden create additional complexities for this coordination. In Sweden, the power grid is divided into transmission, regional and local distribution systems. The regional power system is formed by concessions of lines that connect transmission and local DSOs. Some large customers and generation (wind farms mainly) are connected to the regional system (Wallnerström et al., 2016). In this case, the TSO-DSO coordination could potentially involve three different stakeholders, increasing complexity of coordination and information exchange.

- **Spain:** the TSO and DSO exchange data on a regular basis for operational purposes. The TSO communicates the DSO of the daily operation plan, and the DSO can request changes in case of need. The TSO also informs the DSO the schedules for DER providing balancing services. Moreover, the TSO communicates the schedule of unit tests on a weekly basis. Units of more than 50MW connected to the distribution network have to be tested by the TSO. In this case, the TSO informs weekly the DSO the schedule for these tests with units in the distribution network. Also, structural data is sent by the DSO to the TSO for units of more than 1 MW. DGs above 5MW are monitored on real-time by the TSO. (Lind & Chaves Ávila, 2019).

Overall, most coordination schemes and enhanced information exchanged are still limited to pilot-projects, especially concerning operational issues. Several examples of pilot projects can be found among the countries selected for the regulatory SRA:

- **Germany:** the traffic light system is being implemented by the Westnetz DSO in a demonstration project (Wellssow et al., 2018). In this implementation of the TLS, the green color represents a state of the grid in which the grid is unconstrained and agents can use the network. In the yellow state, there is risk for grid congestion, and therefore the DSO uses DER flexibility to maintain the system stability. In the red state, both DSO and TSO solve network constraints with no regards for the markets. In addition to this pilot project, another major pilot is being implemented by the TransnetBW TSO and the Netze BW DSO, with the support of State Ministry of the Environment, Climate Protection and the Energy Sector ('DA/RE enters pilot phase', 2019). The DA/RE ("DAta exchange/REdispatch") pilot focus on the data exchange between TSOs and DSOs (Constantinescu, 2019).

- **France:** two demonstration projects also explore TSO-DSO coordination aspects, namely the Smart Grid Vendée and Nice Grid project (Wellssow et al., 2018).
- **Belgium:** According to Soens (2017), TSO-DSO regulation was already improved by federal legislation in 2017, defining high level roles and responsibilities for TSO-DSO collaboration. Nevertheless, exact and detailed boundaries of DSO & TSO activities for data operation are not legally defined. In addition, a joint TSO-DSO datahub is also being implemented in Belgium (Constantinescu, 2019; European Smart Grids Task Force, 2019).

In additional to local/regional pilot-project, another important source of innovation in terms of TSO-DSO is the H2020 programme. Several projects have explored or are currently researching the topic. Regarding the are exclusively researching TSO-DSO coordination aspects, SmartNet[57] can be considered the first one, followed by CoordiNet[58] and Interrface[59], which are currently under development. In addition, several other H2020 projects are also researching TSO-DSO coordination aspects, as shown in a recently published BRIDGE initiative report (BRIDGE Initiative, 2019).

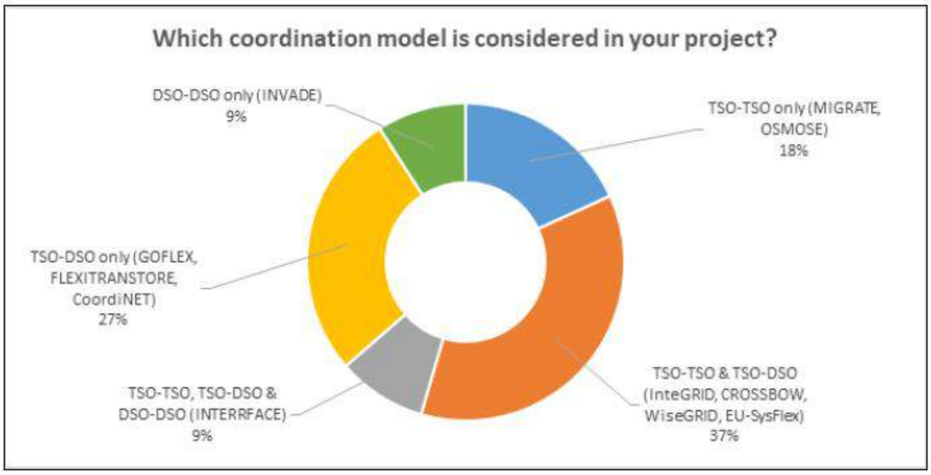


Figure 45: Coordination models considered in different H2020 projects. Source: (BRIDGE Initiative, 2019)

4.4. Maturity analysis and conclusions

This section aims to summarize the key results of the regulatory SRA for the four functionality clusters analysed in this report. The methodology followed to perform such assessment is described on the ensuing. Firstly, a "maturity level" rank was created based on how well adapted current regulation is to enable and promote the implementation of each one of the clusters. This definition is shown in Table 51. Next, for each of the four clusters, the maturity level of existing regulation was assessed on a country basis specifically for each regulatory topic and key regulatory question.

[57] http://smartnet-project.eu/
[58] https://coordinet-project.eu/
[59] http://www.interrface.eu/

Table 51: Definition of regulatory maturity levels

Maturity level	Description
0	Current regulation prohibits or prevents implementation
1	Current regulation does not explicitly prohibit/prevent implementation, but fails to promote it effectively
2	Current regulation enables implementation, but regulation is still immature
3	Current regulation enables implementation and some advanced regulation in place, but still not fully developed
4	Regulation enables and promotes implementation

The overall maturity level of a given cluster is then assessed based on this evaluation, which also allows identifying what regulatory topic is creating the most relevant barriers to replicability. Subsequent sections 4.4.1-4.4.4 show the application of this methodology to each of the four clusters.

4.4.1. Cluster 1: Flexibility Management for Optimized MV Network Operation

The compatibility of cluster 1 with current regulation depends on the actual DSO revenue regulation, the existence of mechanisms enabling DSOs to use local flexibility, and the design of incentives for DSOs to reduce network losses. Based on the analysis of the situation in each country presented in section 4.3.1 and the maturity levels described above, Table 52 presents the resulting qualitative maturity scores for each regulatory question and country. On the ensuing, the scoring for each country and regulatory question is discussed and justified.

Table 52: Cluster 1 maturity assessment per country[60].

Description	Regulatory topic	Key regulatory question	Maturity level							
			PT	SI	SE	ES	AT	UK	IT	DE
Flexibility Management for Optimized MV Network Operation	DSO revenue regulation	Would DSOs benefit from using flexibility to defer or avoid grid investments?	2	1	1	1	3	4	2	1
		Would DSOs recover the costs associated with the use of flexibility?	2	2	1	3	2	4	3	2
		Do DSOs and regulators adopt a long-term vision for grid development/regulation, including the use of flexibilities?	2	2	1	2	1	4	3	2
	Local flexibility mechanisms	Are DSOs enabled by regulation to procure flexibility from grid users to support grid operation?	1	0	0	2	2	4	0	3
	Incentives for the reduction of energy losses	Do DSOs receive (strong) economic incentives to reduce energy losses?	2	4	4	2	3	1	4	NA
		Is the impact of DER and smart grid solutions considered when setting baseline/target levels for losses?	1	2	2	2	1	NA	3	NA

- **DSO revenue regulation:** overall, DSO regulation may still be considered ill adapted to promote the use of flexibilities as an alternative to grid reinforcements. The key issue in this regard is the treatment of OPEX and CAPEX in the determination of allowed revenues. In most countries, CAPEX remuneration is still mostly based on actually incurred investments[61] whilst, at the same time, OPEX reductions are encouraged. Therefore, DSOs would not benefit from reducing CAPEX; in fact, they may actually be penalized if OPEX increase to remunerate the flexibility providers.

  This is why Spain, Slovenia, Sweden and Germany have been rated as "1" in the first regulatory question. Some countries, in spite of presenting a similar situation, may be seen as slightly more positive and rated as "2". For instance, in Portugal investment plans have to reflect the impact of DER on investments. Moreover, the Italian regulator is undergoing a consultation period for the implementation of TOTEX regulation at the beginning of the next regulatory period. In the case of Austria, the RAB is updated according to actual investments; however, DSOs would benefit from the use of flexibilities to reduce overall costs, as they would appear as more efficient in the TOTEX benchmarking analysis carried out by the regulator in the subsequent price review. Lastly, the UK implemented a deep transformation in their network regulation moving towards a TOTEX approach under which the RAB update is decoupled from actual investments.

  Two aspects were considered for rating the second question, i.e. whether DSOs would recover the costs associated with the use of flexibility. Besides the treatment of OPEX discussed above, it was assessed whether DSOs have incentives to deploy innovative solutions or pilot projects. It can be seen that most countries, with the exception of Sweden, reported some form of economic incentive for pilot projects or smart grid investments. Countries that allow pilots but where there is no incentive for a large-scale deployment of proven solutions, were rated as "2", whereas the countries awarded with a rating of "3" already present some deployment incentives embedded in

[60] No information about the incentives for loss reduction in Germany was obtained, thus NA stands for "Not Available" in this case. On the other hand, the UK has no financial incentive for DSOs to reduce losses; therefore, the question about the computation of the reference level of losses is "Not Applicable".

[61] The economic value of new investments may directly correspond to book values or computed based on a set of standard or norm costs (Sweden and Spain).

the general revenue regulation. Lastly, the UK was rated with a "4" as several innovation mechanisms are combined.

The last question that was raised related to the DSO revenue regulation was whether a long-term vision was adopted for grid development and its regulation. In order to address this question, two topics were considered: i) the length of the regulatory periods, and ii) whether DSOs must submit grid development plans and how these are used in the price reviews. The length of regulatory periods in the countries considered in this case are shown in Figure 46. It can be seen that most countries present lengths between the conventional 3 to 5 years, although some have introduced longer regulatory periods such as Spain (6 years), Italy (8 years) and UK (8 years). However, in all these cases, mid-period reviews are common and, in fact, the UK regulator has expressed the possibility to return to five-year regulatory periods after the next price reviews. Therefore, the key topic in this regard is whether and how DSO investment plans are used in the process of determining allowed revenues.

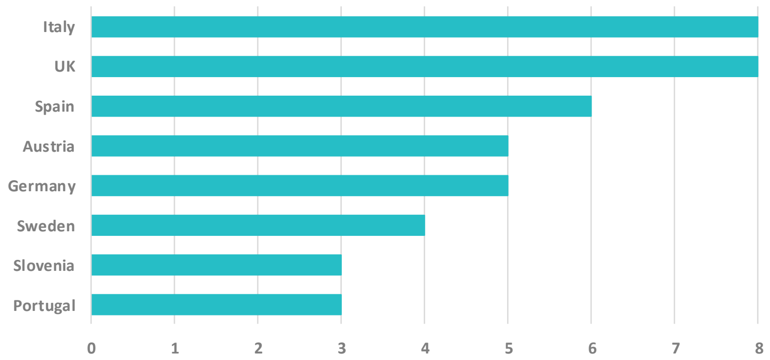


Figure 46: Length of regulatory periods in different countries.

The analysis showed that most of the countries reviewed require DSOs to submit investment plans periodically. The only exception to this rule was Austria. Moreover, in Sweden DSOs submit investment plans, but they are indicative and not explicitly used to determine DSO allowed revenues. Nonetheless, despite the widespread use of investment plans, these rarely explicitly include the possibility of using flexibilities on equal grounds to reinforcements. This is only the case of the UK, where the DSO business plans must explicitly address this possibility and justify the decisions made based on CBA studies. Italy has declared their intention to adopt a similar approach as of the next regulatory period.

- **Local flexibility mechanisms[62]:** the review showed that local flexibility mechanisms are generally poorly developed yet. Several countries, rated with "0", have no such mechanism in place. Moreover, several other countries do have some technical requirements to mitigate the impact of DER, but this is seen as an emergency resort rather that as service that may be used under normal conditions. For instance, Austria and Spain have such sort of regulation and some remuneration for flexibility providers is in place, although the service is not widely used (score of "2"). In the case of

[62] In Sweden, from 2020 the possibility to cover costs for flexibility solutions due to lack of capacity in the grid is being implemented. The analysis in this section considers the regulation at the time of writing, but this change will be addressed in InteGrid deliverable D7.2.

Portugal, the service (curtailment) is not even remunerated (rated as "1"). Lastly, the countries rated with "3" or more present some form of advanced market-based mechanisms for the provision of flexibility. The difference being that the German platform is still a large-scale pilot (the default solution is therefore RES curtailment), whereas the platform in the UK is already under commercial operation.

- **Incentives for the reduction of energy losses:** as discussed previously, reducing network losses is not the main goal of this cluster. However, as shown by the economic SRA, its implementation can actually have an impact on the level of losses (either upwards or downwards depending on the conditions). Therefore, the existence of such incentive schemes and its appropriate design, ensuring that the impact of DER on each DSO area is considered, was deemed a favourable factor for the development of this cluster.

  Overall, it was observed that this type of incentives is widespread, as they are present in all countries but the UK (loss reduction must be nonetheless explicitly considered in the business plans and DSOs showing a good performance may receive a discretionary reward). In other countries, rated as "2", incentives do exist, but their strength is limited in practice due to caps, dead bands, or low economic value on losses. For example, in Portugal, the maximum amount of the incentives or penalties is capped and a deadband is in place. Moreover, the economic value of losses is below the market price. Likewise, in Spain, the incentive is capped and the individual incentive depends on the performance of other DSOs as it is designed as a "zero-sum game". Therefore, it may not be enough to properly drive loss reduction efforts. The remaining countries make grid operators purchase energy to cover their network losses through market mechanisms. DSOs would therefore have an incentive to reduce them as either allowed revenues only include a pre-defined share of losses (Slovenia, Sweden and Italy) or the corresponding cost is included in a TOTEX benchmarking analysis (Austria).

However, in spite of incentive schemes being widespread, reference levels of losses generally do not consider the impact of DER and/or the specific characteristics of each DSO area on grid losses. These reference levels are usually determined simply as an improvement with respect to past performance or based on emission reduction targets. In some cases, some differentiation per DSO area is made, but this usually consists in setting different loss factors or reference levels by load-density areas, regardless of DER penetrations seen by individual DSOs. Only Italy introduces a correction to account for the individual characteristics of each distribution areas. However, this is a one-sided correction to prevent windfall profits by DSOs resulting from exogenous factors decreasing network losses.

In order to illustrate the results graphically, the average scoring for each country[63] has been used to aggregate the regulatory compatibility of cluster 1 in the different countries. This is shown in Figure 47.

[63] This implies that all questions are given the same weight, which may not be completely accurate. Nonetheless, similar maps could be easily developed allocating distinct weights to different regulatory questions.

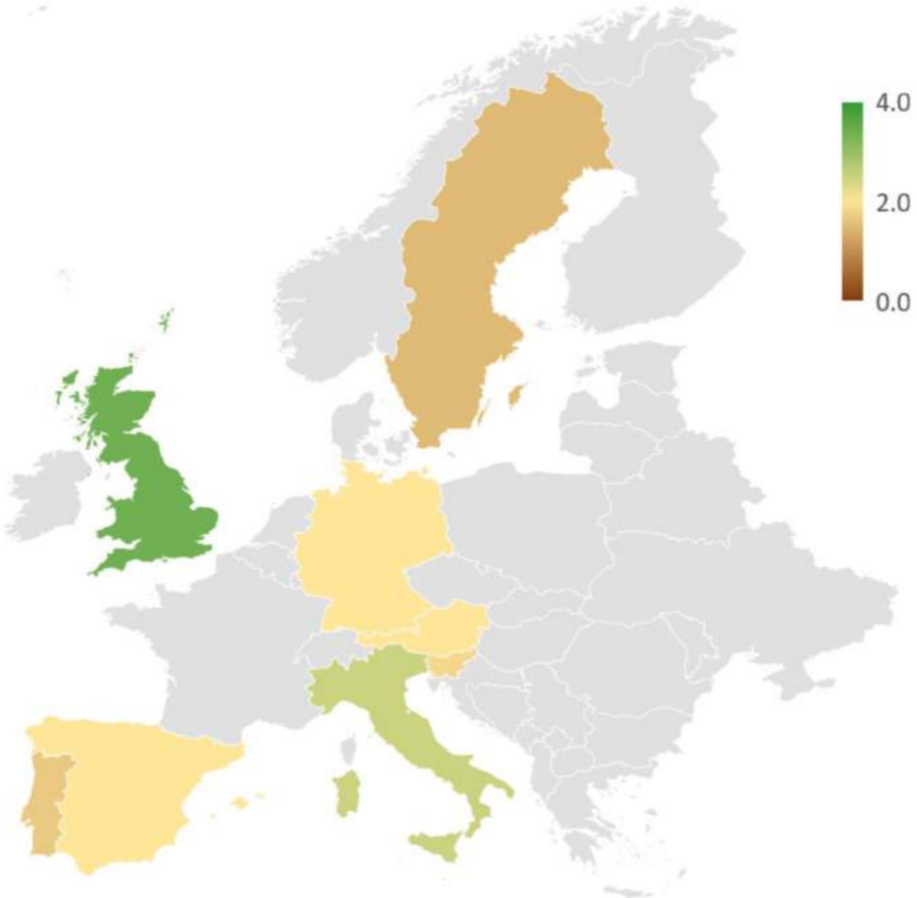


Figure 47: Overall regulatory compatibility of Cluster 1.

4.4.2. Cluster 2: Flexibility Management for Optimized LV Network Operation

As previously discussed, the regulatory topics relevant to 2 are those considered for cluster 1 together with the level and design of regulated charges and how they impact the retail electricity tariff seen by residential consumers. Table 53 presents the resulting qualitative maturity scores for each regulatory question and country. In spite of addressing the same regulatory issues, a few differences may be found as compared to cluster 1. The reason is that current regulation sometimes presents differences between HV/MV networks and LV networks. On the ensuing, the scoring for each country and regulatory question is discussed and justified. In order to avoid repetitions, the focus is placed on the differences with respect to cluster 1 and the additional regulatory issues.

Table 53: Cluster 2 maturity assessment per country[64].

Description	Regulatory topic	Key regulatory question	Maturity level							
			PT	SI	SE	ES	AT	UK	IT	DE
Flexibility Management for Optimized LV Network Operation	DSO revenue regulation	Would DSOs benefit from using flexibility to defer or avoid grid investments?	3	1	1	1	3	4	2	1
		Would DSOs recover the costs associated with the use of flexibility?	2	2	1	3	2	4	3	2
		Do DSOs and regulators adopt a long-term vision for grid development/regulation, including the use of flexibilities?	1	2	1	2	1	4	3	2
	Local flexibility mechanisms	Are DSOs enabled by regulation to procure flexibility from grid users to support grid operation?	1	0	0	0	2	4	0	3
	Incentives for the reduction of energy losses	Do DSOs receive (strong) economic incentives to reduce energy losses?	2	4	4	2	3	1	4	NA
		Is the impact of DER and smart grid solutions considered when setting baseline/target levels for losses?	1	2	2	2	1	NA	3	NA
	Regulated charges and retail tariffs	Are taxes and/or other regulated charges distorting flexibility incentives embedded in the tariffs?	1	3	2	2	2	3	2	0

- **DSO revenue regulation:** a couple of differences may be highlighted for cluster 2 as compared to cluster 1 on this topic. The first difference between the ratings for the two clusters is found for Portugal. Firstly, DSO regulation in this country is asymmetric between HV and MV grids, on the one hand, and LV networks on the other hand. Whilst a separate treatment of CAPEX and OPEX is applied for the former, the use of a TOTEX regulation in the LV is, in principle, more suited to promote the use of flexibilities as an alternative to grid reinforcements. Hence, the score corresponding to the question of whether DSOs would benefit from doing so is higher in cluster 2 than in cluster 1.

  A second difference observed for Portugal may be found in the question about whether a long-term vision is considered when planning the grid development. In this case, the score is lower in this cluster as compared to the previous one as the investment plans submitted by the DSO do not include the LV network. Therefore, there is a risk that the DSO does not adopt a proactive long-term network development strategy for this voltage level, hampering the use of flexibilities.

- **Local flexibility mechanisms:** there is another difference to be pointed out concerning this regulatory topic. It corresponds to the Spanish case; more specifically, why mechanisms enabling the use of local flexibilities by DSOs are deemed less mature in this case. The reason is that, whilst DSOs may be able to access this flexibility through the TSO control centre for resources connected to the distribution grid, this functionality is limited to units above 5MW. Therefore, generation units connected at LV level would be excluded from this mechanism.

- **Regulated charges and retail tariffs:** in addition to the aforementioned modifications, the assessment of cluster 2 includes this new regulatory topic, particularly the weight of regulated charges and taxes over the final retail tariffs and its effect on the response of residential consumers to flexibility signals and the adoption of enabling technologies such as HEMS or self-generation. In this regard, there are two relevant aspects. On the one hand, a high weight of regulated costs over

[64] As compared to Table 32, a question about the structure of the retail tariff has been removed from this table due to the lack of adequate reliable information to assess such a question.

the final electricity prices seen by residential consumers can distort the incentive that time-varying energy prices can have on the adoption of HEMS. On the other hand, since network charges may also be used to promote flexibility (e.g. through dynamic network tariffs), it is relevant to assess the weight of network costs over the total regulated costs.

Overall, the most suitable conditions for the deployment of cluster 2 would be those where regulated charges and taxes distort the least flexibility signals. This would correspond to those countries when regulated costs and taxes account for a lower share of overall electricity prices, as well as those where network costs account for most of the regulated costs. Using the data from Figure 43, these two shares were computed (see Table 54) and combined into a single score value.

Table 54: Comparative analysis of regulated costs.

Country	Regulated costs plus taxes over final prices	Network costs over total regulated costs
Germany	78%	31%
Portugal	70%	37%
Sweden	68%	46%
Austria	65%	42%
Slovenia	57%	54%
Spain	56%	38%
UK	49%	47%
Italy	47%	30%

In order to illustrate the complete results graphically, the average scoring for each country[65] has been used to aggregate the regulatory compatibility of cluster 2 in the different countries. This is shown in Figure 48.

[65] See footnote 63.

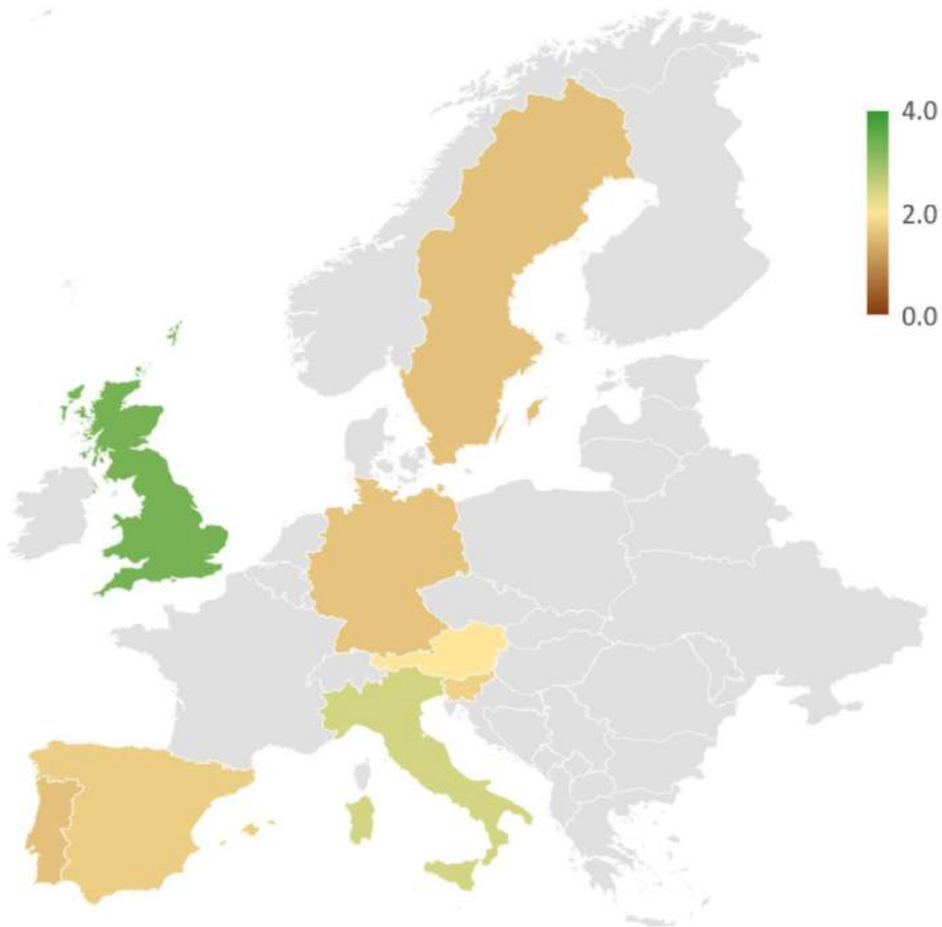


Figure 48: Overall regulatory compatibility of Cluster 2.

4.4.3. Cluster 3: Large customer cVPP

As mentioned in section 4.1, the regulatory compatibility of cluster 3 depends on the fitness of balancing market to the participation of demand response, the aggregation rules and the appropriate TSO-DSO coordination.

The most challenging part of this compatibility analysis is to ensure that the assessment of each country is comparable, considering the different concepts used among them and the many specificities that lay on the details, impossible to be fully captured in this report. Nevertheless, using a set of criteria based on the general structure proposed in Table 51, we are able to give provide a good representation of the overall compatibility of cluster 3 and 4 in the different countries. However, this analysis is not exhaustive, and should be interpreted as a general illustration of how open countries are to the ideas of Cluster 3 and 4.

The following subsections present a compact description of the rationale behind the scoring of each country and for each guiding question. The details related to each country can be found in section 4.4.3, while the complete set of criteria for each question is presented in Annex 2.

Table 55: Cluster 3 maturity assessment per country[66].

Regulatory topic	Key regulatory question	Maturity level									
		PT	SI	SE	ES	AT	UK	IT	DE	FR	BE
Balancing Market Design	Are (mFRR) balancing markets open for demand-response participation?	1	3	3	2	3	2	3	3	4	4
	Are products and conditions suitable for demand/DER participation (in mFRR)?	1	2	2	1	2	2	2	2	3	3
Aggregation	Are there barriers for the aggregation of resources in balancing markets?	1	3	2	1	3	2	2	3	4	4
	Is the independent aggregation allowed? Is it viable?	1	3	2	1	3	2	1	3	4	4
	Is different type of DER aggregation (VPP concept) possible?	1	3	2	0	3	2	1	3	3	4
TSO-DSO coordination	Is TSO-DSO coordination mature enough for DER to provide balancing services?	1	1	1	1	1	1	1	2	2	2

- **Balancing Market Design:** In general, the mFRR markets are open for demand response participation. The only mFRR that is still not open for demand response is in Portugal, although in this country a demo is being developed, therefore being scored as “1”. On the opposite side, France and Belgium considered to have a very open mFRR market, with expressive participation of demand response. The other countries have a somewhat open market for DR. SI, SE, AT, IT and DE are more advanced, with open markets but with practical barriers, such as high bureaucracy (AT), unclear market rules (SI), complicated prequalification (DE), and challenging market conditions (SE). Finally, Spain and the UK have already opened mFRR markets for DR, but additional barriers still exist. In Spain, the markets were only recently opened, and additional regulation is needed. In the UK, tenders are not regular and complex. On the suitability of products and requirements, scores are all correlated to ones referring to how open the mFRR markets are for the participation of DR, being in general one score below the previous one. That means that in general, markets are open, but some additional limitation is imposed by product definition, such as minimum bid size. For example, in Germany and Sweden, real-time monitoring is required, while in the UK the minimum bid size is 3 MW.
- **Aggregation:** Aggregation is in general incipient most of the countries, with the exception of France, Belgium, and to some extent, Slovenia, Germany and Austria. In FR and BE, aggregation is already a commercial reality, while in SI, DE, and AT, some commercial implementations are being made or in place already. In SE, UK, and IT, aggregation is in theory possible, but several barriers exist. Finally, in Portugal and Spain, aggregation was recently acknowledged by regulation, as a consequence of the EBGL implementation, but not further definition as being made. The independent aggregation, however is not completely developed in all countries. The main barrier for this particular activity is

[66] As compared to Table 32, a question about the structure of the retail tariff has been removed from this table due to the lack of adequate reliable information to assess such a question.

the missing framework defining balancing responsibilities between independent aggregators and BRPs/Retailers. France and Belgium have already implemented these frameworks. In the other countries, this framework is being developed or not in place. Nevertheless, in DE, AT and SI, commercial independent aggregators are already participating in balancing markets. In SE and UK, besides the missing framework, additional challenges exist, such as the high cost for an independent aggregator in SE. In Portugal and Spain, the independent aggregator is only acknowledged by recent pieces of regulation. Finally, the possibility of aggregation of different types of DER is in general similar to the independent aggregation viability. In Spain, however, a recent regulation seems to prohibit the aggregation of multiple types of DER, therefore being scored “0” for this topic.

- **Enhanced TSO-DSO coordination:** In general, this topic is very incipient in most countries, being either attributed a “1” or “2” score. The score “1” means that coordination is already done to some extent, but limited to the traditional coordination already being done since the liberalization of power systems, with eventual improvements and/or small-scale pilot projects. The score “2” represents either some relevant regulation on the topic (e.g.: Belgium), or national large-scale sandboxes/pilots (DE, FR, and BE).

Table 55 presents a scoring of the different aspects needed for the compatibility of the cluster. The average of the scoring proposed in this table is then used to finally conclude on the regulatory compatibility of cluster 3 in the ten different countries. Figure 49 presents the regulatory compatibility of cluster 3.

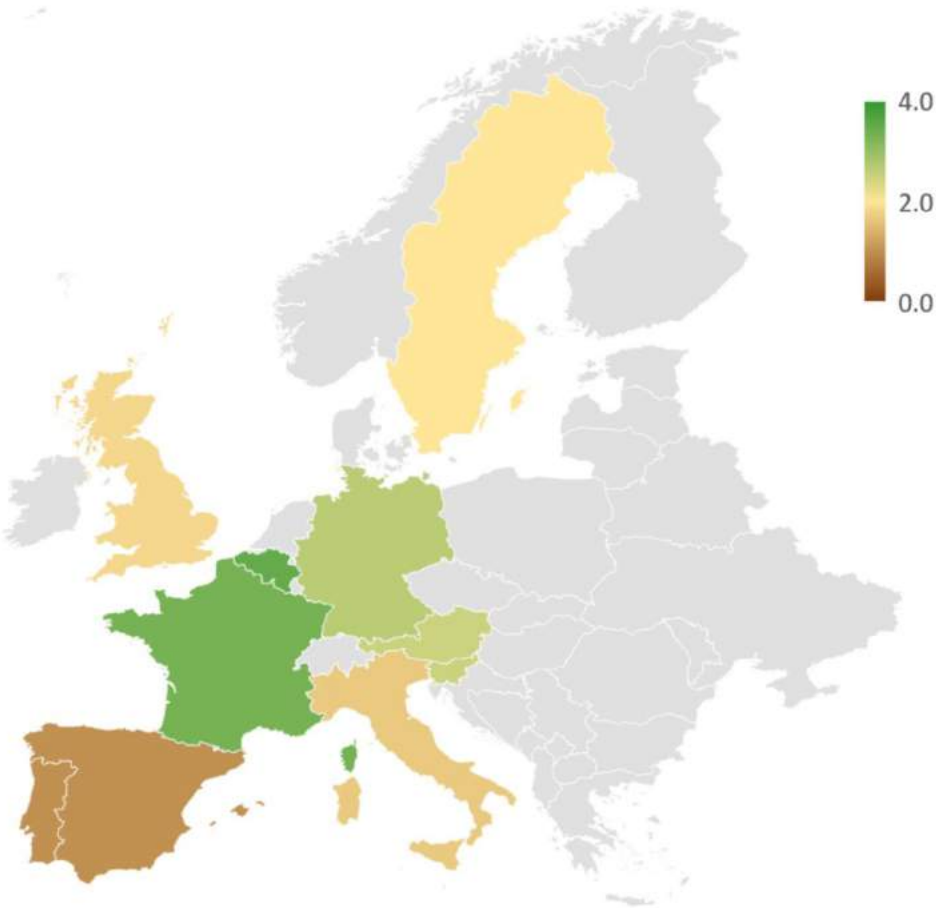


Figure 49: Overall regulatory Compatibility of Cluster 3.

4.4.4. Cluster 4: Office Buildings Aggregation

The assessment of the maturity of cluster 4 falls the same approach done by the previous clusters, in particular for cluster 3, that shares the same overall barriers, namely balancing market design, aggregation, and TSO-DSO coordination. The main differences from cluster 3 to cluster 4 are the different balancing product, being the mFRR in cluster 3 and the aFRR in cluster 4. Additionally, aggregation is treated from a different perspective in cluster 4. The idea of cluster 4 comes from InteGrid's HLUC10, in which aggregation of commercial buildings is done by the retailer and then offered to the aFRR. In this context, independent aggregation is not part of the key concept of this cluster. Also, the aggregation of different types of DER is not that relevant, as only the aggregation of commercial buildings is being considered.

Table 56: Cluster 4 maturity assessment per country[67].

Regulatory topic	Key regulatory question	Maturity level									
		PT	SI	SE	ES	AT	UK	IT	DE	FR	BE
Balancing Market Design	Are (aFRR) balancing markets open for demand-response participation?	1	2	1	1	2	2	1	3	1	1
	Are products and conditions suitable for demand/DER participation (in aFRR)?	1	1	2	1	2	2	2	2	1	1
Aggregation	Are there barriers for the aggregation of resources in balancing markets?	1	2	2	1	2	2	2	3	1	2
TSO-DSO coordination	Is TSO-DSO coordination mature enough for DER to provide balancing services?	1	1	1	1	1	1	1	2	2	2

- **Balancing Market Design:** Differently from cluster 3, cluster 4 is focused on the DR participation in the aFRR market, and therefore requirement for services provision are expected to be higher. Being a faster product and a more critical product for the system, the requirements for aFRR provision are usually more complex. The FAT is usually shorter, below 5 minutes, and the monitoring tends to be done in real-time, requirement additional infrastructure. For these reasons, the provision of this services is not open to demand response, while for mFRR it is. That is the case in France and Belgium, for instance. For countries, demand response is not allowed, but some initiative exists in order to open it for DR participation. That is the case in Italy, Belgium, and France, for instance. In other countries, the participation is somehow allowed, but the product definitions or technical requirements are a barrier. In the UK for instance, the minimum bid is 25 MW (Smart Energy Europe, 2018), while in Slovenia, aFRR bids have to be symmetrical. The only country that can be considered more open for DR participation in aFRR markets is Germany, where DR can participate, and the minimum bid is 1 MW.
- **Aggregation:** The aggregation of DR in aFRR is very much linked with the possibility of DR participation in the first place. Therefore, the only country with a somewhat possible participation of aggregated DR in aFRR is Germany, where pooling for is allowed.
- **Enhanced TSO-DSO coordination:** Regarding the situation of TSO-DSO coordination, the same scoring of cluster 3 can be considered in cluster 4. At this stage, and considering that this coordination is still very immature, there is not significant difference for aFRR and mFRR products.

[67] As compared to Table 32, a question about the structure of the retail tariff has been removed from this table due to the lack of adequate reliable information to assess such a question.

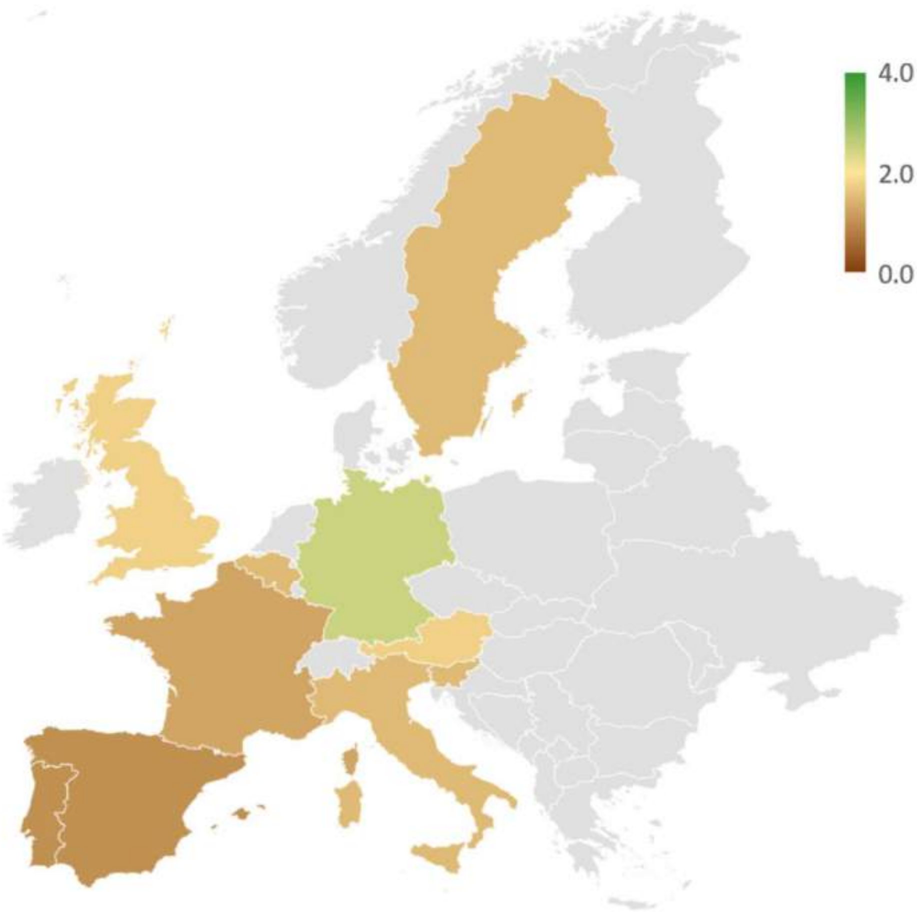


Figure 50: Overall regulatory Compatibility of Cluster 4.

5. Impact of regulatory conditions on the economic scalability and replicability potential

The previous sections 3 and 4 have presented separately the results of the economic and regulatory perspectives of the InteGrid SRA respectively. However, in practice, the economic consequences of replication and scaling-up a given functionality cluster can be significantly affected by the specific regulatory framework in place. More specifically, regulation can impact the allocation of the calculated costs and benefits among stakeholders, or whether external costs are internalized. Therefore, the role of regulation should be to align the individual stakeholder perspectives in line with the overall social desirable outcome. It may even be used to encourage specific stakeholders to adopt certain solutions on the basis of drivers beyond the purely economic benefit (e.g. non-internalized externalities, kick-off the development of immature markets, etc.).

On the ensuing these interactions between the economic and regulatory perspectives are analysed for each one of the four clusters considered in this report. In order to do this, the costs and benefits identified and their allocation presented in section 3.5 will be discussed in the first place. Next, the main lessons learnt from the economic SRA will be summarized, i.e. the key variables that condition the magnitude and sign (i.e. positive or negative) of the economic results. Lastly, the regulatory implications of these results will be discussed in detail, using examples from the countries reviewed in section 4.

5.1. Cluster 1: Flexibility Management for Optimized MV Network Operation

The **main costs** to be incurred in order to enable this cluster essentially correspond to software, and monitoring and control devices required by both by the DSO and the tVPP operator. Additionally, the cluster involves certain payments from DSOs to the flexibility operators; however, note that these may be seen strictly as transfers between agents to reallocate the benefits rather than an actual cost from a social perspective. Thus, the payment made by the DSO offsets the income received by the flexibility operator when the overall CBA results are computed. Moreover, these payments would be exclusively dependent on the existence and design of the local flexibility mechanism that enables such transactions.

On the other hand, the **most relevant potential benefits** brought about by this cluster correspond to those identified as societal benefits. These are the reduced voltage deviations, either over or under voltages, as well as the avoided CO_2 emissions and fossil fuel costs derived for the additional RES production injected into the grid. Additionally, network losses reduction is quantified[68], although as discussed above, network losses do not necessarily need to decrease after the implementation of this solution.

Assessing the results of **the economic SRA**, the following **key lessons learnt** concerning the magnitude and allocation of these costs and benefits can be extracted:

- In most of the scenarios analysed, the overall economic result was negative, and both the DSO and the tVPP operator would incur in a net loss or see no gain at all.
- Nonetheless, even in those cases where the overall result turned out to be positive, both stakeholders generally saw a negative economic perspective. Most of the benefits quantified would correspond to the benefits labelled as societal.
- The economic SRA tended to provide a better business case in those situations where the distribution grid is more stressed, i.e. when DER penetration was high. In fact, it seems that overall net benefits are virtually negligible in situations where the grid is not stressed; this implies that network losses reduction are not a main driver for these solutions.
- The use of DSO-owned resources ought to be prioritized, particularly if these are already deployed. However, the combination of both DSO-owned resources and tVPP contributions will be likely needed in a context with high DER penetration in order to solve all network constraints.

These results present many **regulatory implications**, which will be discussed on the ensuing. This discussion needs to take into account the differences between the two main stakeholders involved. The DSO is a regulated agent, whereas the VPP operator is a non-regulated subject to market competition. Therefore, the scope of regulation would be different concerning both actors.

From a DSO perspective, the key aspects are mostly related to the revenue regulation as this will determine to what extent the DSO will be entitled to pass-through these costs to the network tariffs or whether some of the societal benefits would eventually go to this agent. On the other hand, from a flexibility operator perspective, the key regulatory issue is the existence and design of the local flexibility mechanisms, as this will determine the revenues obtained.

- **DSO perspective:**

The first relevant topic to discuss is how voltage deviations, which was one of the most relevant benefits observed, would be treated in real life. In the scope of the economic SRA, it was assumed that undervoltages would result in load shedding, whereas overvoltages would be solved through RES curtailment. However, under normal circumstances, this type of voltage problems would normally be solved considering grid reinforcement as the solution by default. Therefore, this benefit may be seen as a proxy for the deferred or avoided grid investments that would be driven by voltage limits violations.

[68] Note that a change in network losses would also imply a change in fuel costs and CO_2 emissions. However, it is assumed that the economic value of losses, normally related to the wholesale market price, internalizes both aspects. This assumption is deemed sensible given that market prices would reflect the variable fuel costs of the marginal generation technology and, since power generation is under the European ETS, the economic value of CO_2 emissions.

With the introduction of the tVPP, the DSO would therefore have three types of solutions to address voltage problems[69]: i) grid reinforcement, ii) DSO-owned voltage control devices (OLTC, capacitor banks), and iii) tVPP flexibilities. Results denote that the most suitable combination of these three types of resources depend significantly on the specific situation in each distribution area, i.e. DER penetration, technical network characteristics, grid topology, etc.

It must be noted though that these three different solutions present significantly different cost structures. Whilst grid reinforcement or conventional reactive power control devices are mostly CAPEX-based, the use of flexibilities requires lower CAPEX at the expense of higher software costs as well as compensations to the flexibility providers, i.e. mostly OPEX-based. However, as discussed in section 4, most regulatory frameworks tend to promote capital-intensive solutions. Whilst, in principle, this would ensure the recovery of the DSO-incurred CAPEX required for this functionality, this constitutes a barrier for the DSO for two main reasons: i) lower grid investments would not result in a benefit for the DSO as its remuneration would decrease accordingly, and ii) the DSO may even end up in a worse position as a result of the increase in OPEX.

One may argue that this could be solved by simply mandating DSOs to submit investment plans, including all the three possibilities adequately justified through CBA studies, and setting allowed revenues accordingly. However, in this case, the regulator would require significant resources to assess, virtually on a case by case basis, that the solution proposed by the DSO is the most efficient one.

A last topic that may affect the view of the DSO is that of network losses. The economic SRA results showed that this can be an added benefit of the tVPP, but that it rarely would justify by itself its implementation. This benefit has been allocated to the DSO. Nevertheless, this would naturally depend on the existence of specific incentive schemes allowing DSOs to benefit from a reduction in network losses as well as on the strength of these incentives. However, in case the impact of the tVPP on network losses is uncertain or even potentially negative, the presence of an ill-designed incentive mechanisms, which do not capture the specific conditions of each distribution area, may even be detrimental to the DSO.

- **Flexibility operator perspective:**

The key elements to determine the viability of the tVPP are i) the existence and design of local flexibility mechanisms enabling its business model and ii) the amount of third-party flexibility, i.e. from resources exogenous to the DSO, that is needed by the DSO.

The first factor is a straightforward pre-condition. In the absence of local flexibility mechanisms, or if these are based mostly or exclusively on mandatory requirements, the tVPP would have no room for business. However, as shown by the economic SRA, this is far from the only requirements for financial viability. In many scenarios analysed in the economic SRA, the tVPP would not recover its costs. The reasons for this is either because the local grid did not have significant need for it (as discussed above, loss reduction does not seem to justify its implementation by itself), or because DSO-owned resources, whose activation is generally less costly, were enough to solve most voltage issues.

[69] Increasing the allowed voltage drop/rise could be an additional solution. In fact, it can be seen that the Portuguese case, where a range of ±10% was deemed acceptable, generally presented fewer voltage issues than the Slovenian case, where a range of ±5% was considered. However, this presumably would require an enhanced grid monitoring.

However, in the coming future, DSOs may require more and more of this flexibility. As DER penetration increases, a number of technical problems (e.g. over/under voltage and overload) that may not be solved with OLTC and/or capacitor banks may arise. For instance, if DG is concentrated in only one of the outgoing feeders of a primary substations whereas the remaining parallel feeders are dominated by demand, an OLTC may be unable to solve a voltage rise caused by DG as changing the tap position to address this problem in the DG-dominated feeder could lead to undervoltage problems for the demand connected to the other feeders. Likewise, capacitor banks are designed to solve undervoltage problems caused by demand through the injection of reactive power. Thus, they may be unable to solve a voltage rise caused by DG or voltage problems that require changes in the active power, e.g. in networks with high R/X ratio.

In this context, the tVPP may have a relevant role, as DSO-owned resources might not be enough to face them. In order to prevent flexibility operators from seeing a negative result, even in scenarios where they would be needed, the following regulatory considerations should be taken into account:

- VPP operators should presumably be active in several markets/services to ensure profitability. This requires ensuring access to VPPs to all markets on a level playing field, as it will be discussed for cluster 3 below. A VPP providing services exclusively to the DSO, especially if network problems arise sporadically and depending on meteorological conditions, may not receive enough revenues or face very high risks.
- The economic SRA only considered a payment based on activation. However, there are several alternatives for the definition of the flexibility product and its remuneration that could mitigate the risk of the tVPP by providing a more stable and predictable revenue stream. For instance, tVPPs may be remunerated based on availability besides activation. Likewise, this availability payment could be stipulated in a long-term contract, e.g. allocated through an auction mechanism, as opposed to a short-term purchase only. This would mitigate the risks of the tVPP and provide the DSO with some certainty regarding the fact that the tVPP will be available when required. The DSO may also be interested in such an option in cases where, even if grid reinforcements would be in principle less costly, reinforcing the grid is not possible or it would take a very long time due to permits, etc. (e.g. naturally protected areas, historical city centres).
- Results showed that local network conditions are key to determine the real needs of the DSO. Therefore, fixed mandatory requirements on grid users may be ineffective and inefficient.
- Depending on its business model, the VPP may operate its own resources or act as an independent aggregator operating third-party's resources. In the latter case, the VPP operator would presumably have to pay the final flexibility providers. Whilst this could jeopardize the business model of the tVPP, the economic SRA results show that these users may also be benefitting from the increased RES production injected into the grid thanks to the tVPP in the form of lower curtailment rates[70].

[70] In a long-term horizon, this benefit may be materialized in the form of lower connection costs or a swifter grid connection process.

5.2. Cluster 2: Flexibility Management for Optimized LV Network Operation

The **main costs** involved in this cluster are very similar to the ones discussed for the previous one, replacing the tVPP with residential consumers. The DSO would thus require software, and monitoring and control devices, whereas end consumers would incur in the costs corresponding to the HEMS as well as any necessary upgrade in their home appliances. As discussed above, the payments from DSOs to the end users for the use of flexibility ought to be considered as transfers between agents rather than actual costs.

Concerning the **benefits** derived from this cluster, these are essentially the same as discussed for cluster 1. The only added benefit considered for this cluster is the reduction in the electricity bill achieved by the consumers equipped with a HEMS[71].

In this case, the **key lessons learnt** from the results of **the economic SRA** can be summarized as follows:

- In most of the scenarios analysed, the overall economic results are negative. However, the allocation of costs and benefits is not evenly distributed across stakeholders. Whilst the economic assessment from the DSO perspective is always negative, the net benefits for HEMS owners and society are generally positive.
- In the few scenarios where the overall net benefits are positive this is because the societal benefits are particularly large. In practice, this implies that the business case is more likely to happen where the use of flexibility allows solving significant voltage problems in the local grid driven by a very high DER penetration and its technical characteristics (e.g. R/X ratio).
- DSO-owned OLTCs may solve voltage problems in network dominated by demand. However, they may be ineffective to address overvoltages caused by DG units.
- The provision of flexibility services does not seem to be a major driver for the adoption of HEMS by end-users. Therefore, energy savings or other non-economic benefits will determine HEMS penetration levels and their availability for the use of flexibility in the LV.

These results have **regulatory implications** for both the DSO and end consumers. The view of the DSO and the design of local flexibility mechanisms were already extensively discussed for cluster 1. Therefore, the discussion in this section will mostly focus on the end-user perspective and the drivers for the adoption of HEMS, as a key enabling technology for this functionality.

The cost of the HEMS would be, in principle, born by the end consumer. Despite the fact that this may seem as a way to reduce upfront CAPEX by the DSO as compared to conventional solutions (e.g. OLTCs), there is a risk that end-users will not adopt this technology or that, even if they do, they may not be willing to provide flexibility.

[71] Note that bill savings would probably imply additional savings in fuel costs and CO_2 emissions. However, the approach followed prevents a double counting of these benefits. The societal benefits are computed accounting only for the fuel and emissions costs that are achieved only thanks to the increased RES production integrated, thus excluding the ones corresponding to the end user savings.

A straightforward approach to tackle this risk would consist in setting mandatory requirements on those end-users that may cause a more significant impact on the LV grid, such as self-generators or EV charging points[72]. This approach would be similar to the feed-in limitations set to PV generators in Germany (see section 4.3.1.2). However, doing this can face several challenges. Firstly, given that local network conditions can vary significantly across areas, this may result in imposing an unnecessary requirement in some areas. Secondly, this would represent an added cost, which could be significant for small users, hampering the adoption of solar PV or EVs. Lastly, this type of requirements can be controversial, particularly when residential consumers are affected, and be seen as a purposeful barrier for self-generation.

On the contrary, a potential approach to tackle this risk would be by ensuring that retail tariffs encourage end-users to behave flexibly. This would also allow consumers to benefit from energy savings which, at the same time, could bring about peak load reductions and long-term system savings. As discussed in section 4.4.2, retail tariffs comprise the regulated charges on the one hand, and the energy costs (and retail fees) on the other. The scope of regulation would be different for the two components, as discussed on the ensuing.

- Energy prices: dynamic tariffs that follow hourly energy prices are, in principle, the most suitable to promote flexibility and drive the adoption of HEMS. However, in liberalized retail markets, regulation cannot determine the structure of energy prices seen by end consumers as these are freely negotiated between them (in practice, small consumers essentially choose from the commercial offerings of different retailers). Nonetheless, regulation may still favour this pricing scheme through two mechanisms:
    - i) Using dynamic pricing as the default tariff (if it exists[73]) for consumers without a retailer either permanently or temporarily. For instance, the default tariff in Spain, called voluntary price for the small consumer or PVPC, is computed as the day-ahead spot market prices plus the regulated charges.
    - ii) Mandating retailers to include a real-time pricing option in their commercial offering. contracts. In fact, Article 11 of the recast EU Electricity Directive (Directive 2019/944) states that final customers who have a smart meter should have the right to sign a *"dynamic electricity price contract with at least one supplier and with every supplier that has more than 200 000 final customers"*.
- Regulated charges: regulated charges, especially those associated with policy costs, should avoid distorting the efficient response of end consumers. As discussed above, the most conditions would therefore be when regulated costs and taxes account for a lower share of overall electricity prices, ad where network costs account for most of the regulated costs. However, the country review showed that this is not usually the case in many European countries. Addressing this problem has proven quite challenging, particularly considering that the most common policy cost is the extra remuneration to

[72] Load unbalances in the LV grid have not been analysed herein. However, the single-phase connection of solar PV units of EVs can significantly worsen load unbalances (Rodriguez-Calvo et al., 2017). This may be tackled by mandating certain users to have a three-phase connection of improving grid connection processes to minimize phase unbalances.
[73] According to (ACER, 2018), 27 out of 29 countries in EU-28 and Norway have suppliers of last resort.

RES[74]. These costs may be expected to decrease over the next years as RES technology costs decline. However, some studies reveal that this may not be necessarily the case (Gerres et al., 2019).

The large-scale penetration of RES that is foreseen in many European countries to comply with 2030 and 2050 decarbonization goals, may lead to a drop in the captured price of some intermittent RES technologies. This may be particularly noticeable for solar technologies whose increasing penetration would depress the market price in the central hours of the day[75]. Therefore, even if their installation costs decline over time, they may still require some remuneration over the market price due to the aforementioned effect. The impact of this effect on the retail tariff would depend on how RES generation enters the system. Merchant generators would indeed require additional support presumably financed through the regulated tariffs. On the contrary, the impact on the retail tariff would be lower if these generators sign power purchase agreements (PPA) with demand agents that limit their exposure to low market prices. In this regard, regulators may remove barriers for the development of this kind of PPAs.

5.3. Cluster 3: Large customer cVPP

In cluster 3, the main beneficiaries studied in the economic SRA are the aggregator (cVPP), and the DER owners, in this case large consumers providing demand response. These agents offer flexibility in balancing markets (in this case, the mFRR market), and therefore receive a remuneration for this service. This remuneration is then shared by the aggregator and the flexibility provider. The DSO has a minor role in this cluster, bearing some costs regarding the TLS and the Gm-Hub, without important benefits associated to this cluster. One could argue that the TSO could possible benefit from this cluster, from having access to more (and possibly cheaper) reserves. Nevertheless, these benefits fall out of the scope of this economic SRA. Therefore, for cluster 3, we limit to look at the **aggregator's** perspective and the **flexibility provider's** perspective.

Assessing the results of **the economic SRA**, the following **key lessons learnt** concerning the magnitude and allocation of these costs and benefits can be extracted:

- Both the number of DER aggregated and the average available flexibility per DER may play an important role in the economic results of the cVPP.
- Economic replicability is highly impacted by the procurement scheme of mFRR. In countries where capacity is procured (e.g. Slovenia), remuneration can be much higher than in countries where only activated energy is paid (e.g. Portugal).

The earnings on the tertiary reserve market are lower in Portugal compared with Slovenia, when considering pools with the same characteristics. This can be namely justified by fact than in Portugal only the energy activated is remunerated, while in Slovenia, mFRR products are paid on both availability and

[74] Some countries recover this cost, at least partly, through state budgets or green taxes. However, this discussion exceeds the scope of this report.

[75] Assuming aggregate large-scale electricity storage remains limited at system level.

activation. This situation shows an important regulatory characteristic that greatly impacts the economic viability of cluster 3, namely the procurement terms of mFRR.

In general terms, all balancing products (FCR, aFRR, mFRR, and RR) can be provided to the TSO in the form of availability (capacity), energy, or both. Additionally, procurement of capacity and energy may vary across the different countries. In some countries (e.g. Portugal and Spain), mFRR capacity provision is mandatory for available generators, while the activated energy is paid according to a merit order dispatch. This context can reduce to potential gains for both aggregators (cVPP) and flexibility providers, as shown in the economic SRA. In fact, overall capacity costs tend to be considerably higher than the cost of activated energy, as shown in Figure 51. Therefore, in countries where mFRR capacity provision is mandatory for centralized generators, economic replicability could be limited.

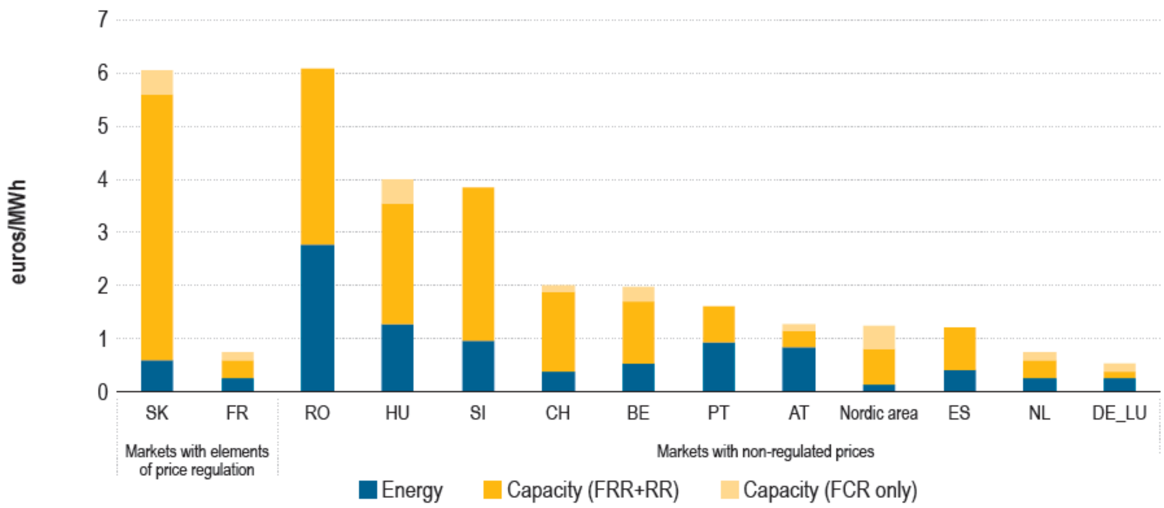


Figure 51: Overall costs of balancing (capacity and energy) over national electricity demand in a selection of European markets - 2017. Source: (ACER & CEER, 2018).

Another possible barrier created by mandatory provision of mFRR capacity is the high share of upward regulation offered into the market, considering that all generators are obliged to provide their capacity. The economic SRA showed that, at least for Portugal, this market design promotes a higher availability of upward regulation compared with downward. Considering that demand response will mostly offer upward regulation[76], a situation in which all generators have to offer their capacity may create a distorted market environment, not in line with the "level playing field" spirit promoted by the EU Target Model. From a society's perspective, promoting a level playing field may also be beneficial. The participation of DER as proposed in cluster 3, means that other agents are entering balancing markets, and therefore more competition and lower balancing costs can be expected.

Besides mFRR product definitions, another regulatory aspect that may play an important role in the economic replicability and scalability of cluster 3 are the rules on aggregation. In general, the economic SRA showed a limited potential for small pools and/or pools with limited flexibility. In Slovenia, for instance, pools with a small size are not economically feasible, regardless of the DER capacity aggregated. In the case

[76] Upward regulation means, from a generator's perspective, increasing the output. Therefore, when demand response reduces consumption, it is, in fact, acting like a generator increasing production.

of Portugal, pools with limited flexibility, regardless of their size, are not economically interesting. That is due to the relatively high fixed cost associated to each DER. In this context, aggregation rules may foster, or not, aggregation in the spirit of cluster 3. One the one hand, aggregation may be limited geographically, for instance limited by DSO/TSO concession area. This could lead to limited pool sizes, in countries or regions with multiple grid operators. Additionally, certain prequalification and minimum bid size requirements could limit the participation.

In cluster 3 too, the importance of allowing aggregator to participate in different markets in a seamless way becomes important. The barriers identified by the economic SRA on the limitation of small pools or pools of resources with reduced flexibility can be partially mitigated by allowing aggregators to participate in multiple markets. These may include other balancing markets such as the aFRR (cluster 4), DSO service provision (clusters 2 and 3), and other markets not directly analysed in this economic-regulatory SRA, such as congestions management, voltage control, black start etc. Such participation of aggregators in different markets is still very incipient in most countries, considering that most of the abovementioned services are not traded in organized markets yet.

In summary, in addition to a somewhat binary replicability compatibility, several regulatory aspects may impact the overall economic scalability and replicability of cluster 3, specially the way mFRR capacity and energy are procured by TSO, aggregation rules for DR participation in mFRR markets, and overall participation of aggregation in multiple markets.

5.4. Cluster 4: Office Buildings Aggregation

Cluster 4 is mainly focused on the costs and benefits of the aggregator and the flexibility provider, similarly to cluster 3. In this cluster however, the flexibility providers are commercial buildings, and the cVPP offer their flexibility in both the aFRR and the mFRR. To highlight the differences with regards to cluster 3, we focus mainly on the aFRR market, as rules and economic results may differ from the mFRR.

The results observed by the economic SRA for the secondary reserve market participation are considerably better when compared against the tertiary reserve market. This can be mainly justified by the following:

1. aFRR products are paid on capacity, which represented around 45% of the total revenues in the conditions simulated. This replicability analysis, with different markets within the same country, reinforces the importance of the remuneration scheme employed to enable these new market players.
2. The ratio between the activated balancing energy and the capacity is much higher, meaning that, once contracted to provide regulation band, the uncertainty around being activated is significantly lower.

Nevertheless, main regulatory aspects of the design of this balancing market have been disregarded for the purpose of this analysis because are currently not well-suited for DER. Besides the technical pre-qualification requirements that have not been considered, the actual bidding relation between up and down capacity (i.e. 2/3 and 1/3, respectively) on the regulation band, required by the TSO, could not be fulfil by the pool since much more flexibility was offered up than down. Indeed, this requirement imposes a barrier on the participation of DR since the provision of downward capacity by consumers implies that whenever aFRR is activated downwards, they have to increase consumption – something which is challenging for many loads, and can be expensive, depending on the network tariff that applies during the delivery period.

In practice, bidding symmetry can represent an important barrier for the overall feasibility of cluster 4. A requirement of providing upward and downward capacity under a certain ration, although not as strict as symmetrical bidding, may undermine the profitability of cluster 4, considering that providing downward regulation may be expensive.

Technical issues such as prequalification procedures and monitoring requirements can also impact the profitability of this cluster. As observed by the economic SRA, the hardware costs (e.g. RTUs) had a relevant impact in the cVPP’s results in cluster 4. If specific infrastructure is necessary for each DER to be able to provide this balancing service, economies of scale become limited, and the pay-back time required for the additional equipment may become too long to justify the investment.

In summary, the lessons learned by cluster 4 build-up on those from cluster 3. The economic SRA observed the impacts of bidding symmetry requirements and the costs of additional hardware deployed to a large number of small flexibility providers. Additionally, regulatory aspects discussed for cluster 3 also apply to cluster 4, namely the procurement scheme of balancing reserves (capacity and energy), the procurement environment of balancing capacity (market vs. mandatory), and the impact of aggregation rules, allowing for a feasible portfolio size. Finally, as mentioned previously, regulation can play an important role in allowing aggregators to participate in multiple energy and service markets, contributing for viability of the overall business case of aggregators and flexibility providers.

6. Conclusions

6.1. Economic SRA

Cluster 1 consisted on the application of the InteGrid tools to medium voltage networks. The analysis allowed concluding that its economic interest and potential to scale up depends very much on the network characteristics, particularly the networks must be stressed by the integration of considerable amounts of renewable energy. It was observed that smaller scale applications in stressed networks, which are not interesting from an economic perspective, can become interesting once they are scaled up. Therefore, increasing scale can be a condition for economic feasibility. In non-stressed networks with moderate renewable generation penetration, one can even encounter situations where there are no technical issues to solve and therefore the only economic value comes from the optimization of network losses, which is not enough to cover the costs of the DSO tools and of the technical VPP (flexibility operator). There is no business case for flexibility operators in most of the analysed scenarios. In fact, the technical VPP only proved feasible in a scenario where a cogeneration plant had its flexibility constantly controlled by it in order to optimize network losses. The same does not happen when wind and solar generation are integrated in the networks, as the need to use flexibility depends on weather patterns. One can be led to think the technical VPP is a concept with low perspectives of success. However, this view is too simplistic. In reality, the possibility to use the flexibilities provided by a technical VPP provides a risk mitigation tool for the grid operation planning, particularly for grids with limited redundancy operation. Although the assets owned by the DSO such as OLTCs and capacitor banks can be used to optimize network losses and solve any issues caused by the moderate integration of renewable energy, the analysis showed that when higher penetrations of renewable energy are considered, although the business case is not positive for the technical VPP, it is actually used to control the flexibilities of generation and demand to solve over/undervoltage issues.

Cluster 2 applied the InteGrid tools to low voltage networks and the main difference to Cluster 1 is that flexibility is now provided by the HEMS users, instead of the technical VPP. As for Cluster 1, the characteristics of the network are key to determine the value of the application of the InteGrid tools. This cluster captures the most value and can actually be viable in larger rural networks with high renewable energy penetration. When scaled up, this cluster can prove interesting for the same type of networks, even with moderate renewable energy penetration. However, the scale must be big enough as the analysis showed that for Portugal, considering the size of EDP’s network, the cluster becomes viable after being scaled, but the same does not hold true for the case of Slovenia given the significantly smaller network of Elektro Ljubljana. It is also interesting to observe that using the flexibility provided by the HEMS can be more advantageous for the DSO than investing in solutions such as batteries or transformers equipped with OLTC. However, this is a high-risk option in a real implementation since it depends on the engagement of domestic consumers. Regulatory changes are required to mitigate this risk, as will be described further below. Nevertheless, a balanced strategy considering a mix of HEMS use and own equipment seems adequate for the DSOs as well, although with less positive business cases.

Cluster 3 shed light on the requirements for profitable operation of commercial VPPs, while illustrating also a particular application for a wastewater treatment plant in Portugal. Essentially the replicability analysis demonstrated that almost all scenarios were viable in Slovenia. The exact opposite happened for the case of Portugal. The main difference between these countries is the fact mFRR is remunerated on availability (capacity) and mobilization in Slovenia and in Portugal it is only remunerated on mobilization. Moreover, the business case in Portugal, especially for pools offering upwards reserve is hurt by the abundance of this product in the market which also results from a regulatory obligation. The risks for a commercial VPP to operate in Portugal under current regulation are regarded as too high by our analysis. The particular application to the wastewater plant only validated this reasoning, since it showed that the costs incurred by the plant to estimate and offer its flexibility on the mFRR market largely surpass the attained revenues.

Cluster 4 focused on the considering the application of flexibility offered by a set of office buildings, considering an aggregator. However, it was considered that it was technically viable to offer aFRR in the market which, even in Portugal, receives compensation for capacity and mobilization. The cluster application is viable for aFRR (and not for mFRR), essentially because there is revenue resulting from the capacity offers and also because the likelihood of mobilization after the capacity (regulation band) was contracted is much higher for aFRR than for mFRR.

6.2. Regulatory Replicability

The regulatory replicability analysis presented in this InteGrid deliverable looked at ten different countries, namely Portugal, Slovenia, Sweden, Austria, Spain, Belgium, France, Germany, Great Britain, and Italy. The first five countries are the InteGrid target countries, while the last five are other EU Member States chosen for the replicability analysis based on the several regulatory aspects that could be informative in the context of this analysis. For each cluster, several regulatory barriers were identified, and analysed for the five target countries and the selected EU Member States.

From a regulatory perspective, the four clusters can be grouped into two main concepts, namely **active grid operation using flexibilities** (clusters 1 and 2) and **demand-side participation in balancing markets** (clusters 3 and 4). The former is mainly assessed from the perspective of the DSO that needs the proper incentives to procure flexibility for grid operation in the MV and LV network respectively. The latter is focused on the aggregator (cVPP) and the flexibility provider (DER). These agents need a proper balancing market design and aggregation rules for the replication of clusters 3 and 4.

The replicability of cluster 1 is associated to a great extent to the DSO revenue regulation, the existence of local flexibility markets, and the incentives for the reduction of energy losses. The analysis of the ten countries shows that most of them still have a CAPEX-oriented regulatory framework. The UK and to some degree Italy are the ones that escape this trend. The former has an advanced economic regulation for DSOs, combining several innovative mechanisms, while the latter is shifting to TOTEX approach. The existence of local flexibility platforms is still limited in most countries. However, the UK and Germany have already implemented large-scale trials or even an initial commercial implementation. Finally, incentives for the reduction of losses are present in most countries, although in many cases there are elements that dilute the strength of these incentives. Moreover, it was observed that they rarely consider the potential impact of DER on grid losses.

From the point of view of regulation, clusters 1 and 2 are very similar. Nonetheless, since cluster 2 requires the flexibility provision by residential consumers, tariff design is an additional topic to consider. Regulated charges and retail tariffs will play an important role in providing price signals to consumers, and consequently incentivizing them to adopt the HEMS. However, the large weight of regulated charges, and particularly policy costs and taxes, on the overall retail tariff tend to weaken the flexibility incentives sent through network tariffs and energy prices. In this regard, Slovenia and the UK are the countries with a more favourable cost structure enabling stronger flexibility signals.

Overall, the results show that clusters 1 and 2 are still far from being totally compatible with current regulation in most countries, mostly due to the lack of advanced local flexibility mechanisms and a network regulation that still tends to favour grid reinforcement over the use of flexibility. Moreover, it is worth mentioning that the lack of appropriate incentives for use of DER flexibility may lead to an even higher grid reinforcement need, as more DER are deployed to the distribution grid.

The key regulatory aspects for clusters 3 and 4 are the balancing market design and rules on aggregation. Replicability of these two clusters require that balancing markets should not only allow for the participation of demand-response but also products should be designed in such a way that demand participation is encouraged in a level playing field. For cluster 3, we specifically focus on the mFRR product, while for cluster 4 the focus is the aFRR. This research concludes that the former is a lot more open for demand response that the latter. The aFRR is still closed to DR participation in many of the analysed countries, and conditions for participation are stricter.

Aggregation also plays a key role in the compatibility of both clusters 3 and 4. In general, a correlation between the openness of balancing markets to DR and the possibility of DR aggregation in these markets can be observed. In other words, when markets (aFRR and mFRR) are open to demand response, they are also open to aggregated demand response. Nevertheless, it does not mean that products and aggregation rules (such as prequalification requirements) are always suitable for this activity. Moreover, clusters 3 and 4 present important differences regarding aggregation. Considering the in cluster 3, the cVPP is the aggregator, two more aspects have to be considered, namely the possibility of aggregating different types of DER and the rules on independent aggregators. The analysis showed that some countries such as France and Belgium have more advanced regulatory frameworks for aggregators, including rules on balancing responsibility for independent aggregators. On the other hand, countries such as Portugal and Spain are lagging on these aspects, although changes are expected soon as the Network Codes are implemented.

From a regulatory perspective, cluster 3 presents a good replication potential in several countries considered in this report. France and Belgium are clearly the most compatible ones, while Germany, Austria and Slovenia can also be considered compatible to some extent. Cluster 4 however, is less compatible, mainly due to the restrictions for DR participation in aFRR. Germany and Slovenia are the most compatible, although many barriers exist even in these two countries.

6.3. Economic and regulatory interaction

This deliverable looked in depth at the economic scalability and replicability as well as the regulatory replicability of the different cluster considered. However, one can point out that these two aspects are not disconnected from each other, and that regulation greatly influences in the potential for economic scalability and replicability. More specifically, regulation can impact the allocation of the calculated costs and benefits among stakeholders, or whether external costs are internalized. For this reason, this report also made an additional exercise, consisting on the identification of the main regulatory aspects that could have an impact on the results observed by the economic SRA.

For clusters 1 and 2, the DSO may be benefited from the reduction in voltage deviations by using flexibility, as shown by the economic SRA. This could be seen as a proxy for grid reinforcement deferral, as this would be a natural way for the DSO to solve voltage problems. Most regulatory frameworks however, tend to promote capital-intensive solutions, while the use of flexibility would require the recognition and incentives for the OPEX associated to the flexibility procurement. For the tVPP, the economic SRA showed a limited economic potential, and this situation can be partially due to the limited constraints in the network, forcing DSOs to use flexibility. In order to have a more favourable business case, VPPs could provide services in multiple markets, and DSO procurement of flexibility can be done not only base on the energy activated, but also on the capacity reserved. Specifically, for cluster 2, the economic SRA reveals that the biggest benefit for residential consumers is the energy savings from the HEMS, rather than the provision of flexibility. Therefore, tariff design can play an important role in incentivizing consumer to opt for the installation of the HEMS. Dynamic tariffs (for default tariffs) and real-time pricing options for retail tariffs can give price signals for the consumers, enabling savings by the HEMS. The regulated charges can also have an effect, as they may distort these price signals.

Cluster 3 and 4, on the other hand, focus on the provision of balancing services by flexibility providers, aggregated by retailers or cVPPs. The economic SRA showed firstly the importance of the balancing procurement method for the overall viability of these clusters. The procurement of capacity in a market-based fashion can improve the economic results for aggregators and flexibility providers. Another conclusion from the economic SRA is the relevance of the portfolio of the aggregators, both in number of aggregated units, and type of units (in terms of flexible capacity available). This reinforces the need for appropriate aggregation rules, that may enable aggregation in a seamless way. Moreover, product definition can also be an important barrier for the economic replicability. Products that require bid symmetry, or even compliance to a predefined upward-downward ratio may undermine the potential benefits for aggregators and consequently for flexibility providers.

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InteGrid Documents

[REF D1.3] Current market and regulatory incentives and barriers

[REF D2.2] Functions to Improve Grid Management Tools

[REF D2.3] Functions to support grid user active participation in grid management and markets

[REF D6.1] Concept of the Market Hub, Central Platform and Services

[REF D7.1] Updated comparative analysis of regulatory frameworks in the target countries

[REF D7.5] Business Models – Internal Deliverable

[REF D8.1] Technical Scalability and Replicability of the InteGrid smart grid functionalities

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Annex 1 – Additional Results (Economic SRA)

Cluster 03

Table 57: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 0.5 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	-447182	-465957	-374423	-282890	-191356	-99823	-8289	83245	174778	266312	357845	339071	430604	522138	613671	705205
1	-465957	-484732	-393198	-301665	-210131	-118597	-27064	64470	156003	247537	339071	320296	411829	503363	594897	686430
2	-386389	-405163	-313630	-222096	-130563	-39029	52504	144038	235572	327105	418639	399864	491398	582931	674465	765998
3	-306820	-325595	-234062	-142528	-50994	40539	132073	223606	315140	406673	498207	479432	570966	662499	754033	845567
4	-227252	-246027	-154493	-62960	28574	120107	211641	303175	394708	486242	577775	559000	650534	742068	833601	925135
5	-147684	-166459	-74925	16608	108142	199676	291209	382743	474276	565810	657344	638569	730102	821636	913169	1004703
6	-68116	-86891	4643	96177	187710	279244	370777	462311	553845	645378	736912	718137	809670	901204	992738	1084271
7	11452	-7322	84211	175745	267278	358812	450346	541879	633413	724946	816480	797705	889239	980772	1072306	1163839
8	91021	72246	163779	255313	346847	438380	529914	621447	712981	804515	896048	877273	968807	1060341	1151874	1243408
9	170589	151814	243348	334881	426415	517948	609482	701016	792549	884083	975616	956842	1048375	1139909	1231442	1322976
10	250157	231382	322916	414449	505983	597517	689050	780584	872117	963651	1055185	1036410	1127943	1219477	1311011	1402544
11	231382	212607	304141	395675	487208	578742	670275	761809	853343	944876	1036410	1017635	1109169	1200702	1292236	1383769
12	310950	292176	383709	475243	566776	658310	749844	841377	932911	1024444	1115978	1097203	1188737	1280270	1371804	1463338
13	390519	371744	463277	554811	646345	737878	829412	920945	1012479	1104013	1195546	1176771	1268305	1359839	1451372	1542906
14	470087	451312	542846	634379	725913	817446	908980	1000514	1092047	1183581	1275114	1256340	1347873	1439407	1530940	1622474
15	549655	530880	622414	713947	805481	897015	988548	1080082	1171615	1263149	1354683	1335908	1427441	1518975	1610509	1702042
16	629223	610448	701982	793516	885049	976583	1068116	1159650	1251184	1342717	1434251	1415476	1507010	1598543	1690077	1781610
17	708791	690017	781550	873084	964617	1056151	1147685	1239218	1330752	1422285	1513819	1495044	1586578	1678111	1769645	1861179
18	788360	769585	861118	952652	1044186	1135719	1227253	1318786	1410320	1501854	1593387	1574612	1666146	1757680	1849213	1940747
19	867928	849153	940687	1032220	1123754	1215287	1306821	1398355	1489888	1581422	1672955	1654181	1745714	1837248	1928781	2020315
20	947496	928721	1020255	1111788	1203322	1294856	1386389	1477923	1569456	1660990	1752524	1733749	1825282	1916816	2008350	2099883
21	928721	909946	1001480	1093014	1184547	1276081	1367614	1459148	1550682	1642215	1733749	1714974	1806508	1898041	1989575	2081108

Down \ Up	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	796739	888272	979806	1071339	1162873	1144098	1235632	1327165	1418699	1510233	1601766	1693300	1784833	1876367	1967901
1	777964	869497	961031	1052565	1144098	1125323	1216857	1308391	1399924	1491458	1582991	1674525	1766059	1857592	1949126
2	857532	949066	1040599	1132133	1223666	1204892	1296425	1387959	1479492	1571026	1662560	1754093	1845627	1937160	2028694
3	937100	1028634	1120167	1211701	1303235	1284460	1375993	1467527	1559061	1650594	1742128	1833661	1925195	2016729	2108262
4	1016668	1108202	1199736	1291269	1382803	1364028	1455562	1547095	1638629	1730162	1821696	1913230	2004763	2096297	2187830
5	1096237	1187770	1279304	1370837	1462371	1443596	1535130	1626663	1718197	1809731	1901264	1992798	2084331	2175865	2267399
6	1175805	1267338	1358872	1450406	1541939	1523164	1614698	1706232	1797765	1889299	1980832	2072366	2163900	2255433	2346967
7	1255373	1346907	1438440	1529974	1621507	1602733	1694266	1785800	1877333	1968867	2060401	2151934	2243468	2335001	2426535
8	1334941	1426475	1518008	1609542	1701076	1682301	1773834	1865368	1956902	2048435	2139969	2231502	2323036	2414570	2506103
9	1414510	1506043	1597577	1689110	1780644	1761869	1853403	1944936	2036470	2128003	2219537	2311071	2402604	2494138	2585671
10	1494078	1585611	1677145	1768679	1860212	1841437	1932971	2024504	2116038	2207572	2299105	2390639	2482172	2573706	2665240
11	1475303	1566836	1658370	1749904	1841437	1822662	1914196	2005730	2097263	2188797	2280330	2371864	2463398	2554931	2646465
12	1554871	1646405	1737938	1829472	1921005	1902231	1993764	2085298	2176831	2268365	2359899	2451432	2542966	2634499	2726033
13	1634439	1725973	1817507	1909040	2000574	1981799	2073332	2164866	2256400	2347933	2439467	2531000	2622534	2714068	2805601
14	1714008	1805541	1897075	1988608	2080142	2061367	2152901	2244434	2335968	2427501	2519035	2610569	2702102	2793636	2885169
15	1793576	1885109	1976643	2068177	2159710	2140935	2232469	2324002	2415536	2507070	2598603	2690137	2781670	2873204	2964738
16	1873144	1964678	2056211	2147745	2239278	2220504	2312037	2403571	2495104	2586638	2678171	2769705	2861239	2952772	3044306
17	1952712	2044246	2135779	2227313	2318847	2300072	2391605	2483139	2574673	2666206	2757740	2849273	2940807	3032340	3123874
18	2032280	2123814	2215348	2306881	2398415	2379640	2471174	2562707	2654241	2745774	2837308	2928842	3020375	3111909	3203442
19	2111849	2203382	2294916	2386449	2477983	2459208	2550742	2642275	2733809	2825343	2916876	3008410	3099943	3191477	3283011
20	2191417	2282950	2374484	2466018	2557551	2538776	2630310	2721844	2813377	2904911	2996444	3087978	3179512	3271045	3362579
21	2172642	2264176	2355709	2447243	2538776	2520002	2611535	2703069	2794602	2886136	2977670	3069203	3160737	3252270	3343804

Up Down	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
22	1008290	989515	1081048	1172582	1264115	1355649	1447183	1538716	1630250	1721783	1813317	1794542	1886076	1977609	2069143	2160677	2252210	2343744	2435277	2526811	2618345	2599570	2691103	2782637	2874171	2965704	3057238	3148771	3240305	3331839	3423372
23	1087858	1069083	1160616	1252150	1343684	1435217	1526751	1618284	1709818	1801352	1892885	1874110	1965644	2057178	2148711	2240245	2331778	2423312	2514846	2606379	2697913	2679138	2770672	2862205	2953739	3045272	3136806	3228340	3319873	3411407	3502940
24	1167426	1148651	1240185	1331718	1423252	1514785	1606319	1697853	1789386	1880920	1972453	1953679	2045212	2136746	2228279	2319813	2411347	2502880	2594414	2685947	2777481	2758706	2850240	2941773	3033307	3124841	3216374	3307908	3399441	3490975	3582509
25	1246994	1228219	1319753	1411287	1502820	1594354	1685887	1777421	1868954	1960488	2052022	2033247	2124780	2216314	2307848	2399381	2490915	2582448	2673982	2765516	2857049	2838274	2929808	3021342	3112875	3204409	3295942	3387476	3479010	3570543	3662077
26	1326562	1307788	1399321	1490855	1582388	1673922	1765456	1856989	1948523	2040056	2131590	2112815	2204349	2295882	2387416	2478949	2570483	2662017	2753550	2845084	2936617	2917843	3009376	3100910	3192443	3283977	3375511	3467044	3558578	3650111	3741645
27	1406131	1387356	1478889	1570423	1661957	1753490	1845024	1936557	2028091	2119625	2211158	2192383	2283917	2375450	2466984	2558518	2650051	2741585	2833118	2924652	3016186	2997411	3088944	3180478	3272012	3363545	3455079	3546612	3638146	3729680	3821213
28	1485699	1466924	1558458	1649991	1741525	1833058	1924592	2016126	2107659	2199193	2290726	2271952	2363485	2455019	2546552	2638086	2729619	2821153	2912687	3004220	3095754	3076979	3168513	3260046	3351580	3443113	3534647	3626181	3717714	3809248	3900781
29	1565267	1546492	1638026	1729559	1821093	1912627	2004160	2095694	2187227	2278761	2370295	2351520	2443053	2534587	2626121	2717654	2809188	2900721	2992255	3083788	3175322	3156547	3248081	3339614	3431148	3522682	3614215	3705749	3797282	3888816	3980350
30	1644835	1626060	1717594	1809128	1900661	1992195	2083728	2175262	2266796	2358329	2449863	2431088	2522622	2614155	2705689	2797222	2888756	2980290	3071823	3163357	3254890	3236115	3327649	3419183	3510716	3602250	3693783	3785317	3876851	3968384	4059918

Table 58: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 0.75 MW. Complete matrix.

Down Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-465957	-365036	-264115	-172581	-71660	29261	120794	221715	322636	414170	404783	505704	597237	698158	799079	890613	991534	1092455	1183988	1284909	1275522	1367056	1467977	1568898	1660431	1761352	1862273	1953807	2054728	2155649
1	-465957	-475344	-374423	-282890	-181969	-81048	10486	111407	212328	303862	404783	395395	486929	587850	688771	780304	881225	982146	1073680	1174601	1275522	1256747	1357668	1458589	1550123	1651044	1751965	1843498	1944419	2045340	2136874
2	-377001	-386389	-294855	-193934	-93013	-1479	99442	200363	291896	392817	493738	474963	575884	676805	768339	869260	970181	1061715	1162636	1263557	1355090	1345703	1446624	1538157	1639078	1739999	1831533	1932454	2033375	2124909	2225830
3	-288046	-306820	-205899	-104978	-13445	87476	188397	279931	380852	481773	573306	563919	664840	756374	857295	958216	1049749	1150670	1251591	1343125	1444046	1434658	1526192	1627113	1728034	1819568	1920489	2021410	2112943	2213864	2314785
4	-208477	-217865	-116944	-25410	75511	176432	267965	368886	469807	561341	662262	652875	744408	845329	946250	1037784	1138705	1239626	1331159	1432080	1533001	1514227	1615148	1716069	1807602	1908523	2009444	2100978	2201899	2302820	2394353
5	-119522	-128909	-37376	63545	164466	256000	356921	457842	549376	650297	751218	732443	833364	934285	1025818	1126739	1227660	1319194	1420115	1521036	1612570	1603182	1704103	1795637	1896558	1997479	2089012	2189933	2290854	2382388	2483309
6	-30566	-49341	51580	152501	244035	344956	445877	537410	638331	739252	830786	821398	922319	1013853	1114774	1215695	1307229	1408150	1509071	1600604	1701525	1692138	1783671	1884592	1985513	2077047	2177968	2278889	2370423	2471344	2572265
7	49002	39615	140536	232069	332990	433911	525445	626366	727287	818820	919741	910354	1001888	1102809	1203730	1295263	1396184	1497105	1588639	1689560	1790481	1771706	1872627	1973548	2065082	2166003	2266924	2358457	2459378	2560299	2651833
8	137958	128570	220104	321025	421946	513479	614400	715321	806855	907776	1008697	989922	1090843	1191764	1283298	1384219	1485140	1576673	1677594	1778515	1870049	1860662	1961583	2053116	2154037	2254958	2346492	2447413	2548334	2639868	2740789
9	226913	208138	309059	409980	501514	602435	703356	794890	895811	996732	1088265	1078878	1179799	1271332	1372253	1473175	1564708	1665629	1766550	1858084	1959005	1949617	2041151	2142072	2242993	2334527	2435448	2536369	2627902	2728823	2829744
10	306481	297094	398015	489549	590470	691391	782924	883845	984766	1076300	1177221	1167834	1259367	1360288	1461209	1552743	1653664	1754585	1846118	1947039	2047960	2029186	2130107	2231028	2322561	2423482	2524403	2615937	2716858	2817779	2909312
11	297094	287707	379240	480161	581082	672616	773537	874458	965991	1066913	1167834	1149059	1249980	1350901	1442434	1543355	1644276	1735810	1836731	1937652	2029186	2019798	2120719	2212253	2313174	2414095	2505628	2606549	2707470	2799004	2899925
12	386050	367275	468196	569117	660650	761572	862493	954026	1054947	1155868	1247402	1238014	1338935	1430469	1531390	1632311	1723845	1824766	1925687	2017220	2118141	2108754	2200287	2301208	2402129	2493663	2594584	2695505	2787039	2887960	2988881
13	465618	456231	557152	648685	749606	850527	942061	1042982	1143903	1235436	1336357	1326970	1418504	1519425	1620346	1711879	1812800	1913721	2005255	2106176	2207097	2188322	2289243	2390164	2481698	2582619	2683540	2775073	2875994	2976915	3068449
14	554574	545186	636720	737641	838562	930095	1031016	1131937	1223471	1324392	1425313	1406538	1507459	1608380	1699914	1800835	1901756	1993289	2094210	2195131	2286665	2277278	2378199	2469732	2570653	2671574	2763108	2864029	2964950	3056483	3157404
15	643529	624754	725675	826596	918130	1019051	1119972	1211506	1312427	1413348	1504881	1495494	1596415	1687948	1788869	1889790	1981324	2082245	2183166	2274700	2375621	2366233	2457767	2558688	2659609	2751142	2852063	2952984	3044518	3145439	3246360

16	723097	713710	814631	906165	1007086	1108007	1199540	1300461	1401382	1492916	1593837	1584449	1675983	1776904	1877825	1969359	2070280	2171201	2262734	2363655	2464576	2445801	2546722	2647643	2739177	2840098	2941019	3032553	3133474	3234395	3325928
17	812053	802666	894199	995120	1096041	1187575	1288496	1389417	1480950	1581871	1682792	1664018	1764939	1865860	1957393	2058314	2159235	2250769	2351690	2452611	2544144	2534757	2635678	2727212	2828133	2929054	3020587	3121508	3222429	3313963	3414884
18	901009	882234	983155	1084076	1175609	1276530	1377451	1468985	1569906	1670827	1762361	1752973	1853894	1945428	2046349	2147270	2238803	2339724	2440645	2532179	2633100	2623713	2715246	2816167	2917088	3008622	3109543	3210464	3301997	3402918	3503839
19	980577	971189	1072110	1163644	1264565	1365486	1457020	1557941	1658862	1750395	1851316	1841929	1933462	2034383	2135304	2226838	2327759	2428680	2520214	2621135	2722056	2703281	2804202	2905123	2996656	3097577	3198498	3290032	3390953	3491874	3583408
20	1069532	1060145	1151679	1252600	1353521	1445054	1545975	1646896	1738430	1839351	1940272	1921497	2022418	2123339	2214873	2315794	2416715	2508248	2609169	2710090	2801624	2792236	2893158	2984691	3085612	3186533	3278067	3378988	3479909	3571442	3672363
21	1060145	1041370	1142291	1243212	1334746	1435667	1536588	1628121	1729042	1829963	1921497	1912110	2013031	2104564	2205485	2306406	2397940	2498861	2599782	2691315	2792236	2782849	2874383	2975304	3076225	3167758	3268679	3369600	3461134	3562055	3662976
22	1139713	1130326	1231247	1322780	1423701	1524622	1616156	1717077	1817998	1909532	2010453	2001065	2092599	2193520	2294441	2385974	2486895	2587817	2679350	2780271	2881192	2862417	2963338	3064259	3155793	3256714	3357635	3449169	3550090	3651011	3742544
23	1228669	1219281	1310815	1411736	1512657	1604191	1705112	1806033	1897566	1998487	2099408	2080633	2181555	2282476	2374009	2474930	2575851	2667385	2768306	2869227	2960760	2951373	3052294	3143828	3244749	3345670	3437203	3538124	3639045	3730579	3831500
24	1317625	1298850	1399771	1500692	1592225	1693146	1794067	1885601	1986522	2087443	2178977	2169589	2270510	2362044	2462965	2563886	2655419	2756340	2857261	2948795	3049716	3040329	3131862	3232783	3333704	3425238	3526159	3627080	3718613	3819534	3920455
25	1397193	1387805	1488726	1580260	1681181	1782102	1873636	1974557	2075478	2167011	2267932	2258545	2350078	2450999	2551920	2643454	2744375	2845296	2936830	3037751	3138672	3119897	3220818	3321739	3413272	3514193	3615114	3706648	3807569	3908490	4000024
26	1486148	1476761	1568295	1669216	1770137	1861670	1962591	2063512	2155046	2255967	2356888	2338113	2439034	2539955	2631489	2732410	2833331	2924864	3025785	3126706	3218240	3208852	3309773	3401307	3502228	3603149	3694683	3795604	3896525	3988058	4088979
27	1575104	1556329	1657250	1758171	1849705	1950626	2051547	2143080	2244001	2344922	2436456	2427069	2527990	2619523	2720444	2821365	2912899	3013820	3114741	3206274	3307195	3297808	3389342	3490263	3591184	3682717	3783638	3884559	3976093	4077014	4177935
28	1654672	1645285	1746206	1837739	1938660	2039581	2131115	2232036	2332957	2424491	2525412	2516024	2607558	2708479	2809400	2900933	3001854	3102775	3194309	3295230	3396151	3377376	3478297	3579218	3670752	3771673	3872594	3964127	4065048	4165969	4257503
29	1743628	1734240	1825774	1926695	2027616	2119150	2220071	2320992	2412525	2513446	2614367	2595592	2696513	2797434	2888968	2989889	3090810	3182344	3283265	3384186	3475719	3466332	3567253	3658786	3759707	3860628	3952162	4053083	4154004	4245538	4346459
30	1832583	1813809	1914730	2015651	2107184	2208105	2309026	2400560	2501481	2602402	2693935	2684548	2785469	2877003	2977924	3078845	3170378	3271299	3372220	3463754	3564675	3555287	3646821	3747742	3848663	3940197	4041118	4142039	4233572	4334493	4435414

Table 59: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 1 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-355648	-254727	-153806	-52885	48036	148957	249878	350799	451720	442332	543253	644174	745095	846016	946937	1047858	1148779	1249700	1350621	1341234	1442155	1543076	1643997	1744918	1845839	1946760	2047681	2148602	2249523
1	-456569	-465957	-365036	-264115	-163194	-62273	38648	139569	240490	341411	442332	432945	533866	634787	735708	836629	937550	1038471	1139392	1240313	1341234	1331846	1432767	1533688	1634609	1735530	1836451	1937372	2038293	2139214	2240135
2	-367614	-377001	-276080	-175159	-74238	26683	127604	228525	329446	430367	531288	521900	622821	723742	824663	925584	1026505	1127426	1228347	1329268	1430189	1420802	1521723	1622644	1723565	1824486	1925407	2026328	2127249	2228170	2329091
3	-278658	-288046	-187125	-86204	14717	115638	216559	317480	418401	519322	620243	610856	711777	812698	913619	1014540	1115461	1216382	1317303	1418224	1519145	1509758	1610679	1711600	1812521	1913442	2014363	2115284	2216205	2317126	2418047
4	-189703	-199090	-98169	2752	103673	204594	305515	406436	507357	608278	709199	699812	800733	901654	1002575	1103496	1204417	1305338	1406259	1507180	1608101	1598713	1699634	1800555	1901476	2002397	2103318	2204239	2305160	2406081	2507002
5	-100747	-110134	-9213	91708	192629	293550	394471	495392	596313	697234	798155	788767	889688	990609	1091530	1192451	1293372	1394293	1495214	1596135	1697056	1687669	1788590	1889511	1990432	2091353	2192274	2293195	2394116	2495037	2595958
6	-11791	-21179	79742	180663	281584	382505	483426	584347	685268	786189	887110	877723	978644	1079565	1180486	1281407	1382328	1483249	1584170	1685091	1786012	1776625	1877546	1978467	2079388	2180309	2281230	2382151	2483072	2583993	2684914
7	77164	67777	168698	269619	370540	471461	572382	673303	774224	875145	976066	966679	1067600	1168521	1269442	1370363	1471284	1572205	1673126	1774047	1874968	1865580	1966501	2067422	2168343	2269264	2370185	2471106	2572027	2672948	2773869
8	166120	156732	257653	358575	459496	560417	661338	762259	863180	964101	1065022	1055634	1156555	1257476	1358397	1459318	1560239	1661160	1762081	1863002	1963923	1954536	2055457	2156378	2257299	2358220	2459141	2560062	2660983	2761904	2862825
9	255076	245688	346609	447530	548451	649372	750293	851214	952135	1053056	1153977	1144590	1245511	1346432	1447353	1548274	1649195	1750116	1851037	1951958	2052879	2043491	2144412	2245333	2346254	2447175	2548096	2649017	2749938	2850859	2951780
10	344031	334644	435565	536486	637407	738328	839249	940170	1041091	1142012	1242933	1233545	1334466	1435387	1536308	1637229	1738150	1839071	1939992	2040913	2141834	2132447	2233368	2334289	2435210	2536131	2637052	2737973	2838894	2939815	3040736

11	334644	325256	426177	527098	628019	728940	829861	930782	1031703	1132624	1233545	1224158	1325079	1426000	1526921	1627842	1728763	1829684	1930605	2031526	2132447	2123060	2223981	2324902	2425823	2526744	2627665	2728586	2829507	2930428	3031349
12	423599	414212	515133	616054	716975	817896	918817	1019738	1120659	1221580	1322501	1313114	1414035	1514956	1615877	1716798	1817719	1918640	2019561	2120482	2221403	2212015	2312936	2413857	2514778	2615699	2716620	2817541	2918462	3019383	3120304
13	512555	503168	604089	705010	805931	906852	1007773	1108694	1209615	1310536	1411457	1402069	1502990	1603911	1704832	1805753	1906674	2007595	2108516	2209437	2310358	2300971	2401892	2502813	2603734	2704655	2805576	2906497	3007418	3108339	3209260
14	601511	592123	693044	793965	894886	995807	1096728	1197649	1298570	1399491	1500412	1491025	1591946	1692867	1793788	1894709	1995630	2096551	2197472	2298393	2399314	2389927	2490848	2591769	2692690	2793611	2894532	2995453	3096374	3197295	3298216
15	690466	681079	782000	882921	983842	1084763	1185684	1286605	1387526	1488447	1589368	1579980	1680901	1781822	1882744	1983665	2084586	2185507	2286428	2387349	2488270	2478882	2579803	2680724	2781645	2882566	2983487	3084408	3185329	3286250	3387171
16	779422	770034	870955	971876	1072797	1173718	1274639	1375560	1476482	1577403	1678324	1668936	1769857	1870778	1971699	2072620	2173541	2274462	2375383	2476304	2577225	2567838	2668759	2769680	2870601	2971522	3072443	3173364	3274285	3375206	3476127
17	868377	858990	959911	1060832	1161753	1262674	1363595	1464516	1565437	1666358	1767279	1757892	1858813	1959734	2060655	2161576	2262497	2363418	2464339	2565260	2666181	2656793	2757714	2858635	2959556	3060477	3161398	3262319	3363240	3464161	3565082
18	957333	947946	1048867	1149788	1250709	1351630	1452551	1553472	1654393	1755314	1856235	1846847	1947768	2048689	2149610	2250531	2351452	2452373	2553294	2654215	2755136	2745749	2846670	2947591	3048512	3149433	3250354	3351275	3452196	3553117	3654038
19	1046289	1036901	1137822	1238743	1339664	1440585	1541506	1642427	1743348	1844269	1945190	1935803	2036724	2137645	2238566	2339487	2440408	2541329	2642250	2743171	2844092	2834705	2935626	3036547	3137468	3238389	3339310	3440231	3541152	3642073	3742994
20	1135244	1125857	1226778	1327699	1428620	1529541	1630462	1731383	1832304	1933225	2034146	2024759	2125680	2226601	2327522	2428443	2529364	2630285	2731206	2832127	2933048	2923660	3024581	3125502	3226423	3327344	3428265	3529186	3630107	3731028	3831949
21	1125857	1116470	1217391	1318312	1419233	1520154	1621075	1721996	1822917	1923838	2024759	2015371	2116292	2217213	2318134	2419055	2519976	2620897	2721818	2822739	2923660	2914273	3015194	3116115	3217036	3317957	3418878	3519799	3620720	3721641	3822562
22	1214813	1205425	1306346	1407267	1508188	1609109	1710030	1810951	1911872	2012793	2113714	2104327	2205248	2306169	2407090	2508011	2608932	2709853	2810774	2911695	3012616	3003228	3104149	3205070	3305991	3406913	3507834	3608755	3709676	3810597	3911518
23	1303768	1294381	1395302	1496223	1597144	1698065	1798986	1899907	2000828	2101749	2202670	2193282	2294203	2395124	2496045	2596966	2697887	2798808	2899729	3000651	3101572	3092184	3193105	3294026	3394947	3495868	3596789	3697710	3798631	3899552	4000473
24	1392724	1383336	1484257	1585178	1686099	1787020	1887941	1988862	2089783	2190704	2291625	2282238	2383159	2484080	2585001	2685922	2786843	2887764	2988685	3089606	3190527	3181140	3282061	3382982	3483903	3584824	3685745	3786666	3887587	3988508	4089429
25	1481679	1472292	1573213	1674134	1775055	1875976	1976897	2077818	2178739	2279660	2380581	2371194	2472115	2573036	2673957	2774878	2875799	2976720	3077641	3178562	3279483	3270095	3371016	3471937	3572858	3673779	3774700	3875621	3976542	4077463	4178384
26	1570635	1561248	1662169	1763090	1864011	1964932	2065853	2166774	2267695	2368616	2469537	2460149	2561070	2661991	2762912	2863833	2964754	3065675	3166596	3267517	3368438	3359051	3459972	3560893	3661814	3762735	3863656	3964577	4065498	4166419	4267340
27	1659591	1650203	1751124	1852045	1952966	2053887	2154808	2255729	2356650	2457571	2558492	2549105	2650026	2750947	2851868	2952789	3053710	3154631	3255552	3356473	3457394	3448007	3548928	3649849	3750770	3851691	3952612	4053533	4154454	4255375	4356296
28	1748546	1739159	1840080	1941001	2041922	2142843	2243764	2344685	2445606	2546527	2647448	2638061	2738982	2839903	2940824	3041745	3142666	3243587	3344508	3445429	3546350	3536962	3637883	3738804	3839725	3940646	4041567	4142488	4243409	4344330	4445251
29	1837502	1828115	1929036	2029957	2130878	2231799	2332720	2433641	2534562	2635483	2736404	2727016	2827937	2928858	3029779	3130700	3231621	3332542	3433463	3534384	3635305	3625918	3726839	3827760	3928681	4029602	4130523	4231444	4332365	4433286	4534207
30	1926458	1917070	2017991	2118912	2219833	2320754	2421675	2522596	2623517	2724438	2825359	2815972	2916893	3017814	3118735	3219656	3320577	3421498	3522419	3623340	3724261	3714873	3815794	3916715	4017636	4118558	4219479	4320400	4421321	4522242	4623163

Table 60: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 1.25 MW. Complete matrix.

Down Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-355648	-254727	-153806	-43498	57423	158344	259265	360186	470494	461107	562028	662949	763870	874178	975099	1076020	1176941	1277862	1388171	1378783	1479704	1580625	1681547	1791855	1892776	1993697	2094618	2195539	2305847
1	-456569	-465957	-365036	-264115	-153806	-52885	48036	148957	249878	360186	461107	451720	552641	653562	763870	864791	965712	1066633	1167554	1277862	1378783	1369396	1470317	1571238	1681547	1782468	1883389	1984310	2085231	2195539	2296460
2	-367614	-377001	-276080	-165772	-64851	36070	136991	237912	348221	449142	550063	540675	641596	751905	852826	953747	1054668	1155589	1265897	1366818	1467739	1458352	1559273	1669581	1770502	1871423	1972344	2073265	2183574	2284495	2385416
3	-278658	-288046	-177737	-76816	24105	125026	225947	336255	437176	538097	639018	629631	739939	840860	941781	1042702	1143623	1253932	1354853	1455774	1556695	1547307	1657616	1758537	1859458	1960379	2061300	2171608	2272529	2373450	2474371
4	-189703	-189703	-88782	12139	113060	213981	324290	425211	526132	627053	727974	727974	828895	929816	1030737	1131658	1241966	1342887	1443808	1544729	1645650	1645650	1746571	1847492	1948413	2049334	2159643	2260564	2361485	2462406	2563327
5	-91360	-100747	174	101095	202016	312324	413245	514166	615087	716008	826317	816930	917851	1018772	1119693	1230001	1330922	1431843	1532764	1633685	1743993	1734606	1835527	1936448	2037369	2147677	2248598	2349519	2450440	2551361	2661670

6	-2404	-11791	89130	190051	300359	401280	502201	603122	704043	814352	915273	905885	1006806	1107727	1218036	1318957	1419878	1520799	1621720	1732028	1832949	1823562	1924483	2025404	2135712	2236633	2337554	2438475	2539396	2649704	2750625
7	86552	77164	178085	288394	389315	490236	591157	692078	802386	903307	1004228	994841	1095762	1206070	1306991	1407912	1508833	1609754	1720063	1820984	1921905	1912517	2013438	2123747	2224668	2325589	2426510	2527431	2637739	2738660	2839581
8	175507	166120	276428	377349	478270	579191	680112	790421	891342	992263	1093184	1083796	1194105	1295026	1395947	1496868	1597789	1708097	1809018	1909939	2010860	2001473	2111781	2212702	2313623	2414544	2515465	2625774	2726695	2827616	2928537
9	264463	264463	365384	466305	567226	668147	778455	879376	980297	1081218	1182139	1182139	1283060	1383981	1484902	1585823	1696132	1797053	1897974	1998895	2099816	2099816	2200737	2301658	2402579	2503500	2613808	2714729	2815650	2916571	3017492
10	362806	353419	454340	555261	656182	766490	867411	968332	1069253	1170174	1280482	1271095	1372016	1472937	1573858	1684166	1785087	1886008	1986930	2087851	2198159	2188772	2289693	2390614	2491535	2601843	2702764	2803685	2904606	3005527	3115835
11	353419	344031	444952	545873	656182	757103	858024	958945	1059866	1170174	1271095	1261708	1362629	1463550	1573858	1674779	1775700	1876621	1977542	2087851	2188772	2179384	2280305	2381226	2491535	2592456	2693377	2794298	2895219	3005527	3106448
12	442374	432987	533908	644216	745137	846058	946979	1047900	1158209	1259130	1360051	1350663	1451584	1561893	1662814	1763735	1864656	1965577	2075885	2176806	2277727	2268340	2369261	2479569	2580490	2681411	2782332	2883253	2993562	3094483	3195404
13	531330	521942	632251	733172	834093	935014	1035935	1146243	1247164	1348085	1449006	1439619	1549927	1650848	1751769	1852690	1953611	2063920	2164841	2265762	2366683	2357295	2467604	2568525	2669446	2770367	2871288	2981596	3082517	3183438	3284359
14	620285	620285	721206	822127	923048	1023969	1134278	1235199	1336120	1437041	1537962	1537962	1638883	1739804	1840725	1941646	2051954	2152875	2253796	2354717	2455638	2455638	2556559	2657480	2758401	2859322	2969631	3070552	3171473	3272394	3373315
15	718628	709241	810162	911083	1012004	1122312	1223234	1324155	1425076	1525997	1636305	1626918	1727839	1828760	1929681	2039989	2140910	2241831	2342752	2443673	2553981	2544594	2645515	2746436	2847357	2957665	3058586	3159507	3260428	3361349	3471658
16	807584	798197	899118	1000039	1110347	1211268	1312189	1413110	1514031	1624340	1725261	1715873	1816794	1917715	2028024	2128945	2229866	2330787	2431708	2542016	2642937	2633550	2734471	2835392	2945700	3046621	3147542	3248463	3349384	3459693	3560614
17	896540	887152	988073	1098382	1199303	1300224	1401145	1502066	1612374	1713295	1814216	1804829	1905750	2016058	2116979	2217900	2318821	2419742	2530051	2630972	2731893	2722505	2823426	2933735	3034656	3135577	3236498	3337419	3447727	3548648	3649569
18	985495	976108	1086416	1187337	1288258	1389179	1490100	1600409	1701330	1802251	1903172	1893784	2004093	2105014	2205935	2306856	2407777	2518085	2619006	2719927	2820848	2811461	2921769	3022690	3123611	3224532	3325453	3435762	3536683	3637604	3738525
19	1074451	1074451	1175372	1276293	1377214	1478135	1588443	1689364	1790285	1891206	1992127	1992127	2093048	2193969	2294890	2395811	2506120	2607041	2707962	2808883	2909804	2909804	3010725	3111646	3212567	3313488	3423796	3524717	3625638	3726559	3827480
20	1172794	1163407	1264328	1365249	1466170	1576478	1677399	1778320	1879241	1980162	2090470	2081083	2182004	2282925	2383846	2494155	2595076	2695997	2796918	2897839	3008147	2998760	3099681	3200602	3301523	3411831	3512752	3613673	3714594	3815515	3925823
21	1163407	1154019	1254940	1355861	1466170	1567091	1668012	1768933	1869854	1980162	2081083	2071696	2172617	2273538	2383846	2484767	2585688	2686609	2787530	2897839	2998760	2989372	3090293	3191214	3301523	3402444	3503365	3604286	3705207	3815515	3916436
22	1252362	1242975	1343896	1454204	1555125	1656046	1756967	1857888	1968197	2069118	2170039	2160651	2261572	2371881	2472802	2573723	2674644	2775565	2885873	2986794	3087715	3078328	3179249	3289557	3390478	3491399	3592320	3693241	3803550	3904471	4005392
23	1341318	1331930	1442239	1543160	1644081	1745002	1845923	1956231	2057152	2158073	2258994	2249607	2359915	2460836	2561757	2662678	2763599	2873908	2974829	3075750	3176671	3167283	3277592	3378513	3479434	3580355	3681276	3791584	3892505	3993426	4094347
24	1430273	1430273	1531194	1632115	1733036	1833957	1944266	2045187	2146108	2247029	2347950	2347950	2448871	2549792	2650713	2751634	2861942	2962863	3063784	3164705	3265626	3265626	3366547	3467468	3568389	3669310	3779619	3880540	3981461	4082382	4183303
25	1528617	1519229	1620150	1721071	1821992	1932301	2033222	2134143	2235064	2335985	2446293	2436906	2537827	2638748	2739669	2849977	2950898	3051819	3152740	3253661	3363969	3354582	3455503	3556424	3657345	3767653	3868575	3969496	4070417	4171338	4281646
26	1617572	1608185	1709106	1810027	1920335	2021256	2122177	2223098	2324019	2434328	2535249	2525861	2626782	2727703	2838012	2938933	3039854	3140775	3241696	3352004	3452925	3443538	3544459	3645380	3755688	3856609	3957530	4058451	4159372	4269681	4370602
27	1706528	1697140	1798061	1908370	2009291	2110212	2211133	2312054	2422362	2523283	2624204	2614817	2715738	2826046	2926967	3027888	3128809	3229730	3340039	3440960	3541881	3532493	3633414	3743723	3844644	3945565	4046486	4147407	4257715	4358636	4459557
28	1795483	1786096	1896404	1997325	2098246	2199167	2300088	2410397	2511318	2612239	2713160	2703772	2814081	2915002	3015923	3116844	3217765	3328073	3428994	3529915	3630836	3621449	3731757	3832678	3933599	4034520	4135441	4245750	4346671	4447592	4548513
29	1884439	1884439	1985360	2086281	2187202	2288123	2398431	2499352	2600273	2701194	2802115	2802115	2903036	3003957	3104879	3205800	3316108	3417029	3517950	3618871	3719792	3719792	3820713	3921634	4022555	4123476	4233784	4334705	4435626	4536547	4637468
30	1982782	1973395	2074316	2175237	2276158	2386466	2487387	2588308	2689229	2790150	2900459	2891071	2991992	3092913	3193834	3304143	3405064	3505985	3606906	3707827	3818135	3808748	3909669	4010590	4111511	4221819	4322740	4423661	4524582	4625503	4735811

Table 61: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 1.5 MW. Complete matrix.

Down Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-355648	-245340	-144419	-43498	66810	167731	268652	378961	479882	470494	580803	681724	782645	892953	993874	1094795	1205104	1306025	1406946	1406946	1507867	1608788	1719096	1820017	1920938	2031247	2132168	2233089	2343397

1	-456569	-465957	-355648	-254727	-153806	-43498	57423	158344	268652	369573	470494	470494	571415	672336	782645	883566	984487	1094795	1195716	1296637	1406946	1397558	1498479	1608788	1709709	1810630	1920938	2021859	2122780	2233089	2334010
2	-367614	-367614	-266693	-165772	-55463	45458	146379	256687	357608	458529	568837	559450	660371	770679	871600	972521	1082830	1183751	1284672	1394980	1495901	1486514	1596822	1697743	1798664	1908973	2009894	2110815	2221123	2322044	2422965
3	-269271	-278658	-177737	-67429	33492	134413	244722	345643	446564	556872	657793	648406	758714	859635	960556	1070865	1171786	1272707	1383015	1483936	1584857	1584857	1685778	1786699	1897007	1997928	2098849	2209158	2310079	2411000	2521308
4	-180315	-189703	-79394	21527	122448	232756	333677	434598	544907	645828	746749	746749	847670	948591	1058899	1159820	1260741	1371050	1471971	1572892	1683200	1673813	1774734	1885042	1985963	2086884	2197192	2298113	2399034	2509343	2610264
5	-91360	-91360	9561	110482	220791	321712	422633	532941	633862	734783	845092	835704	936625	1046934	1147855	1248776	1359084	1460005	1560926	1671235	1772156	1762768	1873077	1973998	2074919	2185227	2286148	2387069	2497378	2598299	2699220
6	6983	-2404	98517	208825	309746	410668	520976	621897	722818	833126	934047	924660	1034968	1135889	1236810	1347119	1448040	1548961	1659269	1760190	1861111	1861111	1962032	2062953	2173262	2274183	2375104	2485412	2586333	2687254	2797563
7	95939	86552	196860	297781	398702	509011	609932	710853	821161	922082	1023003	1023003	1123924	1224845	1335153	1436074	1536995	1647304	1748225	1849146	1959454	1950067	2050988	2161296	2262217	2363138	2473447	2574368	2675289	2785597	2886518
8	184895	184895	285816	386737	497045	597966	698887	809196	910117	1011038	1121346	1111959	1212880	1323188	1424109	1525030	1635338	1736259	1837180	1947489	2048410	2039023	2149331	2250252	2351173	2461481	2562402	2663323	2773632	2874553	2975474
9	283238	273850	374771	485080	586001	686922	797230	898151	999072	1109381	1210302	1200914	1311223	1412144	1513065	1623373	1724294	1825215	1935524	2036445	2137366	2137366	2238287	2339208	2449516	2550437	2651358	2761666	2862587	2963508	3073817
10	372193	362806	473114	574035	674956	785265	886186	987107	1097415	1198336	1299257	1299257	1400178	1501099	1611408	1712329	1813250	1923558	2024479	2125400	2235709	2226321	2327242	2437551	2538472	2639393	2749701	2850622	2951543	3061851	3162772
11	362806	362806	463727	564648	674956	775877	876798	987107	1088028	1188949	1299257	1289870	1390791	1501099	1602020	1702941	1813250	1914171	2015092	2125400	2226321	2216934	2327242	2428163	2529084	2639393	2740314	2841235	2951543	3052464	3153385
12	461149	451762	552683	662991	763912	864833	975141	1076062	1176983	1287292	1388213	1378825	1489134	1590055	1690976	1801284	1902205	2003126	2113435	2214356	2315277	2315277	2416198	2517119	2627427	2728348	2829269	2939578	3040499	3141420	3251728
13	550105	540717	651026	751947	852868	963176	1064097	1165018	1275327	1376248	1477169	1477169	1578090	1679011	1789319	1890240	1991161	2101469	2202390	2303311	2413620	2404232	2505153	2615462	2716383	2817304	2927612	3028533	3129454	3239763	3340684
14	639060	639060	739981	840902	951211	1052132	1153053	1263361	1364282	1465203	1575512	1566124	1667045	1777354	1878275	1979196	2089504	2190425	2291346	2401654	2502575	2493188	2603496	2704417	2805338	2915647	3016568	3117489	3227797	3328718	3429639
15	737403	728016	828937	939245	1040166	1141087	1251396	1352317	1453238	1563546	1664467	1655080	1765388	1866309	1967230	2077539	2178460	2279381	2389689	2490610	2591531	2591531	2692452	2793373	2903682	3004603	3105524	3215832	3316753	3417674	3527982
16	826359	816972	927280	1028201	1129122	1239430	1340351	1441272	1551581	1652502	1753423	1753423	1854344	1955265	2065573	2166494	2267415	2377724	2478645	2579566	2689874	2680487	2781408	2891716	2992637	3093558	3203867	3304788	3405709	3516017	3616938
17	915315	915315	1016236	1117157	1227465	1328386	1429307	1539615	1640536	1741457	1851766	1842378	1943299	2053608	2154529	2255450	2365758	2466679	2567600	2677909	2778830	2769442	2879751	2980672	3081593	3191901	3292822	3393743	3504052	3604973	3705894
18	1013658	1004270	1105191	1215500	1316421	1417342	1527650	1628571	1729492	1839800	1940721	1931334	2041642	2142563	2243484	2353793	2454714	2555635	2665943	2766864	2867785	2867785	2968706	3069627	3179936	3280857	3381778	3492086	3593007	3693928	3804237
19	1102613	1093226	1203534	1304455	1405376	1515685	1616606	1717527	1827835	1928756	2029677	2029677	2130598	2231519	2341828	2442749	2543670	2653978	2754899	2855820	2966128	2956741	3057662	3167970	3268891	3369812	3480121	3581042	3681963	3792271	3893192
20	1191569	1191569	1292490	1393411	1503719	1604640	1705561	1815870	1916791	2017712	2128020	2118633	2219554	2329862	2430783	2531704	2642013	2742934	2843855	2954163	3055084	3045697	3156005	3256926	3357847	3468155	3569076	3669997	3780306	3881227	3982148
21	1191569	1182181	1283102	1393411	1494332	1595253	1705561	1806482	1907403	2017712	2118633	2109245	2219554	2320475	2421396	2531704	2632625	2733546	2843855	2944776	3045697	3045697	3146618	3247539	3357847	3458768	3559689	3669997	3770918	3871839	3982148
22	1280524	1271137	1381445	1482366	1583287	1693596	1794517	1895438	2005746	2106667	2207588	2207588	2308509	2409430	2519739	2620660	2721581	2831889	2932810	3033731	3144040	3134652	3235573	3345882	3446803	3547724	3658032	3758953	3859874	3970183	4071104
23	1369480	1369480	1470401	1571322	1681631	1782552	1883473	1993781	2094702	2195623	2305931	2296544	2397465	2507773	2608694	2709615	2819924	2920845	3021766	3132074	3232995	3223608	3333916	3434837	3535758	3646067	3746988	3847909	3958217	4059138	4160059
24	1467823	1458436	1559357	1669665	1770586	1871507	1981816	2082737	2183658	2293966	2394887	2385500	2495808	2596729	2697650	2807958	2908879	3009800	3120109	3221030	3321951	3321951	3422872	3523793	3634101	3735022	3835943	3946252	4047173	4148094	4258402
25	1556779	1547391	1657700	1758621	1859542	1969850	2070771	2171692	2282001	2382922	2483843	2483843	2584764	2685685	2795993	2896914	2997835	3108144	3209065	3309986	3420294	3410907	3511828	3622136	3723057	3823978	3934286	4035207	4136128	4246437	4347358
26	1645734	1645734	1746655	1847576	1957885	2058806	2159727	2270035	2370956	2471877	2582186	2572798	2673719	2784028	2884949	2985870	3096178	3197099	3298020	3408329	3509250	3499862	3610171	3711092	3812013	3922321	4023242	4124163	4234471	4335392	4436313
27	1744077	1734690	1835611	1945919	2046840	2147761	2258070	2358991	2459912	2570220	2671141	2661754	2772062	2872983	2973904	3084213	3185134	3286055	3396363	3497284	3598205	3598205	3699126	3800047	3910356	4011277	4112198	4222506	4323427	4424348	4534656
28	1833033	1823646	1933954	2034875	2135796	2246104	2347025	2447946	2558255	2659176	2760097	2760097	2861018	2961939	3072247	3173168	3274089	3384398	3485319	3586240	3696548	3687161	3788082	3898390	3999311	4100232	4210541	4311462	4412383	4522691	4623612
29	1921989	1921989	2022910	2123831	2234139	2335060	2435981	2546290	2647211	2748132	2858440	2849053	2949974	3060282	3161203	3262124	3372432	3473353	3574274	3684583	3785504	3776116	3886425	3987346	4088267	4198575	4299496	4400417	4510726	4611647	4712568
30	2020332	2010944	2111865	2222174	2323095	2424016	2534324	2635245	2736166	2846475	2947396	2938008	3048317	3149238	3250159	3360467	3461388	3562309	3672617	3773538	3874459	3874459	3975380	4076301	4186610	4287531	4388452	4498760	4599681	4700602	4810911

Table 62: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 1.75 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-355648	-245340	-144419	-34111	66810	177119	278040	378961	489269	479882	590190	691111	801420	902341	1003262	1113570	1214491	1324800	1425721	1425721	1526642	1627563	1737871	1838792	1949100	2050021	2160330	2261251	2362172
1	-456569	-465957	-355648	-254727	-144419	-43498	66810	167731	268652	378961	479882	479882	580803	691111	792032	892953	1003262	1104183	1214491	1315412	1425721	1416333	1517254	1627563	1728484	1838792	1939713	2050021	2150942	2251863	2362172
2	-367614	-367614	-266693	-156384	-55463	54845	155766	256687	366995	467916	578225	568837	679146	780067	880988	991296	1092217	1202526	1303447	1413755	1514676	1505289	1615597	1716518	1826827	1927748	2038056	2138977	2239898	2350206	2451127
3	-269271	-278658	-168350	-67429	42880	143801	244722	355030	455951	566259	667180	667180	768101	869023	979331	1080252	1190560	1291481	1401790	1502711	1603632	1603632	1704553	1814861	1915782	2026091	2127012	2227933	2338241	2439162	2549471
4	-180315	-180315	-79394	30914	131835	232756	343065	443986	554294	655215	765524	756136	857057	967366	1068287	1178595	1279516	1389824	1490745	1591666	1701975	1692587	1802896	1903817	2014125	2115046	2215967	2326276	2427197	2537505	2638426
5	-81972	-91360	18949	119870	220791	331099	432020	542329	643250	753558	854479	845092	955400	1056321	1166630	1267551	1377859	1478780	1579701	1690009	1790930	1790930	1891851	2002160	2103081	2204002	2314310	2415231	2525540	2626461	2736769
6	6983	6983	107904	208825	319134	420055	530363	631284	741593	842514	943435	943435	1044356	1154664	1255585	1365894	1466815	1567736	1678044	1778965	1889273	1879886	1990194	2091116	2192037	2302345	2403266	2513574	2614495	2724804	2825725
7	105327	95939	196860	307169	408090	518398	619319	729627	830548	931469	1041778	1032390	1142699	1243620	1353928	1454849	1555770	1666079	1767000	1877308	1978229	1978229	2079150	2180071	2290380	2391301	2501609	2602530	2712838	2813759	2914680
8	194282	184895	295203	396124	506433	607354	717662	818583	919504	1029812	1130733	1130733	1231654	1341963	1442884	1543805	1654113	1755034	1865343	1966264	2076572	2067185	2168106	2278414	2379335	2489644	2590565	2700873	2801794	2902715	3013023
9	283238	283238	384159	494467	595388	705697	806618	907539	1017847	1118768	1229076	1219689	1329997	1430918	1531839	1642148	1743069	1853377	1954298	2064607	2165528	2156140	2266449	2367370	2477678	2578599	2688908	2789829	2890750	3001058	3101979
10	381581	372193	482502	583423	693731	794652	895573	1005882	1106803	1217111	1318032	1318032	1418953	1519874	1630183	1731104	1841412	1942333	2052641	2153562	2254483	2254483	2355404	2465713	2566634	2676942	2777863	2878784	2989093	3090014	3200322
11	372193	372193	473114	583423	684344	785265	895573	996494	1106803	1207724	1318032	1308645	1409566	1519874	1620795	1731104	1832025	1942333	2043254	2144175	2254483	2245096	2355404	2456325	2566634	2667555	2768476	2878784	2979705	3090014	3190935
12	470536	461149	571457	672378	773299	883608	984529	1094837	1195758	1306067	1406988	1397600	1507909	1608830	1719138	1820059	1930368	2031289	2132210	2242518	2343439	2343439	2444360	2554668	2655589	2756510	2866819	2967740	3078048	3178969	3289278
13	559492	559492	660413	761334	871642	972563	1082872	1183793	1294101	1395022	1495943	1495943	1596864	1707173	1808094	1918402	2019323	2120244	2230553	2331474	2441782	2432395	2542703	2643624	2744545	2854854	2955775	3066083	3167004	3277312	3378233
14	657835	648448	749369	859677	960598	1070907	1171828	1282136	1383057	1483978	1594286	1584899	1695207	1796128	1906437	2007358	2108279	2218587	2319508	2429817	2530738	2530738	2631659	2732580	2842888	2943809	3054118	3155039	3265347	3366268	3467189
15	746791	737403	847712	948633	1058941	1159862	1270171	1371092	1472013	1582321	1683242	1683242	1784163	1894471	1995392	2096313	2206622	2307543	2417851	2518772	2629081	2619693	2720614	2830923	2931844	3042152	3143073	3253382	3354303	3455224	3565532
16	835746	835746	936667	1046976	1147897	1258205	1359126	1460047	1570356	1671277	1781585	1772198	1882506	1983427	2084348	2194656	2295577	2405886	2506807	2617115	2718036	2708649	2818957	2919878	3030187	3131108	3241416	3342337	3443258	3553567	3654488
17	934089	924702	1035010	1135931	1246240	1347161	1448082	1558390	1659311	1769620	1870541	1870541	1971462	2072383	2182691	2283612	2393921	2494842	2605150	2706071	2806992	2806992	2907913	3018221	3119142	3229451	3330372	3431293	3541601	3642522	3752831
18	1023045	1023045	1123966	1234274	1335195	1436116	1546425	1647346	1757654	1858575	1968884	1959496	2060417	2170726	2271647	2381955	2482876	2593185	2694106	2795027	2905335	2895948	3006256	3107177	3217485	3318406	3419327	3529636	3630557	3740865	3841786
19	1121388	1112001	1222309	1323230	1424151	1534459	1635380	1745689	1846610	1956918	2057839	2048452	2158760	2259681	2369990	2470911	2581219	2682140	2783061	2893370	2994291	2994291	3095212	3205520	3306441	3407362	3517670	3618592	3728900	3829821	3940129
20	1210344	1210344	1311265	1412186	1522494	1623415	1733724	1834645	1944953	2045874	2146795	2146795	2247716	2358024	2458945	2569254	2670175	2771096	2881404	2982325	3092634	3083246	3193555	3294476	3395397	3505705	3606626	3716935	3817856	3928164	4029085
21	1210344	1200956	1301877	1412186	1513107	1623415	1724336	1834645	1935566	2036487	2146795	2137408	2247716	2348637	2458945	2559866	2660787	2771096	2872017	2982325	3083246	3083246	3184167	3285088	3395397	3496318	3606626	3707547	3817856	3918777	4019698
22	1299299	1289912	1400220	1501141	1611450	1712371	1822679	1923600	2024521	2134830	2235751	2235751	2336672	2446980	2547901	2648822	2759130	2860051	2970360	3071281	3181589	3172202	3273123	3383431	3484352	3594661	3695582	3805890	3906811	4007732	4118041
23	1388255	1388255	1489176	1599484	1700405	1810714	1911635	2012556	2122864	2223785	2334094	2324706	2435015	2535936	2636857	2747165	2848086	2958394	3059315	3169624	3270545	3261158	3371466	3472387	3582695	3683616	3793925	3894846	3995767	4106075	4206996
24	1486598	1477211	1587519	1688440	1798748	1899669	2000590	2110899	2211820	2322128	2423049	2423049	2523970	2624891	2735200	2836121	2946429	3047350	3157659	3258580	3359501	3359501	3460422	3570730	3671651	3781959	3882880	3983801	4094110	4195031	4305339
25	1575554	1575554	1676475	1786783	1887704	1988625	2098933	2199854	2310163	2411084	2521392	2512005	2612926	2723234	2824155	2934464	3035385	3145693	3246614	3347535	3457844	3448456	3558765	3659686	3769994	3870915	3971836	4082144	4183065	4293374	4394295
26	1673897	1664509	1774818	1875739	1976660	2086968	2187889	2298197	2399118	2509427	2610348	2600960	2711269	2812190	2922498	3023419	3133728	3234649	3335570	3445878	3546799	3546799	3647720	3758029	3858950	3959871	4070179	4171100	4281408	4382330	4492638
27	1762852	1762852	1863773	1964694	2075003	2175924	2286232	2387153	2497462	2598383	2699304	2699304	2800225	2910533	3011454	3121762	3222683	3323604	3433913	3534834	3645142	3635755	3746063	3846984	3947905	4058214	4159135	4269443	4370364	4480673	4581594

28	1861195	1851808	1952729	2063037	2163958	2274267	2375188	2485496	2586417	2687338	2797647	2788259	2898568	2999489	3109797	3210718	3311639	3421947	3522868	3633177	3734098	3734098	3835019	3935940	4046248	4147169	4257478	4358399	4468707	4569628	4670549
29	1950151	1940763	2051072	2151993	2262301	2363222	2473531	2574452	2675373	2785681	2886602	2886602	2987523	3097832	3198753	3299674	3409982	3510903	3621211	3722132	3832441	3823053	3923975	4034283	4135204	4245512	4346433	4456742	4557663	4658584	4768892
30	2039107	2039107	2140028	2250336	2351257	2461565	2562486	2663407	2773716	2874637	2984945	2975558	3085866	3186787	3287708	3398017	3498938	3609246	3710167	3820476	3921397	3912009	4022318	4123239	4233547	4334468	4444776	4545697	4646618	4756927	4857848

Table 63: Commercial VPP in the Slovenia mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 2 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-346261	-245340	-135032	-34111	76198	177119	287427	388348	498657	489269	599578	700499	810807	911728	1022037	1122958	1233266	1334187	1444495	1435108	1545416	1646337	1756646	1857567	1967875	2068796	2179105	2280026	2390334
1	-456569	-456569	-355648	-245340	-144419	-34111	66810	177119	278040	388348	489269	489269	590190	700499	801420	911728	1012649	1122958	1223879	1334187	1435108	1435108	1536029	1646337	1747258	1857567	1958488	2068796	2169717	2280026	2380947
2	-358226	-367614	-257305	-156384	-46076	54845	165153	266074	376383	477304	587612	578225	688533	789454	899763	1000684	1110992	1211913	1322222	1423143	1533451	1524064	1634372	1735293	1845601	1946522	2056831	2157752	2268060	2368981	2479290
3	-269271	-269271	-168350	-58041	42880	153188	254109	364417	465338	575647	676568	676568	777489	887797	988718	1099027	1199948	1310256	1411177	1521486	1622407	1622407	1723328	1833636	1934557	2044865	2145786	2256095	2357016	2467324	2568245
4	-170928	-180315	-70007	30914	141223	242144	352452	453373	563682	664603	774911	765524	875832	976753	1087061	1187982	1298291	1399212	1509520	1610441	1720750	1711362	1821671	1922592	2032900	2133821	2244130	2345051	2455359	2556280	2666588
5	-81972	-81972	18949	129257	230178	340487	441408	551716	652637	762946	863867	863867	964788	1075096	1176017	1286325	1387246	1497555	1598476	1708784	1809705	1809705	1910626	2020935	2121856	2232164	2333085	2443394	2544315	2654623	2755544
6	16371	6983	117292	218213	328521	429442	539751	640672	750980	851901	962210	952822	1063131	1164052	1274360	1375281	1485589	1586510	1696819	1797740	1908048	1898661	2008969	2109890	2220199	2321120	2431428	2532349	2642658	2743579	2853887
7	105327	105327	206248	316556	417477	527785	628706	739015	839936	950244	1051165	1051165	1152086	1262395	1363316	1473624	1574545	1684854	1785775	1896083	1997004	1997004	2097925	2208233	2309154	2419463	2520384	2630692	2731613	2841922	2942843
8	203670	194282	304591	405512	515820	616741	727049	827970	938279	1039200	1149508	1140121	1250429	1351350	1461659	1562580	1672888	1773809	1884118	1985039	2095347	2085960	2196268	2297189	2407497	2508418	2618727	2719648	2829956	2930877	3041186
9	292625	292625	393546	503855	604776	715084	816005	926313	1027234	1137543	1238464	1238464	1339385	1449693	1550614	1660923	1761844	1872152	1973073	2083382	2184303	2184303	2285224	2395532	2496453	2606761	2707682	2817991	2918912	3029220	3130141
10	390968	381581	491889	592810	703119	804040	914348	1015269	1125577	1226499	1336807	1327420	1437728	1538649	1648957	1749878	1860187	1961108	2071416	2172337	2282646	2273258	2383567	2484488	2594796	2695717	2806025	2906947	3017255	3118176	3228484
11	381581	381581	482502	592810	693731	804040	904961	1015269	1116190	1226499	1327420	1327420	1428341	1538649	1639570	1749878	1850799	1961108	2062029	2172337	2273258	2273258	2374179	2484488	2585409	2695717	2796638	2906947	3007868	3118176	3219097
12	479924	470536	580845	681766	792074	892995	1003304	1104225	1214533	1315454	1425763	1416375	1526684	1627605	1737913	1838834	1949142	2050063	2160372	2261293	2371601	2362214	2472522	2573443	2683752	2784673	2894981	2995902	3106211	3207132	3317440
13	568879	568879	669800	780109	881030	991338	1092259	1202568	1303489	1413797	1514718	1514718	1615639	1725948	1826869	1937177	2038098	2148406	2249327	2359636	2460557	2460557	2561478	2671786	2772707	2883016	2983937	3094245	3195166	3305475	3406396
14	667222	657835	768143	869065	979373	1080294	1190602	1291523	1401832	1502753	1613061	1603674	1713982	1814903	1925212	2026133	2136441	2237362	2347670	2448592	2558900	2549513	2659821	2760742	2871050	2971971	3082280	3183201	3293509	3394430	3504739
15	756178	756178	857099	967408	1068329	1178637	1279558	1389866	1490787	1601096	1702017	1702017	1802938	1913246	2014167	2124476	2225397	2335705	2436626	2546935	2647856	2647856	2748777	2859085	2960006	3070314	3171235	3281544	3382465	3492773	3593694
16	854521	845134	955442	1056363	1166672	1267593	1377901	1478822	1589130	1690051	1800360	1790972	1901281	2002202	2112510	2213431	2323740	2424661	2534969	2635890	2746199	2736811	2847120	2948041	3058349	3159270	3269578	3370499	3480808	3581729	3692037
17	943477	943477	1044398	1154706	1255627	1365936	1466857	1577165	1678086	1788394	1889315	1889315	1990237	2100545	2201466	2311774	2412695	2523004	2623925	2734233	2835154	2835154	2936075	3046384	3147305	3257613	3358534	3468842	3569763	3680072	3780993
18	1041820	1032432	1142741	1243662	1353970	1454891	1565200	1666121	1776429	1877350	1987659	1978271	2088580	2189501	2299809	2400730	2511038	2611959	2722268	2823189	2933497	2924110	3034418	3135339	3245648	3346569	3456877	3557798	3668107	3769028	3879336
19	1130775	1130775	1231696	1342005	1442926	1553234	1654155	1764464	1865385	1975693	2076614	2076614	2177535	2287844	2388765	2499073	2599994	2710302	2811223	2921532	3022453	3022453	3123374	3233682	3334603	3444912	3545833	3656141	3757062	3867371	3968292
20	1229118	1219731	1330039	1430960	1541269	1642190	1752498	1853419	1963728	2064649	2174957	2165570	2275878	2376799	2487108	2588029	2698337	2799258	2909566	3010487	3120796	3111408	3221717	3322638	3432946	3533867	3644176	3745097	3855405	3956326	4066635
21	1219731	1219731	1320652	1430960	1531881	1642190	1743111	1853419	1954340	2064649	2165570	2165570	2266491	2376799	2477720	2588029	2688950	2799258	2900179	3010487	3111408	3111408	3212330	3322638	3423559	3533867	3634788	3745097	3846018	3956326	4057247
22	1318074	1308687	1418995	1519916	1630225	1731146	1841454	1942375	2052683	2153604	2263913	2254525	2364834	2465755	2576063	2676984	2787293	2888214	2998522	3099443	3209752	3200364	3310673	3411594	3521902	3622823	3733131	3834052	3944361	4045282	4155590

23	1407030	1407030	1507951	1618259	1719180	1829489	1930410	2040718	2141639	2251947	2352868	2352868	2453789	2564098	2665019	2775327	2876248	2986557	3087478	3197786	3298707	3298707	3399628	3509937	3610858	3721166	3822087	3932395	4033316	4143625	4244546
24	1505373	1495985	1606294	1707215	1817523	1918444	2028753	2129674	2239982	2340903	2451211	2441824	2552132	2653053	2763362	2864283	2974591	3075512	3185821	3286742	3397050	3387663	3497971	3598892	3709201	3810122	3920430	4021351	4131659	4232580	4342889
25	1594328	1594328	1695249	1805558	1906479	2016787	2117708	2228017	2328938	2439246	2540167	2540167	2641088	2751397	2852318	2962626	3063547	3173855	3274776	3385085	3486006	3486006	3586927	3697235	3798156	3908465	4009386	4119694	4220615	4330924	4431845
26	1692671	1683284	1793592	1894513	2004822	2105743	2216051	2316972	2427281	2528202	2638510	2629123	2739431	2840352	2950661	3051582	3161890	3262811	3373119	3474040	3584349	3574961	3685270	3786191	3896499	3997420	4107729	4208650	4318958	4419879	4530188
27	1781627	1781627	1882548	1992856	2093777	2204086	2305007	2415315	2516236	2626545	2727466	2727466	2828387	2938695	3039616	3149925	3250846	3361154	3462075	3572383	3673304	3673304	3774225	3884534	3985455	4095763	4196684	4306993	4407914	4518222	4619143
28	1879970	1870583	1980891	2081812	2192121	2293042	2403350	2504271	2614579	2715500	2825809	2816421	2926730	3027651	3137959	3238880	3349189	3450110	3560418	3661339	3771648	3762260	3872569	3973490	4083798	4184719	4295027	4395948	4506257	4607178	4717486
29	1968926	1968926	2069847	2180155	2281076	2391385	2492306	2602614	2703535	2813843	2914764	2914764	3015685	3125994	3226915	3337223	3438144	3548453	3649374	3759682	3860603	3860603	3961524	4071833	4172754	4283062	4383983	4494291	4595212	4705521	4806442
30	2067269	2057881	2168190	2269111	2379419	2480340	2590649	2691570	2801878	2902799	3013107	3003720	3114028	3214949	3325258	3426179	3536487	3637408	3747717	3848638	3958946	3949559	4059867	4160788	4271097	4372018	4482326	4583247	4693555	4794476	4904785

Table 64: Commercial VPP in the Portuguese mFRR market. Overall NPV (EUR) of the simulated pools with an average DER capacity of 2 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-447182	-456569	-450885	-454588	-448904	-452607	-446923	-450626	-444941	-448645	-442960	-452348	-446663	-450366	-444682	-448385	-442701	-446404	-440720	-444423	-438738	-448126	-442442	-446145	-440460	-444163	-438479	-442182	-436498	-440201	-434517
1	-456569	-456569	-460273	-454588	-458291	-452607	-456310	-450626	-454329	-448645	-452348	-452348	-456051	-450366	-454070	-448385	-452088	-446404	-450107	-444423	-448126	-448126	-451829	-446145	-449848	-444163	-447866	-442182	-445885	-440201	-443904
2	-434236	-443623	-437939	-441642	-435958	-439661	-433976	-437680	-431995	-435698	-430014	-439401	-433717	-437420	-431736	-435439	-429755	-433458	-427773	-431476	-425792	-435180	-429495	-433198	-427514	-431217	-425533	-429236	-423552	-427255	-421570
3	-421289	-421289	-424993	-419308	-423011	-417327	-421030	-415346	-419049	-413365	-417068	-417068	-420771	-415086	-418790	-413105	-416808	-411124	-414827	-409143	-412846	-412846	-416549	-410865	-414568	-408883	-412587	-406902	-410605	-404921	-408624
4	-398956	-408343	-402659	-406362	-400678	-404381	-398696	-402400	-396715	-400418	-394734	-404121	-398437	-402140	-396456	-400159	-394475	-398178	-392493	-396196	-390512	-399900	-394215	-397918	-392234	-395937	-390253	-393956	-388272	-391975	-386290
5	-386009	-386009	-389713	-384028	-387731	-382047	-385750	-380066	-383769	-378085	-381788	-381788	-385491	-379806	-383510	-377825	-381528	-375844	-379547	-373863	-377566	-377566	-381269	-375585	-379288	-373603	-377307	-371622	-375325	-369641	-373344
6	-363676	-373063	-367379	-371082	-365398	-369101	-363416	-367120	-361435	-365138	-359454	-368841	-363157	-366860	-361176	-364879	-359195	-362898	-357213	-360916	-355232	-364620	-358935	-362638	-356954	-360657	-354973	-358676	-352992	-356695	-351010
7	-350729	-350729	-354433	-348748	-352451	-346767	-350470	-344786	-348489	-342805	-346508	-346508	-350211	-344526	-348230	-342545	-346248	-340564	-344267	-338583	-342286	-342286	-345989	-340305	-344008	-338323	-342027	-336342	-340045	-334361	-338064
8	-328396	-337783	-332099	-335802	-330118	-333821	-328136	-331840	-326155	-329858	-324174	-333561	-327877	-331580	-325896	-329599	-323915	-327618	-321933	-325636	-319952	-329340	-323655	-327358	-321674	-325377	-319693	-323396	-317712	-321415	-315730
9	-315449	-315449	-319153	-313468	-317171	-311487	-315190	-309506	-313209	-307525	-311228	-311228	-314931	-309246	-312950	-307265	-310968	-305284	-308987	-303303	-307006	-307006	-310709	-305025	-308728	-303043	-306747	-301062	-304765	-299081	-302784
10	-293116	-302503	-296819	-300522	-294838	-298541	-292856	-296560	-290875	-294578	-288894	-298281	-292597	-296300	-290616	-294319	-288635	-292338	-286653	-290356	-284672	-294060	-288375	-292078	-286394	-290097	-284413	-288116	-282432	-286135	-280450
11	-302503	-302503	-306206	-300522	-304225	-298541	-302244	-296560	-300263	-294578	-298281	-298281	-301984	-296300	-300003	-294319	-298022	-292338	-296041	-290356	-294060	-294060	-297763	-292078	-295781	-290097	-293800	-288116	-291819	-286135	-289838
12	-280169	-289557	-283873	-287576	-281891	-285594	-279910	-283613	-277929	-281632	-275948	-285335	-279651	-283354	-277670	-281373	-275688	-279391	-273707	-277410	-271726	-281113	-275429	-279132	-273448	-277151	-271467	-275170	-269485	-273188	-267504
13	-267223	-267223	-270926	-265242	-268945	-263261	-266964	-261280	-264983	-259298	-263001	-263001	-266704	-261020	-264723	-259039	-262742	-257058	-260761	-255076	-258780	-258780	-262483	-256798	-260501	-254817	-258520	-252836	-256539	-250855	-254558
14	-244889	-254277	-248593	-252296	-246611	-250314	-244630	-248333	-242649	-246352	-240668	-250055	-244371	-248074	-242390	-246093	-240408	-244111	-238427	-242130	-236446	-245833	-240149	-243852	-238168	-241871	-236187	-239890	-234205	-237908	-232224
15	-231943	-231943	-235646	-229962	-233665	-227981	-231684	-226000	-229703	-224018	-227721	-227721	-231424	-225740	-229443	-223759	-227462	-221778	-225481	-219796	-223500	-223500	-227203	-221518	-225221	-219537	-223240	-217556	-221259	-215575	-219278
16	-209609	-218997	-213313	-217016	-211331	-215034	-209350	-213053	-207369	-211072	-205388	-214775	-209091	-212794	-207110	-210813	-205128	-208831	-203147	-206850	-201166	-210553	-204869	-208572	-202888	-206591	-200907	-204610	-198925	-202628	-196944
17	-196663	-196663	-200366	-194682	-198385	-192701	-196404	-190720	-194423	-188738	-192441	-192441	-196144	-190460	-194163	-188479	-192182	-186498	-190201	-184516	-188220	-188220	-191923	-186238	-189941	-184257	-187960	-182276	-185979	-180295	-183998

18	-174329	-183717	-178033	-181736	-176051	-179754	-174070	-177773	-172089	-175792	-170108	-179495	-173811	-177514	-171830	-175533	-169848	-173551	-167867	-171570	-165886	-175273	-169589	-173292	-167608	-171311	-165627	-169330	-163645	-167348	-161664
19	-161383	-161383	-165086	-159402	-163105	-157421	-161124	-155440	-159143	-153458	-157161	-157161	-160864	-155180	-158883	-153199	-156902	-151218	-154921	-149236	-152940	-152940	-156643	-150958	-154661	-148977	-152680	-146996	-150699	-145015	-148718
20	-139049	-148437	-142753	-146456	-140771	-144474	-138790	-142493	-136809	-140512	-134828	-144215	-138531	-142234	-136550	-140253	-134568	-138271	-132587	-136290	-130606	-139993	-134309	-138012	-132328	-136031	-130347	-134050	-128365	-132068	-126384
21	-148437	-148437	-152140	-146456	-150159	-144474	-148178	-142493	-146196	-140512	-144215	-144215	-147918	-142234	-145937	-140253	-143956	-138271	-141975	-136290	-139993	-139993	-143696	-138012	-141715	-136031	-139734	-134050	-137753	-132068	-135771
22	-126103	-135491	-129806	-133509	-127825	-131528	-125844	-129547	-123863	-127566	-121881	-131269	-125584	-129288	-123603	-127306	-121622	-125325	-119641	-123344	-117660	-127047	-121363	-125066	-119381	-123085	-117400	-121103	-115419	-119122	-113438
23	-113157	-113157	-116860	-111176	-114879	-109194	-112898	-107213	-110916	-105232	-108935	-108935	-112638	-106954	-110657	-104973	-108676	-102991	-106695	-101010	-104713	-104713	-108416	-102732	-106435	-100751	-104454	-98770	-102473	-96788	-100491
24	-90823	-100211	-94526	-98229	-92545	-96248	-90564	-94267	-88583	-92286	-86601	-95989	-90304	-94008	-88323	-92026	-86342	-90045	-84361	-88064	-82380	-91767	-86083	-89786	-84101	-87805	-82120	-85823	-80139	-83842	-78158
25	-77877	-77877	-81580	-75896	-79599	-73914	-77618	-71933	-75636	-69952	-73655	-73655	-77358	-71674	-75377	-69693	-73396	-67711	-71415	-65730	-69433	-69433	-73136	-67452	-71155	-65471	-69174	-63490	-67193	-61508	-65211
26	-55543	-64931	-59246	-62949	-57265	-60968	-55284	-58987	-53303	-57006	-51321	-60709	-55024	-58728	-53043	-56746	-51062	-54765	-49081	-52784	-47100	-56487	-50803	-54506	-48821	-52525	-46840	-50543	-44859	-48562	-42878
27	-42597	-42597	-46300	-40616	-44319	-38634	-42338	-36653	-40356	-34672	-38375	-38375	-42078	-36394	-40097	-34413	-38116	-32431	-36135	-30450	-34153	-34153	-37856	-32172	-35875	-30191	-33894	-28210	-31913	-26228	-29931
28	-20263	-29651	-23966	-27669	-21985	-25688	-20004	-23707	-18023	-21726	-16041	-25429	-19744	-23448	-17763	-21466	-15782	-19485	-13801	-17504	-11820	-21207	-15523	-19226	-13541	-17245	-11560	-15263	-9579	-13282	-7598
29	-7317	-7317	-11020	-5336	-9039	-3354	-7058	-1373	-5076	608	-3095	-3095	-6798	-1114	-4817	867	-2836	2849	-855	4830	1127	1127	-2576	3108	-595	5089	1386	7070	3367	9052	5349
30	15017	5629	11314	7611	13295	9592	15276	11573	17257	13554	19239	9851	15536	11832	17517	13814	19498	15795	21479	17776	23460	14073	19757	16054	21739	18035	23720	20017	25701	21998	27682

Table 65: Commercial VPP in the Portuguese mFRR market. FO's NPV (EUR) of the simulated pools with an average DER capacity of 1 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-291162	-300550	-304253	-307956	-311659	-315362	-319065	-322768	-326471	-330174	-333877	-343265	-346968	-350671	-354374	-358077	-361780	-365483	-369187	-372890	-376593	-385980	-389683	-393386	-397089	-400793	-404496	-408199	-411902	-415605	-419308
1	-300550	-309937	-313640	-317343	-321046	-324749	-328453	-332156	-335859	-339562	-343265	-352652	-356355	-360058	-363762	-367465	-371168	-374871	-378574	-382277	-385980	-395368	-399071	-402774	-406477	-410180	-413883	-417586	-421289	-424992	-428695
2	-287603	-296991	-300694	-304397	-308100	-311803	-315506	-319209	-322912	-326615	-330319	-339706	-343409	-347112	-350815	-354518	-358221	-361925	-365628	-369331	-373034	-382421	-386124	-389827	-393531	-397234	-400937	-404640	-408343	-412046	-415749
3	-274657	-284044	-287748	-291451	-295154	-298857	-302560	-306263	-309966	-313669	-317372	-326760	-330463	-334166	-337869	-341572	-345275	-348978	-352681	-356384	-360088	-369475	-373178	-376881	-380584	-384287	-387990	-391694	-395397	-399100	-402803
4	-261711	-271098	-274801	-278504	-282207	-285911	-289614	-293317	-297020	-300723	-304426	-313813	-317517	-321220	-324923	-328626	-332329	-336032	-339735	-343438	-347141	-356529	-360232	-363935	-367638	-371341	-375044	-378747	-382450	-386153	-389857
5	-248764	-258152	-261855	-265558	-269261	-272964	-276667	-280370	-284074	-287777	-291480	-300867	-304570	-308273	-311976	-315679	-319383	-323086	-326789	-330492	-334195	-343582	-347285	-350989	-354692	-358395	-362098	-365801	-369504	-373207	-376910
6	-235818	-245206	-248909	-252612	-256315	-260018	-263721	-267424	-271127	-274830	-278533	-287921	-291624	-295327	-299030	-302733	-306436	-310139	-313842	-317546	-321249	-330636	-334339	-338042	-341745	-345448	-349152	-352855	-356558	-360261	-363964
7	-222872	-232259	-235962	-239665	-243369	-247072	-250775	-254478	-258181	-261884	-265587	-274975	-278678	-282381	-286084	-289787	-293490	-297193	-300896	-304599	-308302	-317690	-321393	-325096	-328799	-332502	-336205	-339908	-343611	-347315	-351018
8	-209926	-219313	-223016	-226719	-230422	-234125	-237828	-241532	-245235	-248938	-252641	-262028	-265731	-269434	-273138	-276841	-280544	-284247	-287950	-291653	-295356	-304743	-308447	-312150	-315853	-319556	-323259	-326962	-330665	-334368	-338071
9	-196979	-206367	-210070	-213773	-217476	-221179	-224882	-228585	-232288	-235991	-239695	-249082	-252785	-256488	-260191	-263894	-267597	-271301	-275004	-278707	-282410	-291797	-295500	-299203	-302906	-306610	-310313	-314016	-317719	-321422	-325125
10	-184033	-193420	-197123	-200827	-204530	-208233	-211936	-215639	-219342	-223045	-226748	-236136	-239839	-243542	-247245	-250948	-254651	-258354	-262057	-265760	-269463	-278851	-282554	-286257	-289960	-293663	-297366	-301069	-304773	-308476	-312179
11	-193420	-202808	-206511	-210214	-213917	-217620	-221323	-225026	-228729	-232433	-236136	-245523	-249226	-252929	-256632	-260335	-264039	-267742	-271445	-275148	-278851	-288238	-291941	-295645	-299348	-303051	-306754	-310457	-314160	-317863	-321566
12	-180474	-189862	-193565	-197268	-200971	-204674	-208377	-212080	-215783	-219486	-223189	-232577	-236280	-239983	-243686	-247389	-251092	-254795	-258498	-262202	-265905	-275292	-278995	-282698	-286401	-290104	-293807	-297511	-301214	-304917	-308620

13	-167528	-176915	-180618	-184321	-188025	-191728	-195431	-199134	-202837	-206540	-210243	-219630	-223334	-227037	-230740	-234443	-238146	-241849	-245552	-249255	-252958	-262346	-266049	-269752	-273455	-277158	-280861	-284564	-288267	-291970	-295674
14	-154582	-163969	-167672	-171375	-175078	-178781	-182484	-186187	-189891	-193594	-197297	-206684	-210387	-214090	-217793	-221497	-225200	-228903	-232606	-236309	-240012	-249399	-253103	-256806	-260509	-264212	-267915	-271618	-275321	-279024	-282727
15	-141635	-151023	-154726	-158429	-162132	-165835	-169538	-173241	-176944	-180647	-184350	-193738	-197441	-201144	-204847	-208550	-212253	-215956	-219660	-223363	-227066	-236453	-240156	-243859	-247562	-251266	-254969	-258672	-262375	-266078	-269781
16	-128689	-138076	-141779	-145483	-149186	-152889	-156592	-160295	-163998	-167701	-171404	-180792	-184495	-188198	-191901	-195604	-199307	-203010	-206713	-210416	-214119	-223507	-227210	-230913	-234616	-238319	-242022	-245725	-249429	-253132	-256835
17	-115743	-125130	-128833	-132536	-136239	-139942	-143646	-147349	-151052	-154755	-158458	-167845	-171548	-175251	-178955	-182658	-186361	-190064	-193767	-197470	-201173	-210561	-214264	-217967	-221670	-225373	-229076	-232779	-236482	-240185	-243888
18	-102796	-112184	-115887	-119590	-123293	-126996	-130699	-134402	-138105	-141809	-145512	-154899	-158602	-162305	-166008	-169711	-173414	-177118	-180821	-184524	-188227	-197614	-201317	-205020	-208724	-212427	-216130	-219833	-223536	-227239	-230942
19	-89850	-99237	-102941	-106644	-110347	-114050	-117753	-121456	-125159	-128862	-132565	-141953	-145656	-149359	-153062	-156765	-160468	-164171	-167874	-171577	-175281	-184668	-188371	-192074	-195777	-199480	-203183	-206887	-210590	-214293	-217996
20	-76904	-86291	-89994	-93697	-97400	-101104	-104807	-108510	-112213	-115916	-119619	-129006	-132710	-136413	-140116	-143819	-147522	-151225	-154928	-158631	-162334	-171722	-175425	-179128	-182831	-186534	-190237	-193940	-197643	-201346	-205050
21	-86291	-95679	-99382	-103085	-106788	-110491	-114194	-117897	-121600	-125303	-129006	-138394	-142097	-145800	-149503	-153206	-156909	-160612	-164315	-168019	-171722	-181109	-184812	-188515	-192218	-195921	-199625	-203328	-207031	-210734	-214437
22	-73345	-82732	-86435	-90138	-93842	-97545	-101248	-104951	-108654	-112357	-116060	-125448	-129151	-132854	-136557	-140260	-143963	-147666	-151369	-155072	-158775	-168163	-171866	-175569	-179272	-182975	-186678	-190381	-194084	-197788	-201491
23	-60399	-69786	-73489	-77192	-80895	-84598	-88301	-92005	-95708	-99411	-103114	-112501	-116204	-119907	-123611	-127314	-131017	-134720	-138423	-142126	-145829	-155217	-158920	-162623	-166326	-170029	-173732	-177435	-181138	-184841	-188544
24	-47452	-56840	-60543	-64246	-67949	-71652	-75355	-79058	-82761	-86464	-90168	-99555	-103258	-106961	-110664	-114367	-118070	-121774	-125477	-129180	-132883	-142270	-145973	-149676	-153379	-157083	-160786	-164489	-168192	-171895	-175598
25	-34506	-43893	-47597	-51300	-55003	-58706	-62409	-66112	-69815	-73518	-77221	-86609	-90312	-94015	-97718	-101421	-105124	-108827	-112530	-116233	-119937	-129324	-133027	-136730	-140433	-144136	-147839	-151542	-155246	-158949	-162652
26	-21560	-30947	-34650	-38353	-42056	-45759	-49463	-53166	-56869	-60572	-64275	-73662	-77365	-81069	-84772	-88475	-92178	-95881	-99584	-103287	-106990	-116378	-120081	-123784	-127487	-131190	-134893	-138596	-142299	-146002	-149705
27	-8613	-18001	-21704	-25407	-29110	-32813	-36516	-40219	-43922	-47626	-51329	-60716	-64419	-68122	-71825	-75528	-79232	-82935	-86638	-90341	-94044	-103431	-107134	-110838	-114541	-118244	-121947	-125650	-129353	-133056	-136759
28	4333	-5055	-8758	-12461	-16164	-19867	-23570	-27273	-30976	-34679	-38382	-47770	-51473	-55176	-58879	-62582	-66285	-69988	-73691	-77395	-81098	-90485	-94188	-97891	-101594	-105297	-109000	-112704	-116407	-120110	-123813
29	17279	7892	4189	486	-3218	-6921	-10624	-14327	-18030	-21733	-25436	-34823	-38527	-42230	-45933	-49636	-53339	-57042	-60745	-64448	-68151	-77539	-81242	-84945	-88648	-92351	-96054	-99757	-103460	-107163	-110867
30	30225	20838	17135	13432	9729	6026	2323	-1381	-5084	-8787	-12490	-21877	-25580	-29283	-32986	-36690	-40393	-44096	-47799	-51502	-55205	-64592	-68296	-71999	-75702	-79405	-83108	-86811	-90514	-94217	-97920

Table 66: Commercial VPP in the Portuguese mFRR market. FO's NPV (EUR) of the simulated pools with an average DER capacity of 1.25 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-291162	-300550	-304253	-307956	-311659	-305975	-309678	-313381	-317084	-320787	-315103	-324490	-328193	-331896	-335599	-329915	-333618	-337321	-341024	-344727	-339043	-348430	-352134	-355837	-359540	-353855	-357559	-361262	-364965	-368668	-362983
1	-300550	-309937	-313640	-317343	-311659	-315362	-319065	-322768	-326471	-320787	-324490	-333877	-337581	-341284	-335599	-339302	-343006	-346709	-350412	-344727	-348430	-357818	-361521	-365224	-359540	-363243	-366946	-370649	-374352	-368668	-372371
2	-287603	-296991	-300694	-295010	-298713	-302416	-306119	-309822	-304138	-307841	-311544	-320931	-324634	-318950	-322653	-326356	-330059	-333762	-328078	-331781	-335484	-344872	-348575	-342890	-346593	-350297	-354000	-357703	-352018	-355722	-359425
3	-274657	-284044	-278360	-282063	-285766	-289469	-293173	-287488	-291191	-294894	-298597	-307985	-302301	-306004	-309707	-313410	-317113	-311429	-315132	-318835	-322538	-331925	-326241	-329944	-333647	-337350	-341053	-335369	-339072	-342775	-346478
4	-261711	-261711	-265414	-269117	-272820	-276523	-270839	-274542	-278245	-281948	-285651	-285651	-289354	-293057	-296760	-300464	-294779	-298482	-302185	-305889	-309592	-309592	-313295	-316998	-320701	-324404	-318720	-322423	-326126	-329829	-333532
5	-239377	-248764	-252468	-256171	-259874	-254189	-257893	-261596	-265299	-269002	-263317	-272705	-276408	-280111	-283814	-278130	-281833	-285536	-289239	-292942	-287258	-296645	-300348	-304051	-307755	-302070	-305773	-309476	-313180	-316883	-311198
6	-226431	-235818	-239521	-243224	-237540	-241243	-244946	-248649	-252352	-246668	-250371	-259759	-263462	-267165	-261480	-265184	-268887	-272590	-276293	-270609	-274312	-283699	-287402	-291105	-285421	-289124	-292827	-296530	-300233	-294549	-298252
7	-213484	-222872	-226575	-220891	-224594	-228297	-232000	-235703	-230019	-233722	-237425	-246812	-250515	-244831	-248534	-252237	-255940	-259643	-253959	-257662	-261365	-270753	-274456	-268771	-272475	-276178	-279881	-283584	-277900	-281603	-285306

8	-200538	-209926	-204241	-207944	-211647	-215351	-219054	-213369	-217072	-220776	-224479	-233866	-228182	-231885	-235588	-239291	-242994	-237310	-241013	-244716	-248419	-257806	-252122	-255825	-259528	-263231	-266934	-261250	-264953	-268656	-272359
9	-187592	-187592	-191295	-194998	-198701	-202404	-196720	-200423	-204126	-207829	-211532	-211532	-215235	-218938	-222642	-226345	-220660	-224363	-228067	-231770	-235473	-235473	-239176	-242879	-246582	-250285	-244601	-248304	-252007	-255710	-259413
10	-165258	-174646	-178349	-182052	-185755	-180071	-183774	-187477	-191180	-194883	-189199	-198586	-202289	-205992	-209695	-204011	-207714	-211417	-215120	-218823	-213139	-222526	-226230	-229933	-233636	-227951	-231654	-235358	-239061	-242764	-237079
11	-174646	-184033	-187736	-191439	-185755	-189458	-193161	-196864	-200567	-194883	-198586	-207973	-211677	-215380	-209695	-213398	-217101	-220805	-224508	-218823	-222526	-231914	-235617	-239320	-233636	-237339	-241042	-244745	-248448	-242764	-246467
12	-161699	-171087	-174790	-169105	-172809	-176512	-180215	-183918	-178234	-181937	-185640	-195027	-198730	-193046	-196749	-200452	-204155	-207858	-202174	-205877	-209580	-218968	-222671	-216986	-220689	-224393	-228096	-231799	-226114	-229817	-233521
13	-148753	-158140	-152456	-156159	-159862	-163565	-167268	-161584	-165287	-168990	-172693	-182081	-176397	-180100	-183803	-187506	-191209	-185525	-189228	-192931	-196634	-206021	-200337	-204040	-207743	-211446	-215149	-209465	-213168	-216871	-220574
14	-135807	-135807	-139510	-143213	-146916	-150619	-144935	-148638	-152341	-156044	-159747	-159747	-163450	-167153	-170856	-174559	-168875	-172578	-176281	-179984	-183688	-183688	-187391	-191094	-194797	-198500	-192816	-196519	-200222	-203925	-207628
15	-113473	-122860	-126564	-130267	-133970	-128285	-131988	-135692	-139395	-143098	-137413	-146801	-150504	-154207	-157910	-152226	-155929	-159632	-163335	-167038	-161354	-170741	-174444	-178147	-181851	-176166	-179869	-183572	-187275	-190979	-185294
16	-100527	-109914	-113617	-117320	-111636	-115339	-119042	-122745	-126448	-120764	-124467	-133855	-137558	-141261	-135576	-139280	-142983	-146686	-150389	-144704	-148408	-157795	-161498	-165201	-159517	-163220	-166923	-170626	-174329	-168645	-172348
17	-87580	-96968	-100671	-94987	-98690	-102393	-106096	-109799	-104115	-107818	-111521	-120908	-124611	-118927	-122630	-126333	-130036	-133739	-128055	-131758	-135461	-144849	-148552	-142867	-146571	-150274	-153977	-157680	-151996	-155699	-159402
18	-74634	-84022	-78337	-82040	-85743	-89446	-93150	-87465	-91168	-94871	-98575	-107962	-102278	-105981	-109684	-113387	-117090	-111406	-115109	-118812	-122515	-131902	-126218	-129921	-133624	-137327	-141030	-135346	-139049	-142752	-146455
19	-61688	-61688	-65391	-69094	-72797	-76500	-70816	-74519	-78222	-81925	-85628	-85628	-89331	-93034	-96738	-100441	-94756	-98459	-102162	-105866	-109569	-109569	-113272	-116975	-120678	-124381	-118697	-122400	-126103	-129806	-133509
20	-39354	-48742	-52445	-56148	-59851	-54166	-57870	-61573	-65276	-68979	-63295	-72682	-76385	-80088	-83791	-78107	-81810	-85513	-89216	-92919	-87235	-96622	-100325	-104029	-107732	-102047	-105750	-109454	-113157	-116860	-111175
21	-48742	-58129	-61832	-65535	-59851	-63554	-67257	-70960	-74663	-68979	-72682	-82069	-85772	-89476	-83791	-87494	-91197	-94901	-98604	-92919	-96622	-106010	-109713	-113416	-107732	-111435	-115138	-118841	-122544	-116860	-120563
22	-35795	-45183	-48886	-43201	-46905	-50608	-54311	-58014	-52329	-56033	-59736	-69123	-72826	-67142	-70845	-74548	-78251	-81954	-76270	-79973	-83676	-93063	-96767	-91082	-94785	-98488	-102192	-105895	-100210	-103913	-107617
23	-22849	-32236	-26552	-30255	-33958	-37661	-41364	-35680	-39383	-43086	-46789	-56177	-50492	-54196	-57899	-61602	-65305	-59621	-63324	-67027	-70730	-80117	-74433	-78136	-81839	-85542	-89245	-83561	-87264	-90967	-94670
24	-9903	-9903	-13606	-17309	-21012	-24715	-19031	-22734	-26437	-30140	-33843	-33843	-37546	-41249	-44952	-48655	-42971	-46674	-50377	-54080	-57784	-57784	-61487	-65190	-68893	-72596	-66912	-70615	-74318	-78021	-81724
25	12431	3044	-659	-4363	-8066	-2381	-6084	-9788	-13491	-17194	-11509	-20897	-24600	-28303	-32006	-26322	-30025	-33728	-37431	-41134	-35450	-44837	-48540	-52243	-55946	-50262	-53965	-57668	-61371	-65075	-59390
26	25377	15990	12287	8584	14268	10565	6862	3159	-544	5140	1437	-7950	-11654	-15357	-9672	-13375	-17079	-20782	-24485	-18800	-22504	-31891	-35594	-39297	-33613	-37316	-41019	-44722	-48425	-42741	-46444
27	38324	28936	25233	30917	27214	23511	19808	16105	21789	18086	14383	4996	1293	6977	3274	-429	-4132	-7835	-2151	-5854	-9557	-18945	-22648	-16963	-20666	-24370	-28073	-31776	-26091	-29795	-33498
28	51270	41883	47567	43864	40161	36458	32754	38439	34736	31033	27330	17942	23626	19923	16220	12517	8814	14498	10795	7092	3389	-5998	-314	-4017	-7720	-11423	-15126	-9442	-13145	-16848	-20551
29	64216	64216	60513	56810	53107	49404	55088	51385	47682	43979	40276	40276	36573	32870	29167	25463	31148	27445	23742	20038	16335	16335	12632	8929	5226	1523	7207	3504	-199	-3902	-7605
30	86550	77163	73459	69756	66053	71738	68034	64331	60628	56925	62610	53222	49519	45816	42113	47797	44094	40391	36688	32985	38669	29282	25579	21875	18172	23857	20154	16451	12747	9044	14729

Table 67: Commercial in the Portuguese mFRR market. FO's NPV (EUR) of the simulated pools with an average DER capacity of 1.5 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-291162	-300550	-304253	-298568	-302272	-305975	-300290	-303993	-307696	-302012	-305715	-315103	-309418	-313121	-316825	-311140	-314843	-318546	-312862	-316565	-320268	-320268	-323971	-327674	-321990	-325693	-329396	-323712	-327415	-331118	-325434
1	-300550	-309937	-304253	-307956	-311659	-305975	-309678	-313381	-307696	-311400	-315103	-315103	-318806	-322509	-316825	-320528	-324231	-318546	-322249	-325953	-320268	-329656	-333359	-327674	-331378	-335081	-329396	-333099	-336802	-331118	-334821
2	-287603	-287603	-291306	-295010	-289325	-293028	-296731	-291047	-294750	-298453	-292769	-302156	-305859	-300175	-303878	-307581	-301897	-305600	-309303	-303619	-307322	-316709	-311025	-314728	-318431	-312747	-316450	-320153	-314469	-318172	-321875

3	-265270	-274657	-278360	-272676	-276379	-280082	-274398	-278101	-281804	-276120	-279823	-289210	-283526	-287229	-290932	-285248	-288951	-292654	-286969	-290673	-294376	-294376	-298079	-301782	-296098	-299801	-303504	-297819	-301522	-305226	-299541
4	-252323	-261711	-256026	-259730	-263433	-257748	-261451	-265154	-259470	-263173	-266876	-266876	-270579	-274283	-268598	-272301	-276004	-270320	-274023	-277726	-272042	-281429	-285132	-279448	-283151	-286854	-281170	-284873	-288576	-282892	-286595
5	-239377	-239377	-243080	-246783	-241099	-244802	-248505	-242821	-246524	-250227	-244543	-253930	-257633	-251949	-255652	-259355	-253671	-257374	-261077	-255393	-259096	-268483	-262799	-266502	-270205	-264521	-268224	-271927	-266242	-269946	-273649
6	-217043	-226431	-230134	-224450	-228153	-231856	-226171	-229874	-233578	-227893	-231596	-240984	-235299	-239003	-242706	-237021	-240724	-244428	-238743	-242446	-246149	-246149	-249852	-253556	-247871	-251574	-255277	-249593	-253296	-256999	-251315
7	-204097	-213484	-207800	-211503	-215206	-209522	-213225	-216928	-211244	-214947	-218650	-218650	-222353	-226056	-220372	-224075	-227778	-222094	-225797	-229500	-223816	-233203	-236906	-231222	-234925	-238628	-232944	-236647	-240350	-234666	-238369
8	-191151	-191151	-194854	-198557	-192873	-196576	-200279	-194594	-198298	-202001	-196316	-205704	-209407	-203723	-207426	-211129	-205444	-209148	-212851	-207166	-210869	-220257	-214572	-218276	-221979	-216294	-219997	-223701	-218016	-221719	-225422
9	-168817	-178204	-181908	-176223	-179926	-183629	-177945	-181648	-185351	-179667	-183370	-192757	-187073	-190776	-194479	-188795	-192498	-196201	-190517	-194220	-197923	-197923	-201626	-205329	-199645	-203348	-207051	-201367	-205070	-208773	-203089
10	-155871	-165258	-159574	-163277	-166980	-161296	-164999	-168702	-163018	-166721	-170424	-170424	-174127	-177830	-172146	-175849	-179552	-173868	-177571	-181274	-175589	-184977	-188680	-182996	-186699	-190402	-184717	-188421	-192124	-186439	-190142
11	-165258	-165258	-168961	-172664	-166980	-170683	-174386	-168702	-172405	-176108	-170424	-179811	-183514	-177830	-181533	-185236	-179552	-183255	-186958	-181274	-184977	-194364	-188680	-192383	-196086	-190402	-194105	-197808	-192124	-195827	-199530
12	-142924	-152312	-156015	-150331	-154034	-157737	-152053	-155756	-159459	-153774	-157477	-166865	-161181	-164884	-168587	-162902	-166606	-170309	-164624	-168327	-172030	-172030	-175734	-179437	-173752	-177455	-181159	-175474	-179177	-182880	-177196
13	-129978	-139366	-133681	-137384	-141087	-135403	-139106	-142809	-137125	-140828	-144531	-144531	-148234	-151937	-146253	-149956	-153659	-147975	-151678	-155381	-149697	-159084	-162787	-157103	-160806	-164509	-158825	-162528	-166231	-160547	-164250
14	-117032	-117032	-120735	-124438	-118754	-122457	-126160	-120476	-124179	-127882	-122197	-131585	-135288	-129604	-133307	-137010	-131326	-135029	-138732	-133047	-136750	-146138	-140454	-144157	-147860	-142175	-145879	-149582	-143897	-147600	-151304
15	-94698	-104086	-107789	-102104	-105807	-109511	-103826	-107529	-111232	-105548	-109251	-118639	-112954	-116657	-120360	-114676	-118379	-122082	-116398	-120101	-123804	-123804	-127507	-131210	-125526	-129229	-132932	-127248	-130951	-134654	-128970
16	-81752	-91139	-85455	-89158	-92861	-87177	-90880	-94583	-88899	-92602	-96305	-96305	-100008	-103711	-98027	-101730	-105433	-99749	-103452	-107155	-101470	-110858	-114561	-108877	-112580	-116283	-110599	-114302	-118005	-112320	-116024
17	-68806	-68806	-72509	-76212	-70527	-74231	-77934	-72249	-75952	-79656	-73971	-83359	-87062	-81377	-85080	-88784	-83099	-86802	-90505	-84821	-88524	-97912	-92227	-95930	-99633	-93949	-97652	-101355	-95671	-99374	-103077
18	-46472	-55859	-59562	-53878	-57581	-61284	-55600	-59303	-63006	-57322	-61025	-70412	-64728	-68431	-72134	-66450	-70153	-73856	-68172	-71875	-75578	-75578	-79281	-82984	-77300	-81003	-84706	-79022	-82725	-86428	-80744
19	-33526	-42913	-37229	-40932	-44635	-38951	-42654	-46357	-40672	-44376	-48079	-48079	-51782	-55485	-49800	-53504	-57207	-51522	-55225	-58929	-53244	-62632	-66335	-60650	-64353	-68057	-62372	-66075	-69778	-64094	-67797
20	-20579	-20579	-24282	-27985	-22301	-26004	-29707	-24023	-27726	-31429	-25745	-35132	-38835	-33151	-36854	-40557	-34873	-38576	-42279	-36595	-40298	-49685	-44001	-47704	-51407	-45723	-49426	-53129	-47445	-51148	-54851
21	-20579	-29967	-33670	-27985	-31689	-35392	-29707	-33410	-37114	-31429	-35132	-44520	-38835	-42538	-46242	-40557	-44260	-47963	-42279	-45982	-49685	-49685	-53388	-57092	-51407	-55110	-58813	-53129	-56832	-60535	-54851
22	-7633	-17020	-11336	-15039	-18742	-13058	-16761	-20464	-14780	-18483	-22186	-22186	-25889	-29592	-23908	-27611	-31314	-25630	-29333	-33036	-27352	-36739	-40442	-34758	-38461	-42164	-36480	-40183	-43886	-38202	-41905
23	5313	5313	1610	-2093	3591	-112	-3815	1870	-1834	-5537	148	-9240	-12943	-7258	-10962	-14665	-8980	-12683	-16387	-10702	-14405	-23793	-18108	-21812	-25515	-19830	-23533	-27236	-21552	-25255	-28958
24	27647	18260	14556	20241	16538	12835	18519	14816	11113	16797	13094	3707	9391	5688	1985	7669	3966	263	5947	2244	-1459	-1459	-5162	-8865	-3181	-6884	-10587	-4903	-8606	-12309	-6625
25	40593	31206	36890	33187	29484	35168	31465	27762	33446	29743	26040	26040	22337	18634	24318	20615	16912	22597	18893	15190	20875	11487	7784	13468	9765	6062	11747	8044	4340	10025	6322
26	53540	53540	49836	46133	51818	48115	44412	50096	46393	42690	48374	38987	35283	40968	37265	33562	39246	35543	31840	37524	33821	24434	30118	26415	22712	28396	24693	20990	26674	22971	19268
27	75873	66486	62783	68467	64764	61061	66745	63042	59339	65023	61320	51933	57617	53914	50211	55895	52192	48489	54173	50470	46767	46767	43064	39361	45045	41342	37639	43324	39620	35917	41602
28	88820	79432	85116	81413	77710	83395	79692	75988	81673	77970	74267	74267	70563	66860	72545	68842	65139	70823	67120	63417	69101	59714	56010	61695	57992	54289	59973	56270	52567	58251	54548
29	101766	101766	98063	94360	100044	96341	92638	98322	94619	90916	96600	87213	83510	89194	85491	81788	87472	83769	80066	85750	82047	72660	78344	74641	70938	76622	72919	69216	74900	71197	67494
30	124100	114712	111009	116693	112990	109287	114972	111268	107565	113250	109547	100159	105843	102140	98437	104122	100419	96715	102400	98697	94994	94994	91290	87587	93272	89569	85865	91550	87847	84144	89828

Table 68: Commercial VPP in the Portuguese mFRR market. FO's NPV (EUR) of the simulated pools with an average DER capacity of 1.75 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-291162	-300550	-304253	-298568	-302272	-296587	-300290	-294606	-298309	-302012	-296328	-305715	-300031	-303734	-298050	-301753	-305456	-299772	-303475	-297790	-301493	-301493	-305197	-308900	-303215	-306918	-301234	-304937	-299253	-302956	-306659
1	-300550	-309937	-304253	-307956	-302272	-305975	-300290	-303993	-307696	-302012	-305715	-305715	-309418	-303734	-307437	-311140	-305456	-309159	-303475	-307178	-301493	-310881	-314584	-308900	-312603	-306918	-310621	-304937	-308640	-312343	-306659
2	-287603	-287603	-291306	-285622	-289325	-283641	-287344	-291047	-285363	-289066	-283382	-292769	-287085	-290788	-294491	-288806	-292510	-286825	-290528	-284844	-288547	-297935	-292250	-295953	-290269	-293972	-288288	-291991	-295694	-290010	-293713
3	-265270	-274657	-268973	-272676	-266992	-270695	-274398	-268713	-272416	-266732	-270435	-270435	-274138	-277841	-272157	-275860	-270176	-273879	-268195	-271898	-275601	-275601	-279304	-273620	-277323	-271638	-275341	-279045	-273360	-277063	-271379
4	-252323	-252323	-256026	-250342	-254045	-257748	-252064	-255767	-250083	-253786	-248102	-257489	-261192	-255508	-259211	-253526	-257230	-251545	-255248	-258951	-253267	-262655	-256970	-260673	-254989	-258692	-262395	-256711	-260414	-254730	-258433
5	-229990	-239377	-233693	-237396	-241099	-235415	-239118	-233433	-237136	-231452	-235155	-244543	-238858	-242561	-236877	-240580	-234896	-238599	-242302	-236618	-240321	-240321	-244024	-238340	-242043	-245746	-240061	-243765	-238080	-241783	-236099
6	-217043	-217043	-220746	-224450	-218765	-222468	-216784	-220487	-214803	-218506	-222209	-222209	-225912	-220228	-223931	-218246	-221950	-225653	-219968	-223671	-217987	-227375	-221690	-225393	-229096	-223412	-227115	-221431	-225134	-219450	-223153
7	-194710	-204097	-207800	-202116	-205819	-200135	-203838	-198153	-201856	-205560	-199875	-209263	-203578	-207281	-201597	-205300	-209003	-203319	-207022	-201338	-205041	-205041	-208744	-212447	-206763	-210466	-204781	-208485	-202800	-206503	-210206
8	-181763	-191151	-185466	-189170	-183485	-187188	-181504	-185207	-188910	-183226	-186929	-186929	-190632	-184948	-188651	-192354	-186670	-190373	-184688	-188391	-182707	-192095	-195798	-190113	-193816	-188132	-191835	-186151	-189854	-193557	-187873
9	-168817	-168817	-172520	-166836	-170539	-164855	-168558	-172261	-166576	-170280	-164595	-173983	-168298	-172001	-175705	-170020	-173723	-168039	-171742	-166058	-169761	-179148	-173464	-177167	-171483	-175186	-169501	-173205	-176908	-171223	-174926
10	-146483	-155871	-150186	-153890	-148205	-151908	-155611	-149927	-153630	-147946	-151649	-151649	-155352	-159055	-153371	-157074	-151390	-155093	-149408	-153111	-156815	-156815	-160518	-154833	-158536	-152852	-156555	-160258	-154574	-158277	-152593
11	-155871	-155871	-159574	-153890	-157593	-161296	-155611	-159314	-153630	-157333	-151649	-161036	-164739	-159055	-162758	-157074	-160777	-155093	-158796	-162499	-156815	-166202	-160518	-164221	-158536	-162240	-165943	-160258	-163961	-158277	-161980
12	-133537	-142924	-137240	-140943	-144646	-138962	-142665	-136981	-140684	-135000	-138703	-148090	-142406	-146109	-140425	-144128	-138443	-142146	-145849	-140165	-143868	-143868	-147571	-141887	-145590	-149293	-143609	-147312	-141628	-145331	-139646
13	-120591	-120591	-124294	-127997	-122313	-126016	-120331	-124034	-118350	-122053	-125756	-125756	-129459	-123775	-127478	-121794	-125497	-129200	-123516	-127219	-121535	-130922	-125238	-128941	-132644	-126960	-130663	-124978	-128681	-122997	-126700
14	-98257	-107644	-111348	-105663	-109366	-103682	-107385	-101701	-105404	-109107	-103423	-112810	-107126	-110829	-105145	-108848	-112551	-106866	-110569	-104885	-108588	-108588	-112291	-115994	-110310	-114013	-108329	-112032	-106348	-110051	-113754
15	-85311	-94698	-89014	-92717	-87033	-90736	-85051	-88754	-92458	-86773	-90476	-90476	-94179	-88495	-92198	-95901	-90217	-93920	-88236	-91939	-86255	-95642	-99345	-93661	-97364	-91680	-95383	-89698	-93401	-97104	-91420
16	-72364	-72364	-76068	-70383	-74086	-68402	-72105	-75808	-70124	-73827	-68143	-77530	-71846	-75549	-79252	-73568	-77271	-71586	-75289	-69605	-73308	-82696	-77011	-80714	-75030	-78733	-73049	-76752	-80455	-74771	-78474
17	-50031	-59418	-53734	-57437	-51753	-55456	-59159	-53474	-57178	-51493	-55196	-55196	-58899	-62603	-56918	-60621	-54937	-58640	-52956	-56659	-60362	-60362	-64065	-58381	-62084	-56400	-60103	-63806	-58121	-61824	-56140
18	-37084	-37084	-40788	-35103	-38806	-42509	-36825	-40528	-34844	-38547	-32863	-42250	-45953	-40269	-43972	-38288	-41991	-36306	-40009	-43713	-38028	-47416	-41731	-45434	-39750	-43453	-47156	-41472	-45175	-39491	-43194
19	-14751	-24138	-18454	-22157	-25860	-20176	-23879	-18194	-21898	-16213	-19916	-29304	-23619	-27323	-21638	-25341	-19657	-23360	-27063	-21379	-25082	-25082	-28785	-23101	-26804	-30507	-24823	-28526	-22841	-26544	-20860
20	-1804	-1804	-5508	-9211	-3526	-7229	-1545	-5248	436	-3267	-6970	-6970	-10673	-4989	-8692	-3008	-6711	-10414	-4729	-8433	-2748	-12136	-6451	-10154	-13858	-8173	-11876	-6192	-9895	-4211	-7914
21	-1804	-11192	-14895	-9211	-12914	-7229	-10933	-5248	-8951	-12654	-6970	-16357	-10673	-14376	-8692	-12395	-16098	-10414	-14117	-8433	-12136	-12136	-15839	-19542	-13858	-17561	-11876	-15579	-9895	-13598	-17301
22	11142	1754	7439	3736	9420	5717	11401	7698	3995	9679	5976	5976	2273	7957	4254	551	6236	2532	8217	4514	10198	811	-2892	2792	-911	4773	1070	6754	3051	-652	5032
23	24088	24088	20385	26069	22366	28051	24347	20644	26329	22626	28310	18923	24607	20904	17201	22885	19182	24866	21163	26847	23144	13757	19441	15738	21422	17719	23404	19701	15997	21682	17979
24	46422	37034	42719	39016	44700	40997	37294	42978	39275	44959	41256	41256	37553	33850	39534	35831	41516	37812	43497	39794	36091	36091	32388	38072	34369	40053	36350	32647	38331	34628	40312
25	59368	59368	55665	61349	57646	53943	59627	55924	61609	57906	63590	54203	50499	56184	52481	58165	54462	60146	56443	52740	58424	49037	54721	51018	56702	52999	49296	54981	51277	56962	53259
26	81702	72314	77999	74296	70593	76277	72574	78258	74555	80239	76536	67149	72833	69130	74814	71111	76796	73092	69389	75074	71371	71371	67668	73352	69649	65946	71630	67927	73611	69908	75592
27	94648	94648	90945	87242	92926	89223	94907	91204	96889	93186	89483	89483	85779	91464	87761	93445	89742	86039	91723	88020	93704	84317	90001	86298	82595	88279	84576	90261	86557	92242	88539

28	116982	107594	103891	109576	105873	111557	107854	113538	109835	106132	111816	102429	108113	104410	110094	106391	102688	108372	104669	110354	106651	106651	102948	99244	104929	101226	106910	103207	108891	105188	101485
29	129928	120541	126225	122522	128206	124503	130187	126484	122781	128466	124763	124763	121059	126744	123041	119338	125022	121319	127003	123300	128984	119597	115894	121578	117875	123559	119856	125541	121837	118134	123819
30	142874	142874	139171	144856	141153	146837	143134	139431	145115	141412	147096	137709	143393	139690	135987	141671	137968	143652	139949	145634	141931	132543	138228	134524	140209	136506	142190	138487	134784	140468	136765

Table 69: Commercial VPP in the Portuguese mFRR market. FO's NPV (EUR) of the simulated pools with an average DER capacity of 2 MW. Complete matrix.

Down \ Up	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	-291162	-300550	-294865	-298568	-292884	-296587	-290903	-294606	-288922	-292625	-286940	-296328	-290644	-294347	-288662	-292365	-286681	-290384	-284700	-288403	-282719	-292106	-286422	-290125	-284440	-288144	-282459	-286162	-280478	-284181	-278497
1	-300550	-300550	-304253	-298568	-302272	-296587	-300290	-294606	-298309	-292625	-296328	-296328	-300031	-294347	-298050	-292365	-296068	-290384	-294087	-288403	-292106	-292106	-295809	-290125	-293828	-288144	-291847	-286162	-289865	-284181	-287884
2	-278216	-287603	-281919	-285622	-279938	-283641	-277957	-281660	-275975	-279678	-273994	-283382	-277697	-281400	-275716	-279419	-273735	-277438	-271754	-275457	-269772	-279160	-273475	-277178	-271494	-275197	-269513	-273216	-267532	-271235	-265550
3	-265270	-265270	-268973	-263288	-266992	-261307	-265010	-259326	-263029	-257345	-261048	-261048	-264751	-259067	-262770	-257085	-260788	-255104	-258807	-253123	-256826	-256826	-260529	-254845	-258548	-252864	-256567	-250882	-254585	-248901	-252604
4	-242936	-252323	-246639	-250342	-244658	-248361	-242677	-246380	-240695	-244398	-238714	-248102	-242417	-246120	-240436	-244139	-238455	-242158	-236474	-240177	-234492	-243880	-238195	-241898	-236214	-239917	-234233	-237936	-232252	-235955	-230270
5	-229990	-229990	-233693	-228008	-231712	-226027	-229730	-224046	-227749	-222065	-225768	-225768	-229471	-223787	-227490	-221805	-225508	-219824	-223527	-217843	-221546	-221546	-225249	-219565	-223268	-217584	-221287	-215602	-219305	-213621	-217324
6	-207656	-217043	-211359	-215062	-209378	-213081	-207397	-211100	-205415	-209118	-203434	-212822	-207137	-210840	-205156	-208859	-203175	-206878	-201194	-204897	-199212	-208600	-202915	-206618	-200934	-204637	-198953	-202656	-196972	-200675	-194991
7	-194710	-194710	-198413	-192728	-196432	-190747	-194450	-188766	-192469	-186785	-190488	-190488	-194191	-188507	-192210	-186525	-190228	-184544	-188247	-182563	-186266	-186266	-189969	-184285	-187988	-182304	-186007	-180322	-184025	-178341	-182044
8	-172376	-181763	-176079	-179782	-174098	-177801	-172117	-175820	-170135	-173838	-168154	-177542	-171857	-175560	-169876	-173579	-167895	-171598	-165914	-169617	-163932	-173320	-167635	-171338	-165654	-169357	-163673	-167376	-161692	-165395	-159711
9	-159430	-159430	-163133	-157448	-161152	-155467	-159170	-153486	-157189	-151505	-155208	-155208	-158911	-153227	-156930	-151245	-154948	-149264	-152967	-147283	-150986	-150986	-154689	-149005	-152708	-147024	-150727	-145042	-148745	-143061	-146764
10	-137096	-146483	-140799	-144502	-138818	-142521	-136837	-140540	-134855	-138558	-132874	-142262	-136577	-140280	-134596	-138299	-132615	-136318	-130634	-134337	-128652	-138040	-132355	-136059	-130374	-134077	-128393	-132096	-126412	-130115	-124431
11	-146483	-146483	-150186	-144502	-148205	-142521	-146224	-140540	-144243	-138558	-142262	-142262	-145965	-140280	-143983	-138299	-142002	-136318	-140021	-134337	-138040	-138040	-141743	-136059	-139762	-134077	-137780	-132096	-135799	-130115	-133818
12	-124150	-133537	-127853	-131556	-125872	-129575	-123890	-127593	-121909	-125612	-119928	-129315	-123631	-127334	-121650	-125353	-119668	-123372	-117687	-121390	-115706	-125093	-119409	-123112	-117428	-121131	-115447	-119150	-113465	-117169	-111484
13	-111203	-111203	-114906	-109222	-112925	-107241	-110944	-105260	-108963	-103278	-106982	-106982	-110685	-105000	-108703	-103019	-106722	-101038	-104741	-99057	-102760	-102760	-106463	-100779	-104482	-98797	-102500	-96816	-100519	-94835	-98538
14	-88870	-98257	-92573	-96276	-90592	-94295	-88610	-92313	-86629	-90332	-84648	-94035	-88351	-92054	-86370	-90073	-84388	-88092	-82407	-86110	-80426	-89813	-84129	-87832	-82148	-85851	-80167	-83870	-78185	-81889	-76204
15	-75923	-75923	-79626	-73942	-77645	-71961	-75664	-69980	-73683	-67998	-71702	-71702	-75405	-69720	-73423	-67739	-71442	-65758	-69461	-63777	-67480	-67480	-71183	-65499	-69202	-63517	-67220	-61536	-65239	-59555	-63258
16	-53590	-62977	-57293	-60996	-55312	-59015	-53330	-57033	-51349	-55052	-49368	-58755	-53071	-56774	-51090	-54793	-49108	-52812	-47127	-50830	-45146	-54533	-48849	-52552	-46868	-50571	-44887	-48590	-42905	-46609	-40924
17	-40643	-40643	-44346	-38662	-42365	-36681	-40384	-34700	-38403	-32718	-36422	-36422	-40125	-34440	-38143	-32459	-36162	-30478	-34181	-28497	-32200	-32200	-35903	-30219	-33922	-28237	-31940	-26256	-29959	-24275	-27978
18	-18310	-27697	-22013	-25716	-20032	-23735	-18050	-21753	-16069	-19772	-14088	-23475	-17791	-21494	-15810	-19513	-13828	-17532	-11847	-15550	-9866	-19253	-13569	-17272	-11588	-15291	-9607	-13310	-7625	-11329	-5644
19	-5363	-5363	-9066	-3382	-7085	-1401	-5104	580	-3123	2562	-1142	-1142	-4845	840	-2863	2821	-882	4802	1099	6783	3080	3080	-623	5061	1358	7043	3340	9024	5321	11005	7302
20	16970	7583	13267	9564	15248	11545	17230	13527	19211	15508	21192	11805	17489	13786	19470	15767	21452	17748	23433	19730	25414	16027	21711	18008	23692	19989	25673	21970	27655	23951	29636
21	7583	7583	3880	9564	5861	11545	7842	13527	9824	15508	11805	11805	8102	13786	10083	15767	12064	17748	14045	19730	16027	16027	12323	18008	14305	19989	16286	21970	18267	23951	20248
22	29917	20529	26214	22510	28195	24492	30176	26473	32157	28454	34138	24751	30435	26732	32417	28713	34398	30695	36379	32676	38360	28973	34657	30954	36638	32935	38620	34917	40601	36898	42582

23	42863	42863	39160	44844	41141	46825	43122	48807	45104	50788	47085	47085	43382	49066	45363	51047	47344	53028	49325	55010	51307	51307	47603	53288	49585	55269	51566	57250	53547	59231	55528
24	65197	55809	61494	57790	63475	59772	65456	61753	67437	63734	69418	60031	65715	62012	67697	63993	69678	65975	71659	67956	73640	64253	69937	66234	71918	68215	73900	70197	75881	72178	77862
25	78143	78143	74440	80124	76421	82105	78402	84087	80384	86068	82365	82365	78662	84346	80643	86327	82624	88308	84605	90290	86587	86587	82883	88568	84865	90549	86846	92530	88827	94511	90808
26	100477	91089	96774	93070	98755	95052	100736	97033	102717	99014	104698	95311	100995	97292	102977	99273	104958	101255	106939	103236	108920	99533	105217	101514	107198	103495	109180	105477	111161	107458	113142
27	113423	113423	109720	115404	111701	117385	113682	119367	115664	121348	117645	117645	113942	119626	115923	121607	117904	123588	119885	125570	121867	121867	118163	123848	120145	125829	122126	127810	124107	129791	126088
28	135757	126369	132054	128350	134035	130332	136016	132313	137997	134294	139978	130591	136275	132572	138257	134553	140238	136535	142219	138516	144200	134813	140497	136794	142478	138775	144460	140757	146441	142738	148422
29	148703	148703	145000	150684	146981	152665	148962	154647	150944	156628	152925	152925	149222	154906	151203	156887	153184	158868	155165	160850	157147	157147	153443	159128	155425	161109	157406	163090	159387	165071	161368
30	171037	161649	167334	163630	169315	165612	171296	167593	173277	169574	175258	165871	171555	167852	173537	169833	175518	171815	177499	173796	179480	170093	175777	172074	177758	174055	179740	176037	181721	178018	183702

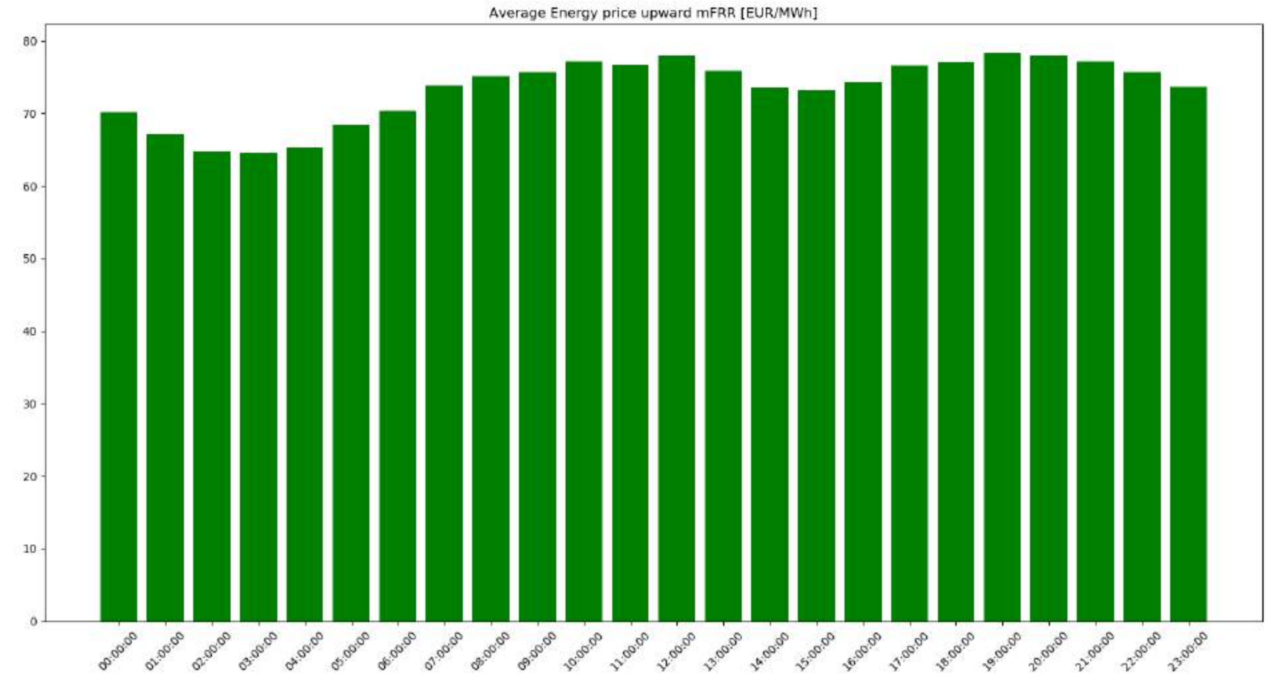

Figure 52: Average daily energy price in the Portuguese upward mFRR market over 2018.

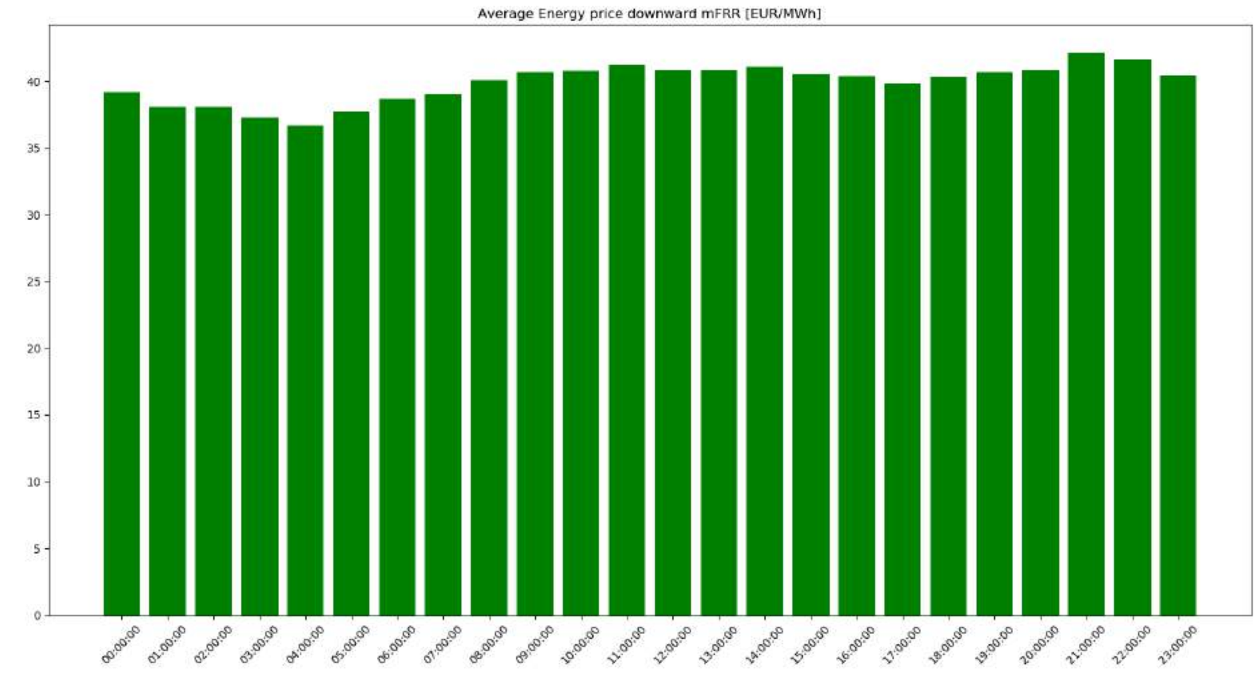

Figure 53: Average daily energy price in the Portuguese upward mFRR market over 2018.

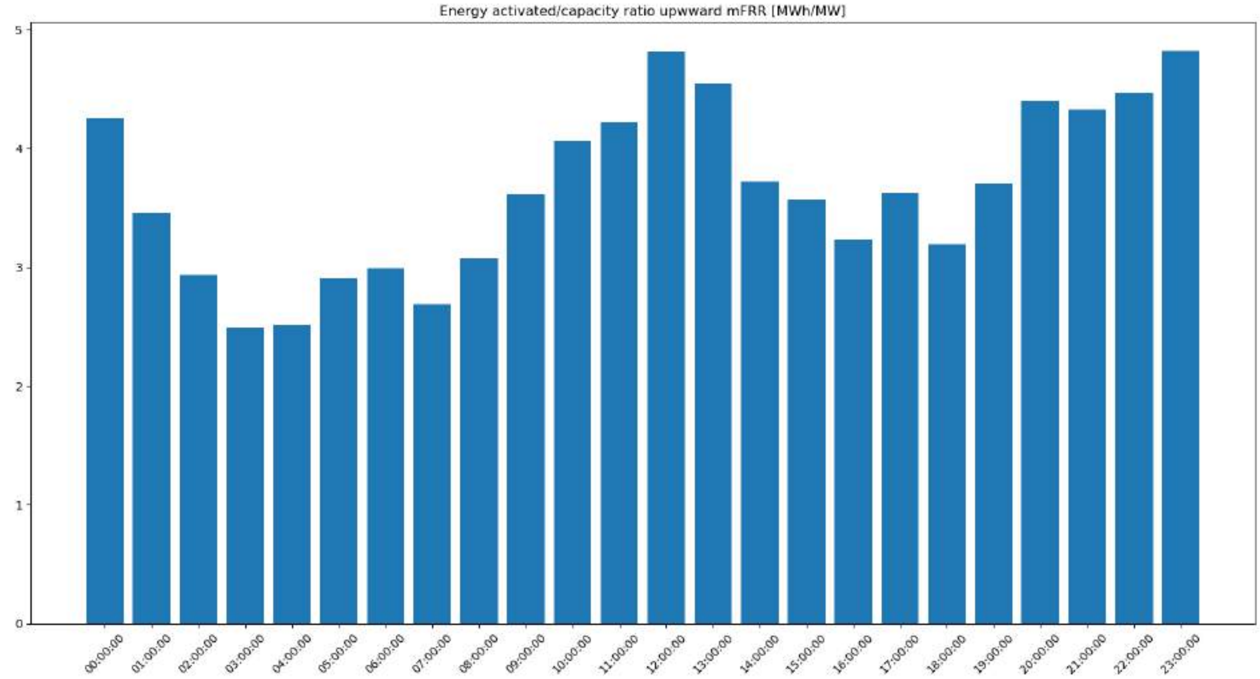

Figure 54: Energy activated/capacity ratio in the Portuguese upward mFRR market over 2018.

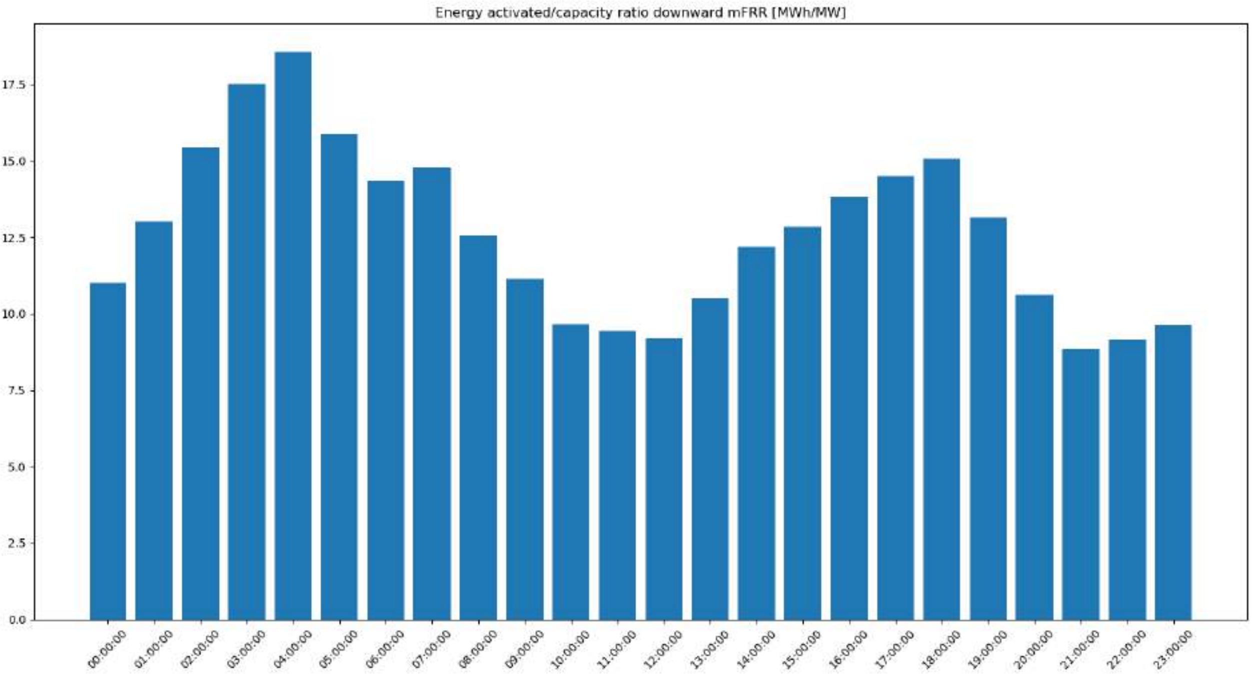

Figure 55: Energy activated/capacity ratio in The Portuguese mFRR market over 2018.

Annex 2 – Criteria for the evaluation of the regulatory replicability

Cluster 3

Are (mFRR) balancing markets open for demand-response participation?

Maturity level	Criteria
0	No. Explicit provisions exist in regulation restricting the participation of demand-response in mFRR provision.
1	No restriction exists, but market conditions are clearly not welcoming to demand-response. In practice, little or no participation is in place.
2	Demand-response participation is acknowledged by regulation, but no further provision for its participation is made.
3	Demand-response is explicitly allowed, and mechanisms exist for its participation, but some limitations may still exist (ex.: complicated bureaucracy).
4	Demand-response is explicitly allowed and encouraged to participate. In practice, considerable participation is observed.

Are products and conditions suitable for demand/DER participation?

Maturity level	Criteria
0	No. Products are clearly restrictive (ex.: symmetrical bidding).
1	Products have many challenging characteristics for DR (ex.: fast response time, complicated prequalification, large minimum bid size, real-time monitoring need)
2	Products are somewhat suitable for demand-response but may still have a few challenging characteristics.
3	Products are suitable, but some additional market conditions jeopardize the full participation of DR.
4	Products are suitable, and DR finds suitable market conditions.

Are there barriers for the aggregation of resources in these balancing markets?

Maturity level	Criteria
0	Yes, aggregation is explicitly not allowed.
1	Aggregation is not acknowledged by regulation. In practice, aggregation does not take place.
2	Aggregation is acknowledged, but there is still no comprehensive framework for its participation.
3	Aggregation is allowed, and aggregators are already participating in this balancing market. Nevertheless, participation is still minor due to market conditions or other limitations.
4	Aggregation is allowed and its participation in this balancing market is developed.

Is the independent aggregation allowed? Is it viable?

Maturity level	Criteria
0	No, aggregation imposes explicit limitations.
1	No mentions to the independent aggregator are made in the regulation. In principle it is allowed, but the complete lack of a regulatory framework makes this agent not technically or economically viable.
2	Independent aggregation is allowed, but there is need for an enabling framework (e.g.: definitions on balancing responsibility)
3	Independent aggregation is allowed, and additional definitions are provided (e.g. balancing responsibility). Nevertheless, other aspects or market conditions limit the development of this activity.
4	Independent aggregation is allowed, required definitions are in place and the activity is already well developed.

Is different type of DER aggregation (VPP concept) possible?

Maturity level	Criteria
0	No, aggregation of different types of DER is explicitly prohibited.
1	No mentions are made in the regulation. In principle, aggregation of different types of DER could be possible, but in practice other product and market characteristics make it not feasible.
2	No mentions are made, and products and market characteristics are somewhat appropriate, but barriers exist.
3	Aggregation of different type of DERs is allowed and some commercial exploration of this type of aggregation is already in place.
4	The VPP concept is allowed and already explored by several companies.

Is TSO-DSO coordination mature enough for DER to provide balancing services?

Maturity level	Criteria
0	TSO-DSO coordination is rather limited, does not consider DER activation at all (ex.: DER activation by the TSO with no communication to the DSO).
1	TSO-DSO coordination is expected to be enhanced (ex. Network Codes implementation) but is still rather limited.
2	TSO-DSO coordination is experiencing at least one major national pilot or sand-box.
3	There are flexibility markets and/or coordination for procurement of DER flexibility for some products and services, as well as some enhanced information exchange.
4	Both procurement and activation of DER flexibility is well coordinated and communicated (ex.: TLS implementation, real-time information exchange).

Cluster 4

Are (aFRR) balancing markets open for demand-response participation?

Maturity level	Criteria
0	No. Explicit provisions exist in regulation restricting the participation of demand-response in aFRR provision.
1	No restriction exists, but market conditions are clearly not welcoming to demand-response. In practice, little or no participation is in place.
2	Demand-response participation is acknowledged by regulation, but no further provision for its participation is made.
3	Demand-response is explicitly allowed, and mechanisms exist for its participation, but some limitations may still exist (ex.: complicated bureaucracy).
4	Demand-response is explicitly allowed and encouraged to participate. In practice, considerable participation is observed.

Are products and conditions suitable for demand/DER participation?

Maturity level	Criteria
0	No. Products are clearly restrictive (ex.: symmetrical bidding).
1	Products have many challenging characteristics for DR (ex.: fast response time, complicated prequalification, large minimum bid size, real-time monitoring need)
2	Products are somewhat suitable for demand-response but may still have a few challenging characteristics.
3	Products are suitable, but some additional market conditions jeopardize the full participation of DR.
4	Products are suitable, and DR finds suitable market conditions.

Are there barriers for the aggregation of resources in this balancing market?

Maturity level	Criteria
0	Yes, aggregation is explicitly not allowed.
1	Aggregation is not acknowledged by regulation. In practice, aggregation does not take place.
2	Aggregation is acknowledged, but there is still no comprehensive framework for its participation.
3	Aggregation is allowed, and aggregators are already participating in this balancing market. Nevertheless, participation is still minor due to market conditions or other limitations.
4	Aggregation is allowed and its participation in this balancing market is developed.

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1	TSO-DSO coordination is expected to be enhanced (ex. Network Codes implementation) but is still rather limited.
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4	Both procurement and activation of DER flexibility is well coordinated and communicated (ex.: TLS implementation, real-time information exchange).