– Deliverable D5.7 –

Regulatory Issues of DVPPs

Authors:

Pablo Rodilla - *Universidad Pontificia Comillas, Instituto de Investigación Tecnológica* (IIT)

Álvaro Ortega - *Universidad Pontificia Comillas, Instituto de Investigación Tecnológica* (IIT)

Lukas Sigrist - *Universidad Pontificia Comillas, Instituto de Investigación Tecnológica* (IIT)

Ione López - *Iberdrola Clientes España* (IBR)

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Executive summary

Concluding Task T5.7, and hence, the work of the POSYTYF project's Work Package WP5, this report provides a critical examination of the regulatory environment affecting Dynamic Virtual Power Plants (DVPPs) at the European level, and outlines key steps towards their effective integration in European energy and ancillary service markets.

To this aim, a detailed analysis of the European regulatory frameworks is first carried out, exploring the definition and value of DVPPs within these structures. The focus is on the role of regulation in enabling value creation through resource aggregation. The deliverable also offers insight into how DVPPs are currently perceived and regulated, and discusses the significant role of regulations in unlocking the full potential of resource aggregation, by exploring the various dimensions of DVPP value creation.

Regulatory barriers for DVPPs are then identified. In particular, the techno-economic and regulatory obstacles that complicate, and in some cases prevent, DVPPs' market participation are investigated. The report also carefully analyzes the regulatory landscape surrounding new resources like storage and aggregation, market product definitions, bidding formats, and the intricacies of price signaling, stressing the need for a regulatory reform.

The report concludes with a synthesis of findings and future directions. It calls for a regulatory reevaluation to promote DVPP integration, emphasizing the need for clear and enhanced regulations on new resources, refined market products, reliable price signals, and the deployment of advanced metering Infrastructures. These recommendations not only serve as a guide for immediate action but also as a blueprint for ongoing research in the dynamic field of energy and ancillary service markets.

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List of Abbreviations

AMI	Advanced Metering Infrastructure
BES	Battery Energy Storage
BRP	Balance-Responsible Party
CEER	Council of European Energy Regulators
DAM	Day-Ahead Market
DER	Distributed Energy Resource
DSO	Distribution System Operator
DVPP	Dynamic Virtual Power Plant
EFR	Enhanced Frequency Response
ESS	Energy Storage System
FCR	Frequency Containment Reserve
FFR	Fast Frequency Response
FSP	Flexibility Service Provider
HPP	Hydroelectric Power Plant
IDM	Intra-Day Market
PHES	Pumped Hydro Energy Storage
PV	Photo-voltaic
RES	Renewable Energy Source

RoCoF Rate-of-Chage-of-Frequency

SO System Operator

STU Solar Thermal Unit

TSO Transmission System Operator

VPP Virtual Power Plant

WP Work Package

1 Introduction

1.1 Task T5.7 Overview

Task T5.7 concludes the work carried out within Work Package (WP) 5 by providing a critical examination of the regulatory landscape that shapes the integration and operation of DVPPs. Recognizing the complexities of current national and regional regulations, Task T5.7 aims to delineate clear operational requirements for DVPPs and to identify the regulatory barriers DVPPs face.

The objectives of Task T5.7 are thus twofold: (i) to analyze the regulatory challenges that DVPPs encounter; and (ii) to propose practical solutions that can be seamlessly integrated within current and future market frameworks.

1.2 Objectives and Outline of the Deliverable

As DVPPs are expected to progressively increase their interaction with both internal and external grid infrastructures, the findings presented in this document aim to propose a framework that balances the technical capabilities and economic realities of DVPPs and the resources that compose them within the existing and evolving regulatory environment.

To this aim, this document presents a comprehensive regulatory framework tailored to the specific needs of DVPPs. Through a synthesis of current barriers, this deliverable presents an updated vision for DVPP regulation, promoting an environment where DVPP capabilities to provide energy and ancillary services are optimally used and where security and efficiency of data exchange is ensured.

Deliverable D5.7 embodies the culmination of WP 5, synthesizing insights from previous tasks to delineate the path toward regulatory coherence and the facilitation of DVPPs integration into the energy landscape.

1.3 Structure of the Deliverable

The remainder of this document is organized as follows.

Chapter 2 investigates the rules and regulations for DVPPs in Europe, and discusses opportunities for regulatory evolution to promote an efficient integration of DVPPs in electricity markets.

Chapter 3 addresses the main challenges currently faced by DVPPs, including operational requirements, market product design, remuneration schemes, and market price signal reliability, while also proposing strategic solutions, which are supported by prior work within this WP.

Finally, Chapter 4 draws the main conclusions extracted from the work performed in this Task. Future directions of the work carried out in this WP are also outlined.

2 DVPPs and the current regulatory framework

This section provides an overview of regulatory frameworks in the European context, and their impact on the deployment and value creation of DVPPs. How current regulatory frameworks consider the figure of a DVPP (and any form of aggregation) is first presented in Section 2.1. Then, Section 2.2 identifies the different ways aggregating resources can provide value, either privately or system-wide, and more importantly, role that regulation plays in shaping such value.

2.1 Definition of a (D)VPP and Its Regulatory Framework

The term Virtual Power Plant (VPP) has not been uniformly and unambiguously defined in the literature, see for instance the discussions in [1] or [2]. In the latter, one of the *least restrictive* definitions can be found:

"*A virtual power plant is a cluster of dispersed generator units, controllable loads and storages systems, aggregated in order to operate as a unique power plant. The generators can use both fossil and renewable energy source. The heart of a VPP is an Energy Management System (EMS) which coordinates the power flows coming from the generators, controllable loads and storages. The communication is bidirectional, so that the VPP can not only receive information about the current status of each unit, but it can also send the signals to control the objects*".

Therefore, and generally speaking, a VPP (and thus, in this context, a DVPP) is a form of aggregation, where different resources are grouped together to act as a single asset when connected and providing services to the electricity system. The main differences among the different definitions of VPPs that can be found in the literature, refer to two main elements, namely (i) the characteristics of the resources that can be aggregated within the VPP, and (ii) the VPPs business model.

- Regarding the former, some definitions only consider as VPPs aggregations of resources of certain technologies (e.g. aggregation of renewables, storage and/or demand response), some restrict the voltage level at which the resources of the VPP are connected (allowing all or conversely only medium and/or low voltage ones) and some others restrict the size of the resources that make up the VPP (sometimes only considering medium and/or small-scale projects).

- With respect to the business models, it is recognized that possibly the most widely implemented business model in a VPP is to sell energy and ancillary services, either to the wholesale market or to the system operator, although other business models can also be envisaged. For instance, a self-supply maximizing business model prioritizes the supply of internal VPP demand with the generation of the VPP whenever possible as it could be the case for an energy community [3].

In [4], the type of VPP that represents the focus of the POSYTYF project is described, i.e., the DVPP. There are three major features defining the DVPP that add to the general concept of grouping resources to act as a single plant:

1. The core of the POSYTYF's DVPP consists of a set of different dispatchable and non-dispatchable Renewable Energy Sources (RESs) and flexible demands. Units such as conventional thermal units, electrochemical (battery) energy storage systems (BES), or hydrogen electrolyzers are thus *excluded* in principle from the portfolio.

2. The resources can be geographically spread on both transmission and distribution levels. Several points of grid connection may exist for the different resources making up the DVPP.

3. The DVPP is mostly focused on the provision of dynamic services (hence the name). The full participation of the DVPP in grid ancillary services is a major objective, and this means "*not only to get some positive impact on grid voltage and frequency dynamics but to bring concepts which allow integrating RESs to existing secondary regulation schemes on the same level as classic synchronous generators*". Although the focus is on these dynamic services, it is also envisioned that the DVPP participates in other wholesale energy markets to enhance their competitiveness against other solutions.

Identifying the regulatory framework for DVPPs

As stated above, a DVPP is a form of aggregation, usually with the major objective of selling energy and/or services with the portfolio of resources as if they were all a single plant. This leads to the two most relevant topics of regulation that set the framework of the DVPPs, namely (i) the framework for the activity of aggregation, and (ii) the regulation and market rules related to allowing a portfolio of resources to sell electricity services.

In section 3, when identifying the major barriers to DVPP configuration and operation, it will be shown how most of such barriers are precisely related to the regulatory framework with respect to the aggregation activity, and whether or not portfolio bidding is allowed (and consequently, how to integrate this portfolio bidding in markets).

Portfolio bidding allows several resources to submit a joint bid in the market as if the portfolio was a single plant. However, different markets regulate portfolio bidding differently by restricting for instance the nature, type or size of resources to be grouped within the portfolio. A DVPP requires a flexible regulation in this regard.

2.2 The Value of Aggregating Resources in a DVPP: the Role of Regulation

This section draws on the findings of [5], where the value of aggregating resources is discussed both from the standpoint of the system and from the point of view of the resources that are aggregated.

It can be said that aggregation has a system value when it increases the economic efficiency of the power system as a whole, and it has private value when it simply increases the economic welfare of the participants that are aggregated. Creating private value may or not imply the creation of system value. In fact, in some extreme situations, creating private value could work against the system value.

Three subcategories of values are discussed below, namely (i) the *Fundamental value*, which corresponds mostly to aggregation system value that will always exist; (ii) the *Temporary value*, associated to aggregation system value that will decrease as technology develops; and (iii) the *Opportunistic value*, which is the aggregation private value that exists as a consequence of flawed regulation.

Note that, although the latter type of value can (and should) be updated and corrected as the regulatory framework evolves, it can still create additional (temporary) value that can enhance the profitability of certain DVPPs business models.

The Fundamental Value of Aggregation: Risk Management and Economies of Scale

In an idealized context characterized by flawless regulation and limitless coordination possibilities for system and market operators (due to more advanced technologies), aggregators would generate value exclusively by first leveraging economies of scale and scope, and second through enhanced risk management via more stable and predictable output.

The (Temporary) Value of Decentralizing Coordination

There are today (and they are expected to continue in the following years) temporary benefits stemming from aggregation that are related to technological and regulatory limits not allowing to coordinate all system resources centrally. Aggregation brings one major benefit consisting of coordinating smaller and scattered resources, none of them coordinated directly (individually) by the operators, and many of which not even under their radar. Aggregating can serve to alleviate this coordination challenge while improving the provision of grid services. Section 6 of Deliverable D5.6 provides a thorough discussion on how allowing small resources (which were initially *invisible* to the system operator) to be aggregated in order to provide ancillary services in isolated systems can significantly enhance the service quality.

The Opportunistic Value Created by Imperfect Regulation

Finally, there are certain regulations that lead to *opportunistic* value for aggregation. Opportunistic aggregation creates mostly private value (that is, value for the resources and agents making up the DVPP), but it does not necessarily create system value. Therefore, in an ideal regulatory setting, these opportunistic values would disappear.

Three major groups of regulations are identified in [5] that may give rise to opportunistic value to aggregation: (i) the existence of a sub-optimal tariff design, (ii) an inadequate definition of products, and (iii) the regulation related to the balancing cost allocation. These groups are briefly reviewed in the remainder of this section.

The Presence of Sub-optimal Tariff Design

A tariff design that does not convey price signals based on accurate cost causality is prone to create opportunistic value when aggregating [6]. One example is that of implementing a not granular enough demand charge[1]. In this case, users who have similar peak demands in magnitude, but whose peak demands are offset in time, may find that by aggregating the individual consumption they can reduce the overall tariff cost (since they can pay a single demand charge among all, instead of one per client). This is a quite clear example of creation of private value that does not create any system value, since aggregating would not change network costs, although aggregation would reduce the amount of money collected from tariffs.

An Inadequate Definition of Products

As highlighted in [6], the products currently purchased by market and system operators are often tailored to the characteristics of conventional generating technologies, not properly accounting how new resources may offer new sources of flexibility.

Current products need to be revisited so as to avoid unnecessary barriers or over-incentives to unnecessary aggregation. Two examples of this, that lead to opportunistic aggregation value, are minimum size requirements or symmetrical reserve products. These examples, which are briefly discussed below, illustrate how aggregation could be over-incentivized beyond what is efficient from the system standpoint.

- A minimum size threshold is typically required to participate in some markets. This limit is often set for the sake of simplicity and in order to maintain the computational effort of clearing the market at an acceptable level. However, this minimum bid size may exclude smaller energy suppliers from participating in the market. Despite the fact that lowering the size threshold could complicate the market clearing process, it could also significantly increase the participation of distributed RESs and demand-side resources. Aggregating units in the form of a DVPP can allow meeting the size requirements, although some of these aggregations would not have been necessary if the proper minimum size had been in place.
- In many European markets, the use of operating reserves typically involves symmetric bids for both upward and downward reserves (i.e., if an entity commits upward ramping capacity, it must also commit a certain amount of capacity for downward ramping). Complying with this symmetry requirement can impose significant costs on an individual market participant. For example, solar or wind generators can easily provide downward regulation by rapidly curtailing some of its generation,

[1] A demand charge is a tariff charge proportional to the highest power demand within a pricing period. Thus, it is a €/kW type of charge.

but it is economically burdensome for them to provide equivalent upward regulation because it would require them to intentionally operate below the setpoint imposed by their respective maximum-power-point-tracking controllers. Aggregating units can significantly ease the capability of providing both upward and downward reserves (see Section 4 of Deliverable D5.5 for an in-depth analysis of RES-based DVPPs optimally participating in wholesale energy and secondary reserve markets). But again, this aggregation would not have been necessary should the proper products had been defined (i.e. upwards and downwards reserves as separate products).

Regulations Associated to the Balancing Costs Allocation

In Europe, energy imbalances and the corresponding imbalance costs are usually computed for an aggregation of different generating units (the balancing scheme is on a portfolio basis). Under a portfolio balancing scheme, aggregations of units can net imbalances, even if the costs to the system associated to the individual imbalances are substantially different across locations.

At the same time, two main approaches for imbalance pricing exist, namely single and dual imbalance pricing. Under a single imbalance pricing approach, imbalance prices are based on the marginal cost of activated reserves. With dual pricing, imbalances in the real time are priced beyond the marginal balancing price signal[2].

When a dual imbalance pricing scheme is coupled with a portfolio settlement of imbalances, a competitive advantage is given to large companies in comparison to smaller ones, effectively creating an over-incentive to the former to aggregate resources. Either a single imbalance pricing or a unit-by-unit settlement would avoid creating these competitive disadvantages and over-incentives to create large portfolios that only translate in the context termed as *private value* in this document.

[2]This scheme applies an additional penalty, on top of the price representing the balancing procurement costs, if the Balance-Responsible Party (BRP) deviation is opposite to grid needs.

3 Regulatory Barriers Affecting DVPPs' Participation in Electricity Markets

While the European energy market is gradually opening up to new entrants, there are significant barriers that prevent DVPPs from participating on an equal footing with traditional power plants.

Some of the most relevant barriers are still techno-economical, such as the high investment costs involved by some technologies (e.g. Solar Thermal Units (STUs)), the limited production predictability when moving away from the real time (the case of wind and to a lesser extent solar Photo-voltaic (PV)), and the lack of sufficiently deployed Advanced Metering Infrastructure (AMI) in certain systems.

There is also a quite significant number of barriers that are related to the regulatory framework. Regulation might bear disincentives to DVPP participation in markets. This section analyzes the major regulatory barriers in place today in the European context, as well as how to overcome them in the future. These barriers are gathered in three groups: (i) those related to the regulatory framework of new resources, in particular, aggregation and storage (Section 3.1); (ii) barriers associated to the product definition in markets and to the bidding formats (Section 3.2); and (iii) barriers introduced by missing markets and imperfect price signals (Section 3.3). The aforementioned groups of barriers are discussed in detailed in the remainder of this section.

3.1 The Regulation of New Resources

It is well known that a proper regulatory design is a key factor in allowing for the efficient deployment of new figures like aggregation and energy storage (a relevant potential component of DVPPs, as observed from the simulation results shown in Section 4 of Deliverable D5.5, where the storage capability of STUs can significantly increase the economic profitability of DVPP participating in electricity markets). Today, regulations are still being fine-tuned to clarify the role of both figures, and enable them to provide value to power systems. We next review the state of the regulation as regards storage and aggregation, as well as the pending issues to ease their integration.

Storage

The regulatory discussion begun with the basic definition of storage. In this regard, the Electricity Directive (EU) 2019/944 [7] provided in Article 2 (59) and (60) the first legal (technology neutral) basic definition of storage and energy storage facility, respectively:

- (59) "***energy storage*** *means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electricity energy or use as another energy carrier";*
- (60) "***energy storage facility*** *means, in the electricity system, a facility where energy storage occurs*".

Today, the next step of the debate involves adapting secondary regulation and deciding whether storage should be treated as generation, as demand or as a new separate asset category altogether in different regulatory pieces. This can have a relevant impact on the possibilities of storage to participate in some services, as well as on the tariff charges they have to bear, which in the end severly affects its profitability.

Aggregation

The role of aggregators as intermediaries enabling the participation of small-scale renewable generation and demand resources, as well as DVPPs in electricity markets is crucial. However, the absence of a clear regulatory framework governing the operation of aggregators can impede the market entry of DVPP. It is thus crucial that a well-defined framework is established to delineate the rights, responsibilities, and operational guidelines for aggregators.

As regards the definition of aggregation, the Directive (EU) 2019/944 [7] states the following in Article 2 (18) and (19):

- (18) "***Aggregator*** *means a function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market*";
- (19) "***Independent aggregator*** *means a market participant engaged in aggregation who is not affiliated to the customer's supplier*".

According to Article 2 (18), the aggregation activity seems to refer to loads or generators but not a mix of both. Apart from introducing the previous definition, the Directive also mandates that every Member State must establish a regulatory framework that permits the entry of aggregators into the markets.

However, it delegates a considerable amount of the implementation specifics to the national authorities, being particularly relevant the rules governing the relationship between the supplier and the independent aggregator [8]. An independent aggregator's interventions may disrupt the real-time program of a supplier, which has economic consequences for the latter. The decision to implement compensation mechanisms between both parties, along with its design, is considered a pivotal factor that greatly influences the viability of demand-side services and therefore of DVPPs integrating demand flexibility.

3.2 The Product Definition in Markets and the Bidding Formats

This section identifies the main barriers that DVPP need to facerelated to the products that are currently available for these agents to participate.

Facilitating Conditions to Participate in the Market

First and foremost, it is worth mentioning that some of the resources that can potentially form a DVPP often face barriers to (individually) entry in electricity markets due to restrictive pre-qualification requirements, minimum size, strict technical specifications or cumbersome registration processes (see section 2.2). Sometimes these demanding conditions apply only to some of the markets[3].

The main issue is when these requirements are unjustified from a cost-benefit standpoint, since they exclude some valuable resources from market participation. The requirements will clearly depend on the particular type of market. In this line, for instance, it is proposed the following minimum size in the context of the project OneNet [9]:

"*The minimum quantity or bid size will be set at 10 kW for Distribution System Operator (DSO) products or 1 MW for Transmission System Operator (TSO) products (in case of active power). These values trade-off the technical requirements for the System Operators (SOs) to have quantities that are meaningful for their needs with the capacity of individual Flexibility Service Providers (FSPs) to deliver the product which could facilitate liquidity in the market.*"

Facilitating as much as possible market access is thus a fundamental prerequisite to increase DVPP participation in markets.

[3] This is more often than not the case with long-term capacity and short-term ancillary services markets

The Need to Rethink Ancillary Services and Other Related Products

As introduced before, it is necessary to fine tune current products so that they do not introduce unnecessary barriers to new resources (this is the case with the aforementioned example of the symmetrical reserve product, and something similar happens with some strict penalties associated with some ancillary services products).

Revisiting existing products is a key step, but it is also necessary to assess the potential benefits of defining new products based on the new characteristics of some resources such as *storage*. In this respect, since some resources included in DVPPs can have high dynamic capabilities and are technically well suited to provide fast ancillary services, the adequate design of new ancillary services products and markets has been identified as a key issue for their business case. This opportunity is strengthened as research and operational experience indicate that using fast ancillary services allows for the reduction of overall frequency regulation requirements [10, 11]. This means that specific products such as Fast Frequency Response (FFR) or Enhanced Frequency Response (EFR) can be designed to replace multiple units of conventional primary reserve products with a single, more responsive unit. The introduction of these products enables a fast response of the system to frequency variations. This will ultimately result in a minimum required inertia online, which otherwise would be necessary to control the Rate-of-Change-of-Frequency (RoCoF). These very fast products are particularly relevant in islands, where inertia can be scarce (see the discussion in Section 6 of Deliverable D5.6).

Additionally, some ancillary services that might have value in the future are not procured and remunerated based on market mechanisms. This is for example the case with Frequency Containment Reserve (FCR) in many systems. Solar PV inverters could be used to provide FCR, but they will do so only to the extent that this service is appropriately priced and rewarded (and, clearly, available).

Therefore, all participants in general, and DVPPs in particular, will have to be paid for all products they provide. To this aim, disaggregating these products as much as possible is required (i.e. there will be an availability price and an energy use price if the product includes capacity and energy).

Moreover, in order to define products that can particularly engage flexible demands to participate, a learning process is required where consumers would play a central role analyzing and disclosing the value they associate with their consumption, and how much they are willing to ask for different types of interruptions involving different amounts of energy, as well as their duration.

The Need to Rethink Bidding Formats

The goal of a market exchange is to facilitate trading to help participants manage their risks and efficiently match available supply with demand. In this respect, a key element for electricity markets is the design of bidding formats that allow market agents to include information about their costs and operating constraints.

For instance, significant limitations to optimally bid with an Energy Storage System (ESS) (e.g., that of a Pumped Hydro Energy Storage (PHES)) exist in some European markets. In some cases, bidding formats require the participant to anticipate specifically in which periods the ESS should be producing electricity and in which periods it should be consuming electricity, and to place separate bids. In some other cases, it is not properly accounted for the energy limitations when providing some ancillary services.

Allowing Portfolio Bidding

Portfolio bidding allows several resources (within the same pricing zone) to submit a joint bid in the market as if the portfolio was a single plant. It is then possible to internally decide the operation of each resource to reach the required production. For an effective integration of DVPPs, portfolio bidding will need to be allowed to all relevant type of configurations of DVPPs, and in particular to those in which the project POSYTYF is focused.

Portfolio bidding regulation depends on the particular market, and the rules are usually different among Member States. Sometimes portfolio bidding is only allowed to specific forms of aggregation, such as for instance a specific type of RES, or only for certain sizes of projects (typically small-scale projects).

For example, portfolio bidding is allowed in most day-ahead energy markets (DAM) for all types of generating units. Only Spain, Portugal and Italy do not allow portfolio bidding to all types of generating units. Indeed, in the other Member States, EUPHEMIA allows using the so-called block orders [12][4]. The basic idea behind these block orders is to allow bidding a daily portfolio production profile that is accepted in the market in case the resulting market revenue is above a price threshold.

But the specific details on how portfolio bidding is allowed can be complex in each particular Member State. For example, although in the DAM the Iberian (Spain + Portugal) market regulator does not allow portfolio bidding to all types of generation, the fact is that it does allow portfolio bidding to RESs (with the exception of large Hydroelectric Power Plants (HPPs)), however the portfolio can only include the plants subject to certain support mechanisms (in particular, those

[4]EUPHEMIA, which is the acronym of Pan-European Hybrid Electricity Market Integration Algorithm, is the single clearing algorithm used to clear the European DAM.

subject to the support scheme established in RD 413/2014 [13]). The plants subject to the last support mechanisms have to bid individually.

In the continuous Intra-Day Market (IDM), portfolio bidding is allowed in all Member States, although the National System Operator might ask to nominate to the specific units that will be producing the committed quantity afterwards. In reserve markets, it is often the case to allow providing some services with a portfolio of generators that are managed by one single agent, who decides how the response is allocated among the different resources.

The previous refer to aggregating generation resources, but including flexible demand in the portfolio is also of the utmost importance. And in this respect the trend is to allow it, although not all systems have already changed the necessary regulations to do so.

Defining the Perimeter of a DVPP

As introduced in [4], the DVPP is a new concept which brings together generation and grid aspects, where resources can be connected to both transmission and distribussion grids, and thus the DVPP perimeter may contain both types of grids.

However, the maximum geographic scope that would be reasonable for a DVPP aiming at bidding all resources within the portfolio as a single plant will depend on the particular type of market in which they are selling services. In general, physical products will involve some restricted perimeters. The constraints over the proximity of resources will depend on the type of services the DVPP is aimed at (e.g., some local services as those reviewed above can only be provided by resources that are electrically close).

The point of view of stakeholders as regards portfolio bidding.

The convenience or not of allowing portfolio bidding is a recurring question that arises when a market is being redesigned. Just to mention some examples, several consultation processes can be found related to specific electricity market redesigns that include among the questions the convenience or not of introducing portfolio bidding or conversely a unit-by-unit bidding process.

For example, on January 2023, the EU Commission launched a reform consultation to support a clean and affordable energy transition. Among other topics, the consultation covered the issues of "improving market functioning to ensure security of supply" and "improving market transparency, surveillance and integrity". In this context, one question was related to the convenience of using portfolio bidding or providing more unit specific details, which was consulted as: "*Q7 - What would be the advantages and drawbacks of having further locational* *and technology-based information in the bidding in the market, for example through information on the composition of portfolio, technology-portfolio bidding or unit-based bidding?*".

The answers to this consultation (some of which are summarized below) are in line with other responses to other previous consultations about similar issues:

- Power exchanges and large generators argue that portfolio-based bidding is the prerequisite for improving efficiency and liquidity of the spot market, and that unit-based bidding is a less efficient model.
- Small generators, consumers and TSOs support that there are clear gains in unit-based bidding, for the market is more transparent and there is more information ahead of real time to efficiently secure the system balance and stability.

The Advantages of Homogenizing Products and Bidding Formats

The EU comprises a diverse array of electricity markets, covering different products (capacity, energy, ancillary services, flexibility, etc.), different timeframes (from months down to seconds) and different geographical locations. Each of these markets is governed by unique sets of regulations and market rules.

This regulatory heterogeneity is relevant within the national dimension (for instance, TSO's ancillary services and DSO's flexibility services can differ to a large extent in their specifications and requirements), but obviously it is all the more varied when we look at the differences between the regulations of different Member States. Harmonizing market rules for similar services within the same member state and across member states could facilitate trading in multiple markets, and hence, the integration of RESs and DVPPs.

This has been discussed in the context of OneNet project, which highlights the advantages and disadvantages that have to be borne in mind when moving to more homogeneous products [9], such as:

- Pooling of resources and easing access to multiple markets: harmonization lowers expenses, since standardization enables the pooling of resources among various operators, leading to greater cost efficiency. It also simplifies the complexities across diverse markets. This simplification would ease the process for DVPP to extend their services, thus enhancing market liquidity and decreasing the acquisition costs.
- TSO-DSO coordination: harmonization streamlines coordination between TSOs and DSOs, aligning their products more closely. This aspect becomes increasingly significant as the number of DSOs that somehow interact with a TSO grows. Minimizing the range of products among DSOs would aid in

their communication with TSOs, as well as among the DSOs themselves.

- Product homogenization would improve the coordination between SOs and DVPPs operators, since standardized products would imply that DVPPs can more easily understand the specifications and requirements they must meet, should they choose to offer flexibility bids in various markets. This consequently would lead to lower learning and bidding expenses.
- Harmonization also presents a clear drawback: it may not accommodate the product definition to the specific national or local necessities. With greater harmonization, the resulting products may not fit as precisely as the ad-hoc products.

3.3 Inneficient Price Signals and Missing Markets

Simulation results from Deliverables D5.5 and D5.6 demonstrated that, as variability increases, the need for reliable market price signals in all times frames increases. In general, price signals are robust in the DAM time frame, for markets in this time frame are liquid enough (see Section 4 of D5.5). However, this is unfortunately not the case neither in the very long (see Section 3 of D5.5) nor in the shorter term (see Sections 3 through 5 of D5.6). Note that there are also missing price signals at the distribution level, since the markets are still in an early stage of development.

The Lack of Efficient Long-term Signals

One of the relevant problems related to electricity markets in general is the lack of liquid signals in the *very* long-term. This situation creates a double (and specular) source of uncertainty that does not allow to take advantage of all potential benefits from DVPPs (or any other resources) in the long term. On the one hand, the system operators (both TSOs and DSOs) cannot predict accurately the potential response of DVPPs in the long-term and, therefore, cannot include their role in the long-term when planning. On the other hand, DVPPs cannot shield against the risks associated to any investment decision to be carried out.

Selling services in the long term can provide stable signals for the potential investors and, if there is a reliable commitment from DVPPs with SOs, the latter can better plan in the long-term the different requirements for the system counting with the DVPP response.

These long-term signals can come from selling capacity in capacity markets, energy in long-term energy markets or ancillary services with longer term contracts.

However, these long-term signals often do not currently exist for one of the following two reasons: (i) either its participation is not allowed in some of these markets (either directly, or indirectly because of the existence of significant barriers) or (ii) these markets simply do not exist in the long-term (for example, not all Member States have implemented the provision of ancillary services in the long-term).

The Lack of Efficient Shorter-term Signals

The expression *shorter-term* refers to the time interval between the DAM and the real-time dispatch. During this period, market participants may, in some cases, adjust their positions (bids) in the market, and the SO must carry out all the necessary actions to ensure supply in real time, managing the resources under its control according to the information available at any given moment. Generally speaking, it can be said that RES penetration has increased the importance of very short-term markets and mechanisms in electrical systems, because it is within this time horizon that the relevant information for the dispatch of these technologies is generated.

The IDM allows participants to *adjust* their offers from the DAM before real time, based on the information that is updated. This operation reduces the difference between market schedules and the actual operation of the system, and with it the deviations, minimizing (in principle) also the need for reserves. Being a market for adjustments of the position matched in the DAM, the product is the same as in this market, i.e., energy.

Current debates point to the creation of more liquid IDMs, and to reform their design to improve efficiency in a context of high RES penetration. Introducing auctions to complement the continuous market, increasing the time resolution of the product, increasing the frequency of these auctions, and bringing them closer to real time are elements that move in this direction.

Local Flexibility Markets

The efficient integration of DVPPs (when including Distributed Energy Resources (DERs)) can provide solutions to local problems in distribution networks. These solutions include (i) relief of local congestion (in the short and long term); (ii) reduction in the overload of some elements; (iii) voltage control, etc. To materialize these solutions, it is necessary to develop new local mechanisms for the acquisition of services.

Local flexibility markets are called to play an important role in distribution network congestion management and long-term planning. In the platforms for the trade of these services, maximum efficiency would be achieved if a level playing field existed for all types of DERs.

However, these markets are still under development. In Europe, there are only a few market platforms that allow DSOs and flexibility providers to purchase or sell, respectively, flexibility services in the distribution grid. Some of these platforms are NODES, Cornwall LEM, Piclo Flex, GOPACS and Enera. For details on these projects, see the review carried out by Schittekatte & Meeus in [14].

In order to foster this type of platforms it is necessary to provide the DSOs with new incentives that allow them to really compare the possibility of using flexible resources instead of investing in upgrading or expanding networks [15].

3.4 Advanced Metering Infrastructure Deployment

In the simulation results presented in previous Deliverables of this WP, it was assumed that *accurate* real-time data was always available and transmitted through *reliable* communication channels. Considering the relatively long time scales considered in the economic studies presented (specially when compared against the time scales that WPs 2, 3 and 4 consider), and the advanced level of development and deployment of current Information and Communication Technologies (with the 5G moving towards taking progressively the lead), this was a rather acceptable assumption.

However, it is important to remark that, to guarantee an optimal operation of DVPPs, accurate real-time data acquisition and communication between the units that conform the DVPP, between the DVPP and the system operators, etc., is essential.

The absence of AMI in certain regions can therefore complicate the real-time monitoring and control of renewable generation and flexible demand resources. Without AMI, it is also more challenging to measure the actual contribution of such resources in balancing supply and demand, which in turn affects their compensation and incentives

Two recommendations are proposed in this regard, as follows:

1. On one hand, to mandate the widespread deployment and upgrading of AMI across all European nations, ensuring a uniform standard of data acquisition, communication, and management.
2. Establish frameworks for data privacy, security, and ownership to encourage consumer acceptance and participation.

Such recommendations are expected to lead to:

- Data Accuracy: AMI enables the accurate, real-time monitoring of energy consumption and generation, which is vital for the efficient operation and market participation of DVPPs.

- Operational Efficiency: With better data, DVPP operators can make more informed decisions, optimize their operations, and respond more effectively to market and grid conditions.
- Encouraged Consumer Participation: By ensuring data privacy and security, consumers may be more willing to engage in demand response programs and other market initiatives.

Consumer's Data Management

Paradoxically with respect to the discussion presented above, both the European Commission [16] and the Council of European Energy Regulators (CEER) [17] have emphasized that smart-meter data management could pose an entry barrier for new electricity market participants such as flexible demands. CEER [18] contends that an adequate data management model should facilitate an efficient, secure, and safe exchange of customer and metering data, promoting retail market competition and ensuring proper customer protection.

Data ought to be available to competitive market actors in a standardized format and guarantee that customers retain full ownership and control over their data. In alignment with these overarching guidelines, CEER introduced a set of guiding principles for data management models [19], as follows:

- Privacy and security: *"Customer meter data should be protected by the application of appropriate security and privacy measures. Customers should control access to their customer meter data, with the exception of data required to fulfil regulated duties and within the national market model."*
- Transparency: *"The relevant body in each MS […] shall make the following general information on meter data management publicly available […] (a) the customer's rights with regard to customer data management; (b) what type of customer meter data exists and what it is used for; (c) how customer data is stored and for how long; (d) how the customer and market participants authorized by the customer get access to that data; and (e) within what time period the customer and market participants authorized by the customer have to wait to get disaggregated data."*
- Accuracy: *"The relevant body […] should communicate to the customer any inaccuracies that might have taken place in relation with customer meter data and how these inaccuracies have been addressed."*

- Accessibility: *"The customer […] should have easy access to customer meter data."*
- Non-discrimination: *"To support an effective and competitive market, the data management model should not give undue preference to one stakeholder over another. This is particularly crucial in regards to DSO-led smart meters roll-outs."*

3.5 Portfolio Flexibility

In Deliverable D5.5, it was showed how seasonality has a direct impact on the optimal DVPP portfolio to maximize the profit when participating in energy and reserve markets. In particular, simulation results highlighted the enhanced profitability and operational efficiency achieved through the dynamic adaptation of the DVPP portfolio to reflect the varying generation profiles of different RESs throughout the year. It is thus greatly important to allow for more frequent *reconfigurations* of the DVPP portfolio to ensure their viability in the long term.

The optimal aggregation and operation of diverse resources within a DVPP may be compromised if European electricity markets show a rigid nature regarding portfolio re-configurations, limiting the ability of DVPPs to adapt to changing weather conditions, evolving market requirements, and regulatory landscapes.

Amending market rules to allow for more flexible configurations of the DVPP portfolio is thus crucial. In this regard, it is recommended the facilitation of dynamic DVPP portfolio configurations that can be adapted on a seasonal or even monthly basis to reflect the changing availability of RESs and market conditions.

Making the configuration of DVPP portfolio more flexible can thus allow for (i) a more efficient utilization of diverse resources within the DVPP, thus maximizing the overall operational efficiency and economic benefits; and (ii) a seamless adaptation to fluctuating market conditions, regulatory changes, and the varying availability of renewable resources.

4 Conclusions and Future Work

This report concludes Task T5.7, and proposes a thorough list of recommendations for revising the current regulatory frameworks of European electricity markets to promote and facilitate the participation of DVPPs in these activities.

After a comprehensive review of current regulatory documents, technical reports and research papers at European level, and based on the results of the studies carried out in WP5 since the beginning of the POSYTYF project, a number of concepts that need to be carefully revised in such regulatory frameworks have been identified with the aim to promote the integration of DVPPs into the different layers of the wholesale energy and ancillary service markets.

In this regard, and as a first step, a contextualization of the current regulatory framework has been provided, where concepts such as aggregator, portfolio bidding and VPPs have been visited, and the value for such resource aggregation solutions discussed.

Then, a number of challenges that DVPPs might encounter considering the aforementioned market regulatory landscape have been identified. Such challenges include, but are not limited to, (i) the need to regulate *new* resources and to define new market products; (ii) the importance of having updated and accurate price signals and other forecast signals of uncertain parameters, which need to be transmitted through Advanced Metering Infrastructure to ensure reliability in the communication and coordination while guaranteeing aspects such as privacy, transparency and accessibility; and (iii) the relevance of allowing flexible configurations of DVPP portfolios to adapt to seasonal changes and evolving market requirements.

Beyond the completion of this Task and, subsequently, of this WP, the following areas have been deemed as worthy of further investigation.

The potential of DVPPs to evolve into price-maker entities within the energy market was recognized as a significant yet complex subject during the initial proposal phase of the POSYTYF project. At that time, the intricacies involved in accurately estimating the market participation strategies of other players and the decisions of market operators made this area of study too challenging to pursue effectively. However, the advancements and insights gained through the POSYTYF project have now set a stronger foundation to address these complexities. Future research would focus on developing advanced models that can accurately simulate the interactions between DVPPs and other market participants, as well as the responses of market operators. These decision-making tools should help operators optimize their bidding strategies not just for profit maximization but also for maintaining market health and stability.

Also in this vein, analyzing how DVPPs with significant market power can impact price formation, market stability, and the overall energy landscape becomes apparent. This includes assessing the potential for market distortion, benefits in terms of competitive pricing, and impacts on smaller market participants. This would also require revisiting and refining regulatory frameworks, such as those discussed in this report, to accommodate the increasing influence of DVPPs as price-makers. This involves ensuring that regulations promote fair competition and market efficiency while mitigating any negative impacts of concentrated market power.

In the current framework presented in the POSYTYF project, DVPP bids are treated as a 'black box' by system operators, where only the aggregated energy/power is known. However, as the energy landscape evolves, the increasing prevalence of RES-based DVPPs introduces new challenges, particularly for low-inertia power systems. In this regard, specific details on the mix of synchronous versus converter-interfaced generation present in the DVPP becomes critical information for system operators to make informed decisions about the overall generation mix and to maintain system stability in low-inertia scenarios. It thus essential to investigate potential changes in regulatory frameworks that mandate DVPPs to report their generation mix, including guidelines on how such information should be shared to balance transparency with competitive concerns.

Finally, The European electricity markets are about to experience significant transformations with the implementation of new market mechanisms (e.g., capacity markets open to all types of resources, local flexibility markets at the distribution level, new ancillary services markets at a regional level, etc.) Some of these changes involve the creation of new platforms, as it is the case with PICASSO and MARI for the aforementioned regional ancillary service markets. These changes will inevitably affect how DVPPs participate in the market. The POSYTYF project's current models and studies need to be revisited and adapted in light of these upcoming shifts. This includes incorporating new market rules, pricing structures, and operational guidelines into DVPP operational strategies. An evaluation on how these changes will affect DVPP profitability, market participation strategies, and overall sustainability becomes essential.

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