D1.1

Regulatory framework for fostering flexibility deployment: roles, responsibility of agents & flexibility mechanism designs

BE FLEXIBLE

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D1.1	Work Package No.	WP1	Task/s No.	Task 1.2
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Document Contributors

Deliverable responsible Matteo Troncia (Comillas)

Contributors	**Organization**	**Reviewers**	**Organization**
Matteo Troncia	COMILLAS	Ferdinando Bosco	ENG
Miguel Ángel Ruiz Hernández	COMILLAS	Stephane Dotto	SAP
Eliana Carolina Ormeño Mejía	COMILLAS		
Jesús José Fernández García	COMILLAS		
Nicolás Morell	COMILLAS		
Leslie Herding	COMILLAS		
Orlando Valarezo	COMILLAS		
Shilpa Bindu	COMILLAS		
José Pablo Chaves Ávila	COMILLAS		
Tomás Gomez	COMILLAS		
Daniel Davi Arderius	EDE		
Santiago Gallego Amores	i-DE		
Serena Cianotti	ENEL		
Carolina Manaresi	ENEL		
Adam Christensson	E.ON		
Alain Malot	SCHN FR		
Tommaso De Marco	TERNA		
Fabio Lucidi	TERNA		

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List of abbreviations

ABS	Abstract
ACER	European Union Agency for the Cooperation of Energy Regulators
ADEME	French Agency for Ecological Transition
API	Application Programming Interface
ARENH	Accès Régulé à l'Électricité Nucléaire Historique
ARERA	Autorità di Regolazione per Energia Reti e Ambiente
ASM	Active System Management
AT	Austria
AtS	Aggregator To Supplier
BOE	Agencia Estatal Boletín Oficial del Estado
BRP	Balance Responsible Party
BSC	Balancing and Settlement Code
BSP	Balance Service Provider
CA	Connection Agreements
CAISO	California Independent System Operator
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CDN	Closed Distribution Network
CEC	Citizen Energy Community
CEER	Council of European Energy Regulators
CHP	Combined Heat and Power
CNMC	Comisión Nacional de los Mercados y la Competencia
CPE	Customer Point Identifier
CRCP	Compte De Régularisation Des Charges Et Des Produits
CRE	French Regulatory Authority
CSC	Collective Self-Consumption
CSP	Congestion Service Provider
DCF	discounted cash flow
DER	Distributed Energy Resource
DG	Distributed Generation
DLR	Dynamic Line Rating
DNP	Distribution network planning
DR	Demand Response
DSF	demand-side flexibility
DSO	Distribution System Operator
EL	Greece
ERSE	Portuguese national regulatory authority
ES	Spain
ESS	Energy Storage System
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FCR	Frequency Control Reserve
FFR	Fast Frequency Response
FIFO	First Input First Output
FRR	Frequency Restoration Reserve

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SP	Flexible Service Provider
GDP	Gross domestic product
GEG	Gaz Electricité de Grenoble
GHG	Green House Gas
GW	Giga Watt
HH	Half-Hourly
ICT	Information Communication Technology
IT	Italy
JAAC	Jointly-Acting Active Customers
JARSC	Jointly-Acting Renewable Self-Consumers
LIFO	Last In, First Out
LNG	Liquified Natural Gas
LV	Low Voltage
MBMA	Meter before, Meter after
ME	Mutually Exclusive
MJ	Mega Joule
ML	Machine Learning
MS	Member State
MSD	ancillary services market
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Mega Watt
NA	Not Applicable
NDP	Network Development Plans
NEBEF	Notification d'Échange des Blocs d'Effacement
NECP	National Electricity and Climate Plan
NES	National Electricity System
NL	Netherlands
NPV	Net Present Value
NRA	National Regulatory Authority
OLTC	On Load Tap Changers
OPEX	Operational Expenditure
PLC	Public limited company
POD	Point of Delivery
PPA	Power Purchase Agreement
PV	Photovoltaic
RAB	regulatory asset base
REC	Renewable Energy Community
RES	Renewable Energy Source
RIIO	Revenue = Incentives + Innovation + Outputs
RR	Replacement Reserve
SDA	Specific Demand Adjustments
SE	Sweden
SGU	Significant Grid Users
SME	Small or Medium-sized Enterprise
SO	System Operator
SP	Service Provider
StA	supplier to aggregator

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ToE	transfer of energy
TOTEX	Total Expenditure
TRL	Technology Readiness Level
TSO	Transmission System Operator
TW	Tera Watt
UK	United Kingdome
UVAM	Mixed Enabled Virtual Units
VAT	Value-added tax
WAC	Weighted Average Cost
WP	Work Package

Executive Summary

The BeFlexible project primary objectives are to improve collaboration between Distribution System Operators (DSOs) and Transmission System Operators (TSOs), integrate stakeholders in energy-related sectors, and foster innovative business models in line with a stable regulatory framework. The project is executed through validating cross-sectoral services, developing interoperable data exchange platforms for smart grids, and constructing a system architecture framework conducive to new business models.

Work Package 1 (WP1) of the BeFlexible project focuses on establishing a regulatory framework and market mechanisms to facilitate flexibility-centric services. This package sets the groundwork for the project by outlining regulatory proposals and market dynamics. It includes developing reference business models, business use cases, and key performance indicators for testing in demonstrators.

This document presents the outcome of Task 1.1 and Task 1.2. Task 1.1 of WP1 addresses the regulatory framework for fostering flexibility deployment. It focuses on defining roles and responsibilities emerging agents in the energy market, aiming to dissolve current regulatory barriers. The task emphasizes strategies for regulatory experimentation, establishing remuneration schemes for flexibility usage, and rules for system operator ownership of flexible resources. It also seeks to enable resource aggregation and ensure a level playing field in resource usage. Task 1.2 proposes designs for flexibility mechanisms, ranging from flexible connection agreements to local and system-wide markets. The task considers various factors like service nature, market environment specifics, and SP characteristics in designing these mechanisms. It also underscores the importance of customer engagement in developing flexibility acquisition methods.

As a first step, the document undertakes a detailed analysis of DSO remuneration schemes across six European countries to understand the regulatory requirements for deploying flexibility solutions. This analysis addresses the calculation of ex-ante allowed revenue, adjustments based on quality incentives or profit-sharing mechanisms, and the potential inclusion of flexibility in network development plans. The BeFlexible project identifies key areas for reforming DSO remuneration:

- Regulatory Evolution: It emphasizes updating regulatory frameworks to align with the growing integration of renewables and broader electrification.
- Flexible Planning: Advocates shifting from fixed, CAPEX-focused investments to flexible planning, maximizing the economic value of flexibility in system services.
- Flexibility in Network Plans: Highlights diverse approaches in integrating flexibility into network planning, suggesting a more unified strategy across Europe for better efficiency.
- Neutral Incentives: Recommends moving towards cost-efficient, neutral incentives that emphasize adaptability, enabling DSOs to meet evolving energy market demands.

Moreover, Task 1.1 delves into the characterization of energy communities and aggregators, key emerging actors in the flexibility landscape. It includes an examination of the European and national regulations for energy communities, identifying gaps and proposing a taxonomy to categorize and organize this area. For aggregators, the task assesses legal frameworks and barriers to flexibility provision through aggregated resources.

The BeFlexible project's analysis of energy communities presents as conclusions:

- Diverse Regulatory Landscapes: Across Europe, energy communities operate under varied regulatory frameworks. This diversity poses challenges in standardization and harmonization.
- Regulatory Gaps: The study identifies crucial gaps in existing regulations, particularly in terms of compliance and operational scope. These gaps hinder the optimal functioning and growth of energy communities.
- Tailored approaches needed: Emphasizes tailoring approaches to local conditions, such as population density and network characteristics, for effective implementation of energy communities in different European regions.

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To outclass those gaps, The project suggests specific, measurable regulatory requirements to ensure alignment with European standards. It also recommends considering a broader spectrum of energy carriers to enhance the scope and viability of energy communities. Moreover, a novel taxonomy for energy communities is proposed, offering a structured approach to categorize and understand these entities better, addressing the lack of a common regulatory and terminological framework.

Regarding the role of aggregators in the energy market, key findings include:

- Diverse Regulatory Landscapes: The document examines existing European regulatory frameworks for aggregators, revealing a mix of synergies and disparities across different regions.
- Regulatory gaps: regulatory reforms are needed to create an enabling environment for aggregators. This includes balanced mechanisms for managing imbalances, clearly defined responsibilities, and measures to address potential rebound effects.
- These findings underscore the necessity of a supportive regulatory framework and the strategic integration of aggregators to unlock their full potential in advancing a dynamic and sustainable electricity grid in Europe, since are identified as key to enhancing grid resilience, sustainability, and efficiency by pooling distributed energy resources.

This document also highlights the importance of baselining methodologies and dedicated metering devices (also called submetering technologies) as enablers for flexibility deployment. It evaluates various baselining solutions and emphasizes the role of smart meters in accurate consumer billing, efficient energy usage management, and participation in electricity markets. The concept of submetering within aggregator models is introduced, enhancing flexibility offerings and providing advantages to service providers and system operators.

The report identifies specific barriers and requirements for baselining adoption. Proposing a decision-making process that ensures that the selected methodologies are not only effective but also feasible and practical for implementation in different scenarios. The proposed framework is instrumental for the BeFlexible demonstrators to provide real-world experiences that can highlight the practical benefits of various baselining methodologies. This information is invaluable for policymakers and regulators in selecting appropriate baseline methods tailored to specific flexibility use cases.

Regarding submetering adoption, it is acknowledged that submeters are emerging as crucial for enabling small-scale entities to participate in electricity markets, especially where smart meters are not widespread. They facilitate detailed measurements essential for various market phases, from prequalification to monitoring and activation. Key findings of stakeholder consultation include:

- The need for standards and functionalities: Effective implementation of submetering requires adherence to specific standards and functionalities, as outlined in the Electricity Directive (EU) 2019/944. National authorities play a critical role in ensuring these standards are met.
- Installation Responsibility and Technical Requirements: There is a consensus among stakeholders that submeters should meet the same standards as smart meters. The responsibility for installing submeters, whether by aggregators, suppliers, or embedded in devices, is a subject of discussion.
- Diverse Applications: Submeters are valuable across various market phases, including prequalification, forecasting, bid collection, monitoring, and activation. However, for settlement purposes, their effectiveness is debated due to impacts occurring at the connection point.
- Consumer Empowerment and Efficiency: Submetering technologies provide detailed energy data, empowering consumers to manage their energy usage more effectively. This leads to increased market efficiency and consumer engagement.

The operational needs of the SOs can be satisfied by acquiring support from network customers. System services can be obtained using several different acquisition mechanisms that in practices coexist. However, their development has been based on a standalone design that does not account for incompatibilities and possible synergies. To promote a

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comprehensive and efficient design of the acquisition mechanism that can be used, this report presents a qualitative analysis methodology aimed at assessing the feasibility of integrating various mechanisms to acquire services from distribution system operators (DSOs) in order to meet system service requirements. Initially, the focus is on identifying the most impactful mechanisms in power systems that have reached a level of maturity in the pilots associated with the BeFlexible initiative. These mechanisms include network tariffs, connection agreements, local markets, and rule-based approaches. First, each mechanism is analysed individually to identify and describe the relevant design dimensions. Subsequently, by applying the proposed methodological framework, several combinations of mechanisms are analysed to identify the strengths and weaknesses of their integrated design. The outcome of the analysis highlights that, when mechanism design sends similar economic signals to customers, it can lead to scenarios of double rewards or charges, distorting economically efficient behaviours. Preferential access to information or market influence may create market power issues. Moreover, even if local markets for flexibility acquisition emerge as a very valid solution, there is no single solution but a multitude of combinations of the above mechanisms that could be used for each specific case. Careful mechanism design is essential to avoid redundant incentives that interfere with desired behaviours.

To complete the methodological framework for assessing combined DSO service mechanisms, we present the definition of need attributes and evaluation criteria. A survey assessed their relevance and qualitative values, highlighting the importance of frequency of need, economic efficiency, and customer engagement ease. The reduction of controllability by end-users on their equipment, although ranked lowest, remains significant. Additionally, information on dimensions and options considered in BeFlexible project demos was collected for case studies within the decision framework. Examining the interplay between existing tariffs and developing local markets for system services, as specified by the demonstrations, reveals that these mechanisms are highly compatible under the currently studied conditions. This compatibility is mainly constrained by the considered temporal and spatial granularities. A similar observation is made regarding tariffs and flexible connections, particularly when the latter lacks compensations. The potential interaction largely hinges on the granularity of particular dimensions. Lastly, analysing the interaction between local markets and flexible connections might expose conditions ranging from inefficiencies to potential infeasibilities. In some scenarios, flexible connections could detrimentally affect local markets by diminishing their liquidity. In general, the analyses conducted based on the collected information have facilitated a better understanding of the interaction of mechanisms for acquiring DSO services from third parties, considering fundamental characteristics such as dimensions and options.

This document explores regulatory experimentation frameworks, crucial for fostering innovation in the energy sector. It analyses different national approaches and emphasizes the need for regulatory bodies to provide clear guidance and support to innovators. The focus is on balancing regulatory learning with the dynamic needs of innovators, ensuring responsive and sustainable regulatory frameworks. The examination of regulatory experimentation frameworks underscores their critical role in fostering innovation within the energy sector, key findings include:

- Innovator Guidance: A significant portion of innovators seeking regulatory experiments merely require regulatory advice. Many find that existing frameworks already permit their business models, highlighting the need for accessible regulatory advisory services.
- Learning Mechanisms: The effectiveness of regulatory experimentation depends on its approach. Top-down, policy-oriented frameworks favour regulatory learning and alignment with regulatory agency objectives, leading to well-functioning regulatory changes. Conversely, bottom-up, innovator-oriented approaches keep pace with innovators' needs but may hinder regulatory learning from experiment results.
- Staffing and Collaboration: Successful implementation of regulatory experimentation frameworks necessitates specialized staffing. Collaborations between different regulatory bodies broaden the scope for testing regulatory changes and avoid duplication of efforts.
- Practical Application: Regulatory experiments should address real-world problems and align with principles of good regulation, including simplicity, clarity, and general welfare improvement. They should not be mere theoretical exercises.

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- Evaluation and Exit Strategy: A well-crafted evaluation and exit strategy are crucial. This includes periodic reporting, cost-benefit analysis, and scalability and replicability analysis during and post-experimentation.
- Cross-NRA Collaboration: Collaboration among National Regulatory Authorities (NRAs) of different countries enhances learning experiences, helping avoid unnecessary errors and enhancing the effectiveness of regulatory experimentation.

In conclusion, this report, through comprehensive analysis and regulatory proposals, aims to contribute to the dialogue on electricity market design and flexibility integration. It offers valuable insights and recommendations for TSOs, DSOs, market operators, regulatory bodies, and policymakers. The BeFlexibile project's future research and activities are expected to be based on this document's analysis to define and assess the demonstrators' solutions aimed at the deployment of flexibility solutions.

1 Introduction

1.1 BeFlexible project

The BeFlexible project aims to increase the flexibility of the energy system, improve cooperation between Distribution System Operators (DSOs) and Transmission System Operators (TSOs) and facilitate the participation of all energy-related stakeholders. This is pursued through the validation and large-scale demonstration of adapted and proven cross-sectoral services, interoperable data exchange platforms for smart grids operation and the creation of the required system architecture framework that will enable the creation of new business models providing additional value to meet consumers' needs in compliance with a stable regulatory framework.

1.2 Work Package 1 organization and interaction with other Work Packages

In the BeFlexible project, Work Package 1 (WP1) "Regulatory analysis, proposals for efficient flexibility mechanisms and demonstrators' framework" WP1 sets the general frameworks for the project by defining the proposals for a regulatory framework, the market mechanisms, a framework for flexibility-centric services, and the reference business models, business use cases and key performance indicators to be tested in the demonstrators.

WP1 is divided in fours tasks:

- Task 1.1 – Regulatory framework for fostering flexibility deployment: roles and responsibility of existing and new agents (T1.1)
- Task 1.2 – Proposal for flexibility mechanisms designs: from standalone mechanisms to efficient combinations (T1.2)
- Task 1.3 – Design of a flexibility-centric energy and cross-sector value chain (T1.3)
- Task 1.4 – Business Use Cases and KPIs definitions (T1.4)

The goal of T1.1 is to propose a framework to overcome existing regulatory barriers hindering the deployment of flexibility. This proposal involves strategies to address regulatory experimentation, establish remuneration schemes that include flexibility, establish ownership rules, ensure a level playing field in the use of flexible resources owned by system operators and third parties, and enable the aggregation of these resources. In T1.2 the goal is to propose new acquisition mechanisms and regulations that promote an efficient exploitation of flexibility and foster customer engagement. The results of T1.1 and T1.2 are provided in D1.1.

Regarding the tasks associated with this document, T1.3 and T1.4. First, in T1.3, the objective is to design an energy and cross-sector value chain to sustain flexibility-centric services and business models. Since the value chain is also meant to serve as the basis for the development of the Grid Data and Business Network (GDBN) in WP3, its pre-specification is included in this task. T1.4 is centred on the design and development of high-level Business Use Cases (BUCs) to be demonstrated in the project pilots, and also in the definition of Key Performance Indicators (KPIs), which are defined considering different dimensions: technical, economic, environmental, and social.

In what concerns the interactions between these tasks and between this WP and other WPs (see Figure 1.1), T1.1 and T1.2 provides inputs to T1.3 and T1.4 (i.e. results of the regulatory framework analysis and efficient combination of flexibility acquisition mechanisms). Regarding the interactions with other WPs, on the one hand, the regulatory framework analysis, and the definition of novel designs for acquisition mechanisms for system services received inputs in terms of essential information on the countries' context necessary to develop the analysis. On the other hand, the output of T1.1 and T1.2 represents a reference for further development of demonstration activities of WP4, WP5, and WP6 as well as for the other horizontal WPs (i.e. WP2, WP3, WP7, WP8). In particular, WP7 will leverage the WP1 work to address the assessment of the project and demonstrators' results, WP8 will rely on WP1 outcome (regulatory analysis, acquisition mechanisms, design, value chain and business model analysis, BUC definition) for communication and dissemination activities.

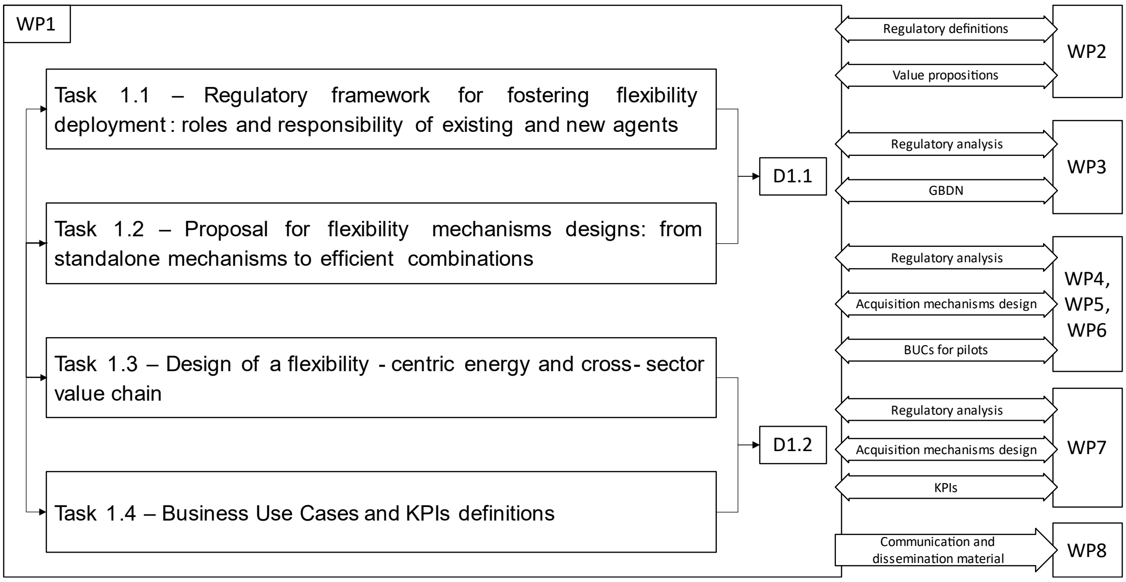

Figure 1.1 Overview of the interactions between WP1 and other BeFlexible WPs

1.3 Scope and objectives of this deliverable

In WP1, Task 1.1 (T1.1) “Regulatory framework for fostering flexibility deployment: roles and responsibility of existing and new agents” proposes a framework to overcome current regulatory barriers. Regulatory proposals need to include strategies to address regulatory experimentation gained from pilot projects, establish remuneration schemes that consider the use of flexibility, establish the rules under which the system operators can own certain flexible resources, ensure a level playing field in the use of flexibility resources owned by system operators and third parties, and enable the aggregation of flexible resources. T1.1 aims to define the roles to fully unlock the potential of distributed resource aggregation and energy communities’ emergence. Several challenges still need to be investigated: contracting with Flexibility Service Providers, arrangements with retailers, the definition of baseline methodology, and the definition of balance responsibility. Independent market operators are becoming new players, facilitating local flexibility markets’ development. The current national market designs in the demonstrator countries and identified relevant countries would be the starting point for further developments and improvements.

As a part of T1.1, this document represents the Deliverable 1.1 “Regulatory framework for fostering flexibility deployment: roles, responsibility of agents & flexibility mechanism designs”. D1.1 is the product of two WP1 tasks:

- Task 1.1: Regulatory framework for fostering flexibility deployment: roles and responsibility of existing and new agents
- Task 1.2: Proposal for flexibility mechanisms designs: from standalone mechanisms to efficient combinations

Task 1.1 investigates the current regulatory barriers related to the flexibility deployment to formulate proposals to overcome them. Overall, the regulatory proposals presented in this document aim to establish remuneration schemes that consider the use of flexibility, establish the rules under which the system operators can own certain flexible resources, enable the aggregation of flexible resources, ensure a level playing field in the use of flexibility resources owned by system operators and third parties, and define strategies to address regulatory experimentation gained from pilot projects. The regulatory proposals described in this document are based on an extensive literature review and the analysis of the applicable regulatory frameworks at European. Moreover, the current national market designs in the demonstrator countries and identified relevant countries represent the starting point for the regulatory proposals.

Task 1.1 aims at defining the roles to fully unlock the potential of aggregation of distributed resources and the emergence of energy communities, by investigating challenges such as: contracting with service providers,

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arrangements with retailers, the definition of baseline methodology, the definition of balance responsibility, and the definition of independent market operators to facilitate the development of local flexibility markets.

In this document, the Task 1.1 outputs include the analysis of the current remuneration schemes for DSOs in 6 European countries (France, Italy, Portugal, Spain, Sweden and The United Kingdom) to highlight the European regulatory frameworks requirements to achieve a full deployment of the flexibility solutions. The applicable regulation is analysed to describe the current legal framework and assess the readiness and barriers for the provision for flexibility. The analysis of the national regulation considered the main aspects that characterize the DSO remuneration schemes; how the ex-ante allowed revenue is calculated (e.g. by the approval of network development plans), how is this revenue adjusted ex-post (by quality incentives or profit-sharing mechanisms among other incentives), the possibility or not to include flexibility in the network development plans. Based on the analysis, this document proposes recommendations and regulatory solutions to overcome the identified challenges to be further considered in the BeFlexible project.

Moreover, the Task 1.1 activity focused on the characterization of the role and responsibilities of the two key emerging actors: energy communities and aggregators.

Concerning the analysis of the regulatory landscape for Energy Communities, the regulation at the European level and at the national level for several target countries (i.e., France, Italy, Portugal, Spain, Sweden) is analysed to describe the legal framework concerning energy communities and identify the main gaps. A taxonomy for energy communities is developed based on a review of regulatory frameworks and existing literature to address the lack of a common framework in terms of regulation and terminology. This taxonomy provides a hierarchical classification to effectively organise and categorise the energy communities' subject area. Recommendations and regulatory practices are proposed to overcome the identified challenges and establish a framework for subsequent project activities.

As a part of Task 1.1, this document presents the analysis of the landscape for aggregation schemes. The regulation at the European level and at the national level for several target countries (i.e., France, Italy, Portugal, Spain, and Sweden) is analysed to describe the current legal framework and assess the readiness and barriers for the provision for flexibility trough aggregated resources. The analysis of the national regulation considered the main aspects that characterize the aggregation schemes. Based on the analysis, this document proposes recommendations and regulatory solutions to overcome the identified challenges to be further considered in the BeFlexible project.

To complement the key elements to foster the flexibility deployment, the two key enablers are discussed: baselining and dedicated metering devices, as a complement to smart meters. The evolving landscape of flexibility markets is marked by a diverse range of product characteristics and a wide array of potential Service Providers (SPs). Generally, SPs that lack a pre-established schedule from prior markets, such as wholesale energy markets, require a reference point for service verification, commonly referred to as the baseline. Smart meters play a pivotal role in ensuring accurate billing for consumers based on their actual consumption. These advanced meters offer real-time data on energy usage, enabling proactive consumers to better manage their consumption. Additionally, smart meters open avenues for consumers to participate in the electricity market, either independently or through intermediaries. For SOs, smart metering provides deeper insights into network behaviour, facilitating improved infrastructure planning and operation, which in turn can lead to cost savings. The Draft Proposal for Network Code on Demand Response proposes two aggregation models, the first one using smart (regulated) meters for the provision of flexibility, the second introducing the concept of dedicated metering devices within aggregator models. This last setup involves using submeters or metering equipment of controllable units to track electricity withdrawals and/or injections associated with services like balancing, congestion management, and voltage control. While smart meters remain the primary and most efficient means of offering flexibility, especially when already installed, submetering can offer advantages to both service providers and SOs. This document presents the Task 1.1 analysis on the requirements and motivations behind adopting submetering.

This document also presents the Task 1.2 proposal for flexibility mechanisms designs. To acquire or obtain flexibility from the network customers, both TSOs and DSOs may utilize a variety of mechanisms [1], [2] that allow to define the

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possibility of requiring the network customers to adapt their electricity profile to satisfy specific SOs needs[1] (as defined in [3], [4]):

a) flexible connection and access agreements,
b) dynamic network tariffs,
c) local flexibility markets,
d) system-wide markets managed by TSO and energy markets,
e) other regulated options when liquidity is limited.

The detailed definitions of those mechanisms are provided in section 4.3.

These mechanisms can be tailored based on several factors, including the nature of the services and products being traded, and the specific circumstances of the market environment, like the voltage level of connected resources, frequency of demand, contractual timeframes, issue volume, network structure, as well as the temporal and locational resolution of the traded services. The size and type of SPs also play a significant role in determining the design of these mechanisms. Furthermore, it is essential to consider customer engagement when designing these flexibility acquisition methods to ensure that customer needs and preferences are appropriately addressed.

This report outlines the results of Task 1.2, which delves into the intricate interplay among various mechanisms for acquiring system flexibility. The analysis encompasses the characterization of each single mechanism through design dimensions, the specific needs of the electrical system, the comprehensive market design—including the sequencing of electricity markets—and the interplay with adjacent sectors. The document offers insights and recommendations for the effective design and integration of multiple flexibility acquisition mechanisms, ensuring they operate cohesively within the broader market infrastructure.

To conclude the discussion on the necessary regulatory innovation to foster flexibility deployment, the possible strategies to address regulatory experimentation are examined. Innovation in the energy sector requires regulation to evolve; otherwise, regulatory barriers may limit the potential benefits of new technologies and the rise of new business models. Regulatory experimentation allows testing innovative solutions for a limited time in a controlled real environment. This approach aims to give room for innovation while minimizing the impact on regulatory stability and quality of supply. Since there is no one-size-fits-all solution, NRAs with different objectives have adopted different approaches. In this document, the regulatory experimentation framework adopted in target countries are analysed (e.g., Belgium, Croatia, Italy, Austria, Sweden, Denmark, Spain, France, Hungary, the Netherlands, and Portugal). The analysis drives to the discussion of the implications of the potential choices by the authorities in the design of a regulatory experimentation framework based on past experiences and current research and give some recommendations for regulators.

This document contributes to the development of the BeFlexible project's foundational framework through an examination of pivotal topics that promote the deployment of flexibility in energy systems. It delineates the roles and responsibilities of emerging market participants and proposes innovative changes to regulatory structures and market mechanisms. These proposals aim to facilitate the integration of flexibility solutions within the current and future energy landscape.

[1] As defined in [3], [4], SO needs can be defined in terms of need for system services, which definition answers "what are the service required to ensure stability of the grid?". Hence a system service is defined as the action (generally undertaken by the system operator) needed to mitigate a technical scarcity that otherwise would undermine network operation. Therefore, system services can be classified as:

- Frequency ancillary service: a service used by a transmission system operator for the active power balancing the power system.
- Non-frequency ancillary service: a service used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability.
- Congestion management service: a service used by a transmission system operator or distribution system operator to avoid or solve grid congestions and bottlenecks that saturate the power transfer capacity of the network.

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1.4 Deliverable structure

The structure of this deliverable is the following:

- Section 2 presents the analysis of the regulation concerning the DSO remuneration for investments and the use of flexibility resources. The regulatory analysis concerns the European Union regulation and the national regulation of six European countries (i.e., France, Italy, Portugal, Spain, Sweden, and the United Kingdom).
- Section 3 focus on the analysis of the regulatory framework for fostering flexibility deployment: roles, responsibility of new agents. The regulatory framework concerning energy communities and aggregators is analysed for the European Union and France, Italy, Portugal, Spain, Sweden. Moreover, section 3 also provides the review of baselining methodologies and metering solutions.
- Section 4 deals with the analysis of the acquisition mechanisms for system services that can be exploited. Through a design-oriented perspective, the analysis culminates in the formalization of proposals aimed at efficiently combining flexibility mechanisms.
- Section 5 concerns the review of the strategies to address regulatory experimentation aimed at fostering flexibility deployment in the electricity sector.
- Section 6 offers concluding remarks, summarizing the main results and key messages gleaned from the activities detailed in this document.

The Annexes of this document contain the glossary of the key definitions adopted (section 8.1), as well as the templates utilized for collecting necessary information from project partners regarding country characteristics and stakeholders' perspectives:

- Section 8.2: Questionnaire on DSO remuneration schemes regulation
- Section 8.3: Questionnaire on energy communities' regulation
- Section 8.4: Questionnaire on aggregators' role regulation
- Section 0: Questionnaire on aggregators' role regulation
- Section 8.6: Survey on metering and submetering solutions
- Section 8.7: Survey on Combined Mechanisms for acquiring DSO Services
- Section 8.8: Survey on Combined Mechanisms for acquiring DSO Services – Customer's engagement

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2 Analysis of regulation for DSO remuneration

The electricity grid is facing important challenges in operation and planning due to the increase in intermittent renewable generation and the penetration of distributed energy resources. The increase in renewable generation and electrification of energy sectors such as heating and cooling, transport, and industrial processes could require massive investment in electricity networks. Efficiently developed flexibility mechanisms can partially reduce this investment need. Under this context, remuneration schemes of distribution system operators (DSOs) in most European countries should evolve and incentivize cost-efficiency [5], integrating and taking also potential advantages of long-term and short-term flexibility solutions; otherwise, the deployment of renewables would delay due to the need of grid investments to solve structural congestions, and the cost for bill-payers during the energy transition may inappropriately increase more than needed. These flexibility solutions may include SO services provided by third parties as defined in [6] and the use of DSO owned resources (e.g. switches for network reconfiguration, on-load tap changers (OLTC) in transformers, or dynamic line rating (DLR) for using the real-time thermal limits in power lines).

Electricity distribution is a regulated monopoly, requiring regulation (NRA) that defines DSO remuneration schemes. The European Electricity Market Directive 944/2019 and the 2023 EU Grid Action Plan [5] recognizes the need for DSO remuneration schemes to evolve. Highlighting the need to incentivize OPEX solutions (e.g. procurement of flexibility) and delay network reinforcement when cost-efficient. Additionally, DSOs must submit network development plans to the regulatory agency every two years, covering the investment needs for the next 5-10 years as is already defined in the same Electricity Market Directive. The requirement of updating the network development plans with a two-year frequency is a measure to deal with the high uncertainty faced by DSOs due to the unknown uptake pace of new technologies and users' requirements. A recent proposal for amending regulations by the European Commission to improve the Union's electricity market design [7] highlights again the need for regulation to incentivize the most cost-efficient operation and planning of the distribution, considering both network developments and service procurement and including anticipatory investments as well. Moreover, ACER (2022) also mandates to establish guiding principles in the scope of the new Network Code on Demand Response on how to consider demand response (and other relevant resources) in the NDP.

Next, we discuss the potential benefits that flexibility solutions can bring to distribution network planning and how flexible planning methodologies, described in 2.3, may increase these potential benefits, especially under future scenarios with high uncertainty about the penetration of renewable generation, electrification of energy sectors, and penetration of distributed energy resources. Since the DSOs are regulated monopolies, we discuss how remuneration schemes should evolve to encourage cost-efficiency while integrating flexibility solutions. A survey of 6 European countries (France, Italy, Portugal, Spain, Sweden, and the United Kingdom) was conducted, and the majority of the regulations reviewed in this study still present still present a lack of incentives for new OPEX possibilities, such as the use of flexibility, the traditional CAPEX bias that may constitute a barrier to utilize flexibility solutions. Incentivizing cost-efficiency requires non-biased (OPEX vs. CAPEX) incentives. It is required to evolve from cost-of-service approaches to multi-year revenue trajectories with profit sharing, to encourage cost-efficiency and share the potential benefits and risks between DSOs and consumers. This document also includes brief comments on quality and innovation incentives.

2.1 Why flexibility?

The distribution network is a key enabler for achieving European renewable generation and electrification goals by 2050. Thus, Distribution network planning (DNP) is receiving increased attention by regulatory agencies in recent years [5]. DNP aims to anticipate organic growth grid needs and identify needs to connect new grid users (generators, consumers, storage), while ensuring the efficiency, reliability, minimize electricity losses, etc. In this context, DNP, considering long-term scenarios, presents a trade-off between pursuing the aforementioned aim and avoiding an overdimensioned network. When the peak load is close to the network capacity limits, the DSO should decide whether to reinforce the grid considering the grid planning criteria defined by NRA. Therefore, if demand or renewables does not grow as expected, the investment decision would result in an unnecessary cost (i.e. over-dimensioned network, which could not be necessary negative per se as different criteria than the rate of use of the network, like the n-1 or resilience, drive network investment decisions; for example, new installations may be required to redirect electricity flows to less congested portions of the grid, therefore there are rare situations in which new installations are under-used, at least for a period), whereas if demand grows above expectations, this could result in quality-of-service degradation and potential damage to installations. In this decision it is important to highlight that some grid investments might require several years to be commissioned, which requires taking decisions several years in advance, increasing the uncertainty faced by the DSO.

For the sake of illustration, Figure 2.1 represents the aforementioned trade-off situation, where the dotted line (20 MW) is the current capacity limit of the network, the yellow line represents the peak load, 18 MW for the year 0. Let's consider the DSO has the alternative to invest in a feeder now with a 2-year lead time[2], and the alternative to not invest this year and wait to see how the peak load evolves during the following year. In the first alternative, the DSO risk is to commit to an expensive irreversible investment that may result in unnecessary if the peak load does not grow over the network capacity limit after 2 years. In the second alternative, the DSO risk is to incur service interruptions if the peak load grows beyond the capacity during the next 3 years.

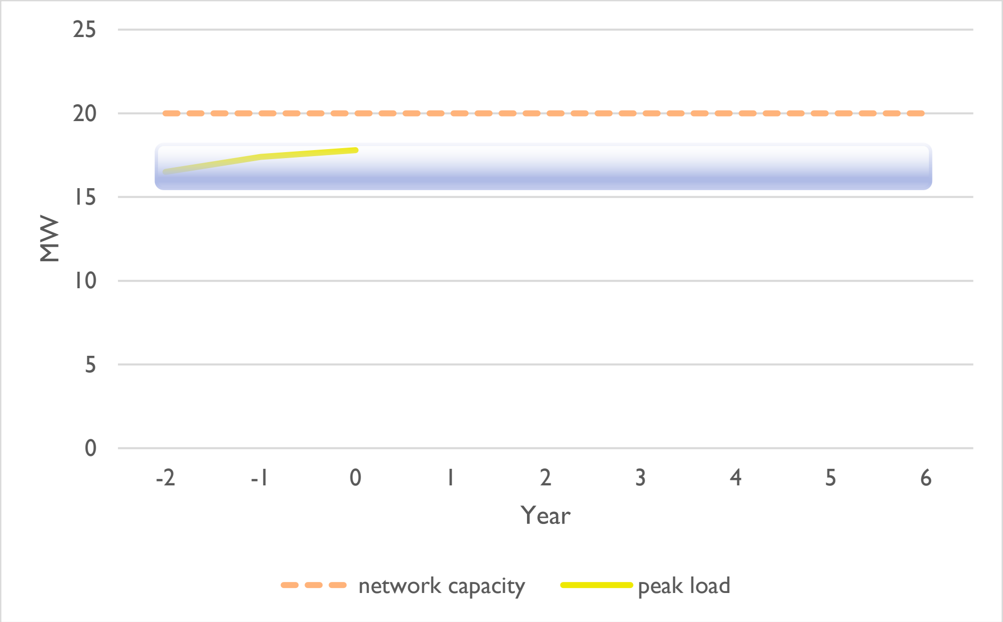

Figure 2.1 Peak load close to network capacity limit

Flexibility solutions allow the DSO to reduce the network peak load during a specific timeframe (i.e., peak hours) or solve voltage issues.[3] This may represent an opportunity for cost-efficiency in the distribution network as it allows the DSO to not commit to irreversible investment while simultaneously avoiding the risk of potential service interruptions. Thus, the value of flexibility in distribution network planning is commonly associated with grid investment deferral for additional grid capacity or accelerating the connection of renewables without waiting for grid reinforcements to be commissioned. It is important to note that grid investments related to assets aging are essential to ensure the reliability of the power system.

The blue band in Figure 2.1, around the network capacity limits, represents the values of the peak load where the value of flexibility in planning the distribution network is expected to be higher, as it potentially could defer or avoid network reinforcements. The blue band begins below but close the network capacity limit, where the DSO faces the following dilemma, the DSO can either decide to not invest in network reinforcement, facing the risk of overloads, if the peak load surpasses the grid capacity limits in the near future, or the DSO can decide to invest in irreversible[4] network

[2] The lead time for deployment of distribution network lines typically varies from 2-4 years in European countries [8].
[3] Voltage problems at MV or LV grids are mostly solved with active energy.
[4] Once network reinforcement is commissioned the capital expenditures are sunk costs.

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reinforcement, bearing the risks that the peak load may not surpass the initial network capacity limits[5], thus the investment may result unnecessary, at least in the near future. The consequences of both decisions are not symmetric, the electricity grid is considered a critical infrastructure and the negative effects of having overloads and triggering subsequent curtailments of generation and demand facilities often exceed the benefits of having a short-term less expensive solution to solve the potential congestion. Therefore, investment decisions must be carefully studied and based on the available information and forecasted scenarios, considering the uncertainties present in this decision-making process and the lead time of the investment decisions. This is where the flexibility may help to maintain service quality while not committing in the long term, and the decision to invest may be delayed with no overloading risks until the peak load surpasses the blue band where the investment decision bears less risk.

In section 2.3, we briefly discuss the effects of uncertainty on the value of flexibility, more specifically, long-term system services procurement, and the importance of flexible planning.

2.2 Flexibility from DSO owned resources & flexibility from third parties

Flexibility may be defined 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"* [9]. This definition only considers flexibility offered to DSOs by third parties, i.e. flexibility as a service. However, we may consider a broader definition of flexibility from [10] "The ability of the power system to cope with variability and uncertainty in demand, generation and grid capacity, while maintaining grid safety and a satisfactory level of reliability at all times". This definition includes DSO owned resources (e.g., switches used for network reconfiguration, on-load tap-changers (OLTC) in transformers, or dynamic line rating for using the real-time thermal limits in power lines) as a source of flexibility, other sources of flexibility (e.g., flexible connection agreements) are also contained in this definition. Thus, a flexibility solution may combine flexibility resources (DSO owned) and flexibility mechanisms (providing third party´s flexibility) to solve a need in the distribution network, as motivated in [11]. Previous studies showed how both DSO owned resources and flexibility from third parties may help to maintain load within network capacity limits and defer a potential reinforcement in situations similar to the one already presented in Figure 2.1.

From the perspective of DNP, flexibility from third parties and flexibility from DSO owned resources differ in nature. The former, after a substantial upfront CAPEX for setting up ICT and advanced grid management infrastructure, will mainly be an OPEX for procuring flexibility [12]. The latter is a combination of CAPEX and OPEX, e.g., the investment in a transformer with OLTCs would result in a CAPEX increase compared to a transformer without OLTCs. The flexibility solutions owned by DSOs would have also an OPEX associated with the use of the flexibility, e.g., the active management of switches for network reconfiguration. The consequences of incentives in the regulatory framework for these flexibility solutions are discussed in Section 2.7.2.

2.3 Flexible planning and the value of flexibility

The DSOs face increasing uncertainties about the penetration of distributed energy resources (DERs) in the upcoming years (Quantity of RES, location of RES, external shocks that could boost (or delay) the speed of connecting RES, penetration of Evs, location of EV chargers, etc.). These increasing uncertainties accentuate the trade-off between maintaining high service levels and fast connection times anticipating the needs of networks users [5], (e.g., EV charging points, PV connections, etc.) in on one hand and avoiding an over-dimensioned network on the other hand. [13] shows how flexibility may be especially valuable when uncertainty is modelled and proposes a flexible planning approach using real options for the DNP cost-benefit analysis (CBA).

Planning activities in any sector can be classified in either traditional planning or flexible planning as defined in [14]. It is essential to understand the difference between traditional planning and flexible planning. Traditional planning

[5] Additional considerations such as the impact on network losses, the risk of assets aging faster due to operating close to their limits for a long time, should be included in the analysis made by the DSO.

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techniques based on discounted cash flow (DCF) are deterministic. These techniques result in a series of fixed decisions projected into the future based on today's forecast. In contrast, flexible planning captures the decision-maker's ability to adapt to future conditions [14]. In a flexible plan, future investment decisions are contingent on resolving future uncertainties in scenarios. Thus, it results in dynamic strategies with defined reactions/responses to future events/conditions during the planning period. Next, we characterize deterministic and flexible plans in the context of DNP.

Consider an illustrative example where the peak demand is close to the network capacity limits, similar example and more detailed discussion can be found in [15]. The peak load uncertainty is modelled by a multi-scenario representation, see Figure 2.2.

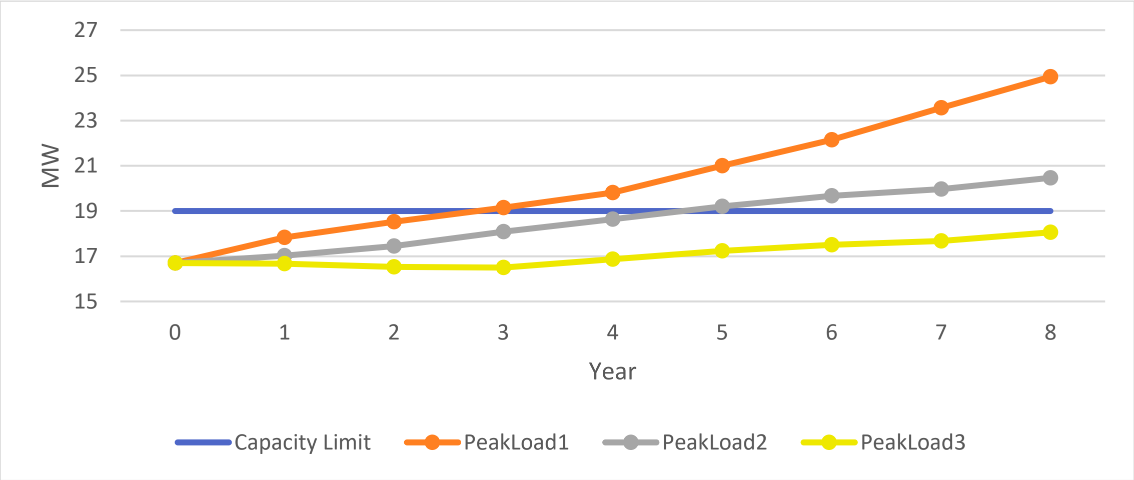

Figure 2.2 Peak Load scenarios considering uncertainty and the network capacity limit

For the example presented in Figure 2.2, the network capacity limit is represented by the blue line (19 MW) and three scenarios (orange line, grey line, and yellow line) represent the peak load evolution under uncertainty.

The DSO identifies two possible upgrades for the distribution network:

- Invest in a feeder (2-year lead time and 10 MW additional capacity for the grid)
- Contract demand response (2-year lead time, 1 MW additional capacity)

For the sake of simplicity in this illustrative example, no overload is permitted.

First planning alternative: Grid reinforcement

The first alternative in this example is to invest in a feeder. The peak load in this example surpasses the network capacity limit during year 3 for the worst-case scenario (orange line). Thus, the DSO should invest in a feeder today, the 10 MW additional capacity would be available at the beginning of year 3 avoiding any potential overload. Otherwise, if the DSO would delay the investment decision to the end of year 1, the feeder will be completed at the beginning of year 4 and there would be a potential overload during year 3, the peak load would surpass the network capacity limit of 19 MW (blue line), if the orange scenario would come to reality. In this process, it is important to consider the necessary time period to have the administrative permits, which is increasingly becoming a more relevant issue.

Second planning alternative: Flexibility + Grid reinforcement under traditional planning

The second alternative in this example is to contract demand response contract and delay the grid reinforcement. As explained in the first alternative, the peak load surpasses the initial capacity limit of 19 MW (blue line) during year 3 (orange line). Then, the DSO should contract demand response today and the additional 1 MW of capacity would be available at the beginning of year 3, then increasing the network capacity limit to 20 MW. This increased capacity limit is surpassed by the worst possible scenario (orange line) during year 5. To avoid the potential overload, the DSO should invest in a feeder at the end of year 2, the additional 10 MW of capacity would be available at the beginning of year 5.

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This avoids any potential overload during the planning period. In conclusion, investing in a demand response contract allowed the DSO to delay the grid reinforcement by 2 years compared to the grid only alternative (first alternative). The economic evaluation of this planning alternative should consider the hours of flexibility needed.

Third planning alternative: Flexibility + Grid reinforcement under flexible planning

The second alternative changes dramatically affecting the value of the demand response contract if flexible planning criteria are considered, please see Figure 2.3 along with the following explanation.

As previously described under traditional planning, the DSO needs to invest today in a demand response contract increasing the network capacity to 20 MW at the beginning of year 3 (brown line). As explained before, flexible planning considers the decision-maker's ability to adapt to future conditions. In this case, a decision rule will trigger the grid investment decision. The decision rule is to invest in a feeder when the network peak load reaches or surpasses 18.5 MW (black dotted line). This flexible plan would result in different investment decisions for the three proposed scenarios.

First, if the peak load grows as in the orange scenario, the peak load surpasses the decision rule (black dotted line) during the second year. The DSO then decides to invest in a feeder at the end of year 2. The additional capacity of 10 MW would be available at the beginning of year 5, avoiding any potential overload for this scenario during the planning period.

Second, if the peak load grows as in the grey scenario, the peak load surpasses the decision rule (black dotted line) during the fourth year. The DSO then decides to invest in a feeder at the end of year 4. The additional capacity of 10 MW would be available at the beginning of year 7, avoiding any potential overload for this scenario during the planning period.

Third, if the peak load grows as in the yellow scenario, the peak load does not surpass the decision rule (black dotted line), then no grid reinforcement decision is triggered.

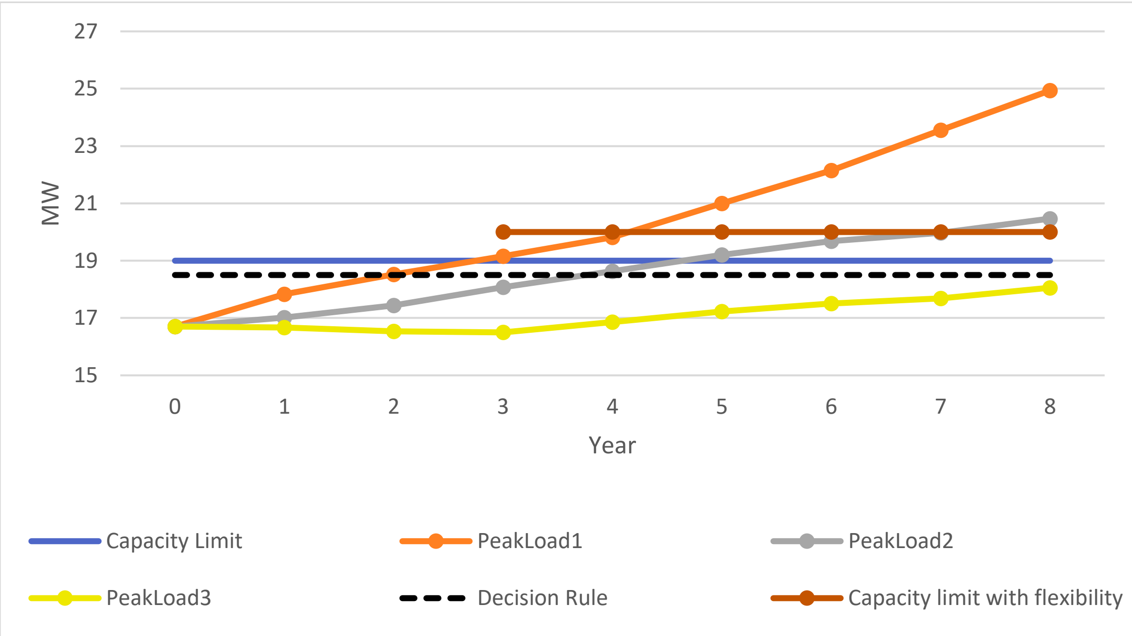

Figure 2.3 Peak load scenarios considering uncertainty and network capacity limits considering demand response

In this simplified illustrative example, demand response allows the DSO to defer the grid reinforcement by 2 years when considering traditional planning. Flexible planning results in the same grid reinforcement deferral (2 years) for the fastest growth scenario (orange line), greater deferral (4 years) for the mid growth scenario (grey line) and avoids the grid reinforcement during the planning period for the lowest growth scenario (yellow line). *Table 2.1* summarizes the results.

Table 2.1. Investment decisions for the 3 planning alternatives

Scenario	Planning alternative		
	Grid reinforcement only	Flex + Grid reinforcement (Traditional planning)	Flex + Grid reinforcement (Flexible planning)
Fastest growth (orange line)	G: y0 (in operation y3) F: N/A	G: y2 (in operation y5) F: y0 (in operation y3)	G: y2 (in operation y5) F: y0 (in operation y3)
Mid growth (orange line)	G: y0 (in operation y3) F: N/A	G: y2 (in operation y5) F: y0 (in operation y3)	G: y4 (in operation y7) F: y0 (in operation y3)
Lowest growth (yellow line)	G: y0 (in operation y3) F: N/A	G: y2 (in operation y5) F: y0 (in operation y3)	G: N/A F: y0 (in operation y3)

G: Grid reinforcement decision / F: Flexibility investment decision (demand response contract) / N/A: Not applicable

In conclusion, flexible planning[6] may increase the expected grid investment deferral and thus the value of flexibility (a demand response contract in this particular case) in distribution network planning under uncertainty, while traditional deterministic network planning, where the decisions are fixed may undervalue flexibility and result in higher cost for bill payers [15].

2.4 How to incentivize flexibility?

Electricity distribution is a regulated monopoly, requiring regulation that defines the DSO remuneration schemes and economic incentives. As acknowledged by the council of European Energy Regulators (CEER): "The DSOs' decisions when planning, expanding and managing their networks are led by the incentives in the revenue/remuneration regime and direct regulatory requirements." Thus, the DSO remuneration schemes need to evolve as recognized by the European Electricity Market Directive 944/2019. As previously mentioned, incentivizing non-biased cost-efficiency and dealing with uncertainty are key aspects to consider in the evolution of the regulatory frameworks.

In order to assess how to foster the use of flexibility solutions by DSOs, T1.1 (Regulatory framework for fostering flexibility deployment) reviews the current DSO remuneration schemes in six European countries (i.e., France, Italy, Portugal, Spain, Sweden, and the United Kingdom). France, Italy, Spain, and Sweden have demonstrators in the BeFlexible project. They are relevant countries in the European context and present different characteristics regarding the network, the climate, remuneration schemes, etc. The UK was also included because it has one of Europe's most advanced regulatory frameworks for procuring flexibility. Moreover, Portugal was considered to study one additional approach referred as TOTEX apart from the UK.

There are some key characteristics for a remuneration scheme to incentivize flexibility procurement as an alternative to grid reinforcement:

- First, it should incentivize long-term cost-efficiency while maintaining security of supply and service quality standards. Otherwise, a remuneration scheme may result in excessive costs by not encouraging the selection of the most cost-efficient of the identified alternatives to solve potential grid capacity limitations and could delay the decarbonization of the power system. This is increasingly important as the inclusion of flexibility solutions increases the number of alternatives in distribution network planning.
- Second, it should be a non-biased remuneration scheme[7]. Traditional regulatory frameworks tend to be CAPEX-biased. Since flexibility procurement is mainly an OPEX, these traditional frameworks would discourage the procurement of flexibility over conventional network reinforcement. This has been noticed by researchers and regulatory agencies [5], [7], [12], [17], [18], [19], [20].
- Third, the regulatory framework should consider an approach to deal with uncertainty. The DSOs face increasing uncertainty about the penetration of distributed energy resources (e.g., renewable generation and new loads due

[6] Planning future decisions contingent on unfolding information.

[7] A non-biased remuneration scheme stablishes equal incentives for capital and operational expenditures as described in [16]

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to increasing electrification), even more considering that there is a significantly asymmetric risk to the disadvantage of under-investments with weak networks rapidly causing high costs mainly due to congestion costs from curtailment of renewable generation and restrictions for customers minus the saved network investments. These uncertainties may lead to conservative plans and over dimensioned networks if the national regulatory agencies require traditional deterministic plans from DSOs as motivated in Section 2.3. Moreover, grid planning processes should be dynamic and include the possibility to adjust future investment decisions according to the unfolding needs (e.g. connecting new customers or generators, increasing/decreasing demand).

Additionally, any remuneration scheme focusing only on cost-efficiency may result in quality-of-service deterioration [21]. Therefore, quality incentives should be included. Innovation incentives may also be desirable to foster innovative flexibility procurement approaches.

This work highlights the importance of three key characteristics mentioned above based on current research and analyses the status of the six European countries regarding these three aspects of DSO remuneration and their alignment with current European regulation. The first two topics are discussed together as they are both closely related to the formulation of the DSO regulated allowed revenue.

2.5 Methodology

T1.1 (Regulatory framework for fostering flexibility deployment) reviews the current regulatory frameworks for DSO remuneration in the selected European countries (i.e., France, Italy, Portugal, Spain, Sweden, and the United Kingdom). Particular emphasis is placed on the allowed revenue calculation and the network development plan requirements by national regulatory frameworks. The alignment of these regulatory frameworks with European regulation is also analyzed.

A questionnaire was designed to gather information on national regulations for DSO remuneration. This questionnaire covers the main aspects of interest identified to assess the readiness of the different regulatory frameworks for flexibility procurement. The questionnaire is included in the annex and Figure 2.4 summarizes the topics covered in the questionnaire.

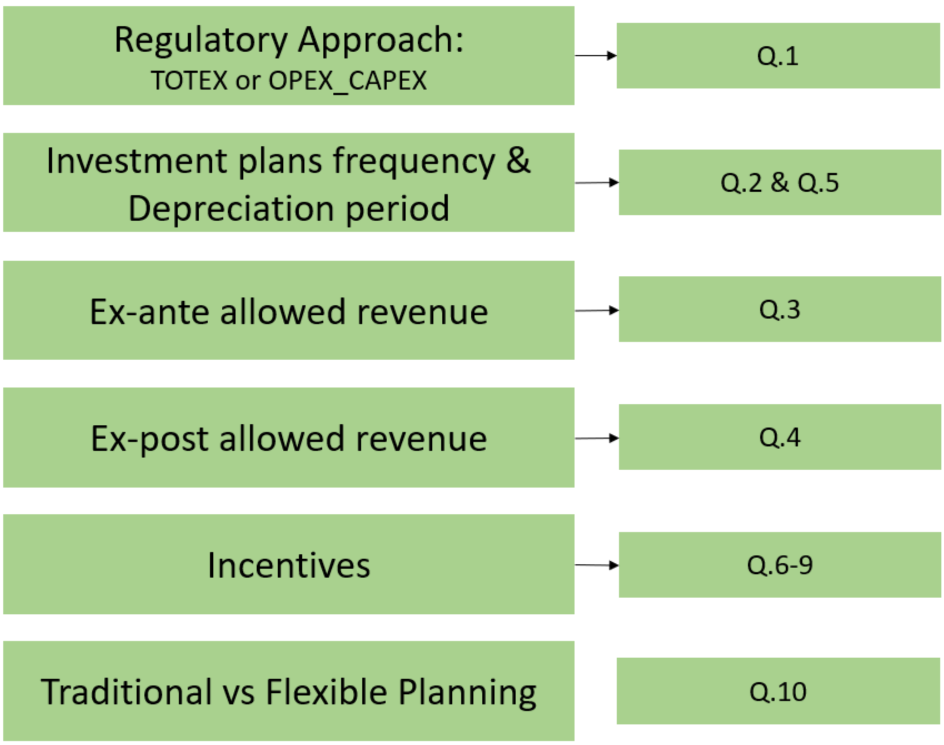

Figure 2.4. Summary of survey topics

For the purpose of clarity, the first question intends to classify the regulatory approach of the different countries between TOTEX and OPEX_CAPEX approach. The following definitions are considered in this study. In the OPEX_CAPEX approach, capital expenditures (CAPEX) are included in the regulatory asset base (RAB) while operational expenditures (OPEX) are direct allowances not included in the RAB. In the TOTEX approach, any expenditure whether the expenditure is related to CAPEX (e.g. asset investment cost) or OPEX (e.g. operation and maintenance expenditures) is (totally or partially) included in the RAB. This classification of the regulatory approach turned particularly important in the regulatory analysis.

The information gathered with this questionnaire allowed to assess the readiness of the remuneration schemes regarding flexibility procurement in the selected countries and also allowed to evaluate the degree of alignment of these schemes with the European Electricity Market Directive 944/2019. Please see the results and discussion in the next section

2.6 Results and discussion

With the contribution of the project partners, the survey for the 6 countries was completed. We discuss the results in this section.

As motivated in the introduction promoting non-biased cost-efficiency is necessary for promoting SO services and should result in savings for bill-payers. This is evaluated mainly by the answers to questions 1, 3 and 4 of the survey presented in the methodology. Next, we discuss this topic.

2.7 Allowed revenue schemes and flexibility costs acknowledgment

As distribution networks are considered a natural monopoly, it should be regulated to prevent excessive prices for consumers and also have the adequate network to guarantee security of supply. Thus, regulation must encourage the monopoly company (DSO) to seek and pursue cost efficiencies in its business.

The regulatory approaches to define the company's allowed revenues can be conceptually classified into two categories [12].

First, under the **cost-of-service** regulation, the DSOs actual costs are covered with a reasonable rate of return applied to capital expenditures. This ex-post approach represents a barrier for the pursuit of cost efficiencies by the DSO.

Second, under the **multi-year revenue trajectory**, the regulator defines the company allowed revenues ex-ante. Since the revenues are fixed, the DSO's earnings will depend on its actual costs during the period; lower-than-expected actual costs will lead to higher earnings for the DSO and vice-versa. Therefore, the second approach encourages the DSO to pursue cost efficiency.

Combining the first and second approaches would result in a multi-year revenue trajectory with a **profit-sharing mechanism** [21]. The profit-sharing mechanism is an ex-post adjustment for the DSO's revenues. This mechanism defines the final allowed revenue as a weighted average between the ex-ante trajectory (second approach) and the actual costs (first approach). The weight given to the ex-ante revenue trajectory is known as the incentive rate. A 100% incentive rate would result in a pure ex-ante multi-year revenue trajectory. On the contrary, a 0% incentive rate would result in a pure cost-of-service regulation. This third approach, the multi-year revenue trajectory with a profit-sharing mechanism, allows the regulator to share the DSO's actual cost savings with consumers while incentivizing DSO to achieve cost efficiencies. This third approach, while encouraging cost-efficiency, may still retain a bias depending on what expenditures are to be included in the regulatory asset base (RAB).

It is clear that flexibility procurement may represent an opportunity for cost-efficiency in distribution network as they allow the DSO to not commit to irreversible investment while at the same time avoiding the risk of service interruptions. However, traditional regulatory approaches tend to be CAPEX-biased, aiming to cover operational expenditures of the regulated firm and remunerate capital expenditures with an attractive rate of return, which may discourage to the procurement of flexibility. This barrier has already been noticed by several researchers and some regulatory agencies [7], [12], [17], [18], [19], [20]. Incentivizing cost-efficiency in the context of increasing penetration of distributed energy resources will require a non-biased regulation. Still, most European regulatory frameworks maintain the traditional CAPEX bias [22].

On the other hand, this traditional incentive to increase CAPEX can shift to reduce CAPEX instead if the regulator puts an unattractive rate of return in place. However, this shift is not desirable as the quality of supply may deteriorate and could jeopardize the difficult challenges posed by the energy transition. Moreover, it contradicts one principle of regulation: "provide a reasonable return on capital and attract new resources of funding to finance any new facilities needed to cope with demand growth" [23]. The United Kingdom overcame this CAPEX bias with a TOTEX approach, where a fixed portion of the total expenditures is capitalized and remunerated with an attractive rate of return. Table 2.2 presents the results obtained from the surveys and shows the main characteristics of the current DSO allowed revenue schemes in the selected European countries.

Table 2.2. Allowed revenue for DSOs and flexibility procurement consideration

Country	Regulatory Approach	Flexibility procurement included in the remuneration scheme?	How are flexibility procurement costs recovered?	Allowed revenues for DSOs
France	OPEX_CAPEX	Y	Ex-post adjustment	OPEX: ex-ante allowance with 100% incentive rate CAPEX: cost-of-service, incentive to reduce unit investment price
Italy	OPEX_CAPEX	N	Not defined	OPEX: ex-ante allowance with 100% incentive rate + mechanism to capture previous efficiencies CAPEX: cost-of-service
Portugal	OPEX_CAPEX	N	Not defined. Pilot began during 2023	OPEX: ex-ante allowance with 100% incentive rate + mechanism to capture previous efficiencies CAPEX: ex-ante allowance with 100% incentive rate for new investments + rate of return ex-post assessment with profit sharing
Spain	OPEX_CAPEX	N	Not defined.	OPEX: ex-post allowance based on predefined terms, annual efficiency coefficient are implemented to reduce allowed OPEX CAPEX: cost-of-service + incentive to control unit investment price + investment limit
Sweden	OPEX_CAPEX	Y	OPEX (ex-ante calculation)	OPEX: ex-ante allowance with 50% Profit sharing on controllable OPEX CAPEX: leaning towards cost-of-service regulation
United Kingdom	TOTEX	Y	As any other cost	TOTEX: ex-ante allowance + Profit sharing

France has an ex-ante allowance for operational expenditures (OPEX) with a 100% incentive rate. The regulator defines the allowed amount based on the DSO proposal and an external audit [24]. Flexibility procurement costs are fully covered by an ex-post mechanism as they are considered unpredictable by the current regulation. The French regulation applies a cost-of-service approach for capital expenditure (CAPEX) where the allowed revenue covers commissioned network investments [24]. There is an incentive to reduce the unit price of investments in comparison to a reference unit cost model. If the total investment amount results lower than the sum of asset prices based on the reference model, the incentive rewards the DSO with 20% of the difference. This incentive is symmetric. If the total investment amount results higher than the model, a 20% penalty on the difference applies. The reward/penalty is capped at ±30 M€/year.

In conclusion, the cost-efficiency incentives in the French regulation encourage DSO to reduce OPEX and to control the unit investment price on CAPEX but does not encourage to reduce the total amount of CAPEX, assuming that the DSO considers the rate of return for CAPEX attractive.

Italy has an ex-ante allowance for OPEX with a 100% incentive rate. Each period's ex-ante OPEX allowance is calculated as the sum of actual OPEX in the previous period (on a reference year, t-2) and 50% of difference between allowed and actual OPEX measured in the reference year. The objective of this mechanisms is to share efficiencies between customers and DSO (for the DSO these efficiencies are gradually and yearly nulled over the period, and the 50% is passed to customers at the start of the new period) [25]. Therefore, an actual OPEX resulting below the ex-ante OPEX allowance will result in a lower OPEX allowance for the following periods. On the other hand, capital expenditure is covered with a cost-of-service approach. Regarding flexibility, there is no current regulation on how to recover flexibility costs.

Therefore, the Italian regulation incentivizes the DSO to reduce OPEX and does not directly incentivize CAPEX reduction assuming the remuneration rate is attractive for the DSO to invest in infrastructure. Starting from 2024, the regulator plans to introduce a TOTEX approach [26], with the intention to, among other things, overcome the already mentioned capex-bias.

Portugal has a regulatory approach referred as TOTEX; yet there are different incentives for CAPEX and OPEX, and only CAPEX is included in the regulatory asset base (RAB). Thus, this approach maintains a different treatment for CAPEX and OPEX and may not be considered as a full proper TOTEX approach. There is an ex-ante allowance for OPEX with a 100% incentive rate, and similar to the Italian regulation, it has a mechanism to capture previously achieved efficiencies. Efficiencies achieved in previous periods are considered for the calculation of each period ex-ante OPEX allowance. Each period ex-ante allowance is calculated as a weighted average between actual OPEX (80% weight) and allowed OPEX (20% weight) from the previous, most recent, two audited years. This mechanism aims to capture 80% of the achieved efficiencies on OPEX from the previous period for the benefit of consumers. While reducing risks for the DSO in case actual OPEX surpassed the allowed OPEX in the previous period. Therefore, sharing potential benefits or losses between consumers and the DSO. Regarding flexibility, the current regulation does not define how to recover flexibility costs. Regarding CAPEX, there is a revenue cap for new investments. When the regulator approves the investment plan, an ex-ante revenue cap for new investments during the regulatory period is defined, and a 100% incentive rate applies. Then, assets commissioned during the regulatory period are included in the consolidated regulatory asset base (RAB) at the end of the regulatory period, thus, no longer affected by the revenue cap. There is a rate of return ex-post adjustment at the end of the regulatory period to share achieved efficiencies with the customers if the actual rate of return results higher than the predefined value. On the contrary, if the actual rate of return results lower than predefined, then this adjustment protects the company against low returns.

As a result, the Portuguese regulation encourages DSO to reduce OPEX and CAPEX but with different incentives. Still, only CAPEX is included in the RAB. Therefore, a bias towards CAPEX/OPEX may appear if the rate of return applied to CAPEX is higher/lower than the DSO´s cost of capital.

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Spain has an ex-post allowance for OPEX and CAPEX. The allowed revenues for year *n* cover the expenditures of year *n-2*. The calculation of OPEX uses previously defined standard costs (e.g. operation and maintenance costs increase with network investments), but the total OPEX costs cannot be reviewed under the COMGES term. Moreover, the current regulation does not define how to recover flexibility costs as they are not included in the regulation. Regarding CAPEX, there is a cost-of-service regulation where commissioned assets are included in the RAB with the 2-year delay mentioned above. The Spanish regulation has an incentive to reduce the unit price of investments. There is a list of standard investment prices, and an incentive mechanism applies after comparison with this list. Investments are included in the RAB at their actual cost if the sum of actual investment cost fall within a range of +5% and -10% of the sum of standard investment costs. A penalty/reward to the value of investment included in the RAB applies if the sum of actual costs results above/below the sum of standard costs by +5%/-10% [27]. In addition, there is a limit for the total amount of investment in each semi-period (3 years) [27], defined as 0.13% of GDP (divided between the different DSOs), disconnected from the technical needs of the network. There is also a penalty for surpassing the total investment limit.

In conclusion, the cost-efficiency incentives in the Spanish regulation encourage DSOs to reduce OPEX and to control the unit investment price on CAPEX, while maintaining the total amount of investment per year at the investment limit, assuming the rate of return is attractive.

Sweden has an ex-ante allowed revenue for controllable OPEX (the regulator distinguishes between controllable OPEX that are subject to an efficiency requirement as the DSO is considered to be able to make an effort to reduce them, and non-controllable OPEX that are fully covered [28]) with a 50% profit-sharing mechanism. This ex-ante allowance is based on the most recent available historic costs [29]. Non-controllable OPEX (e.g. energy losses, agency fees, and others) are fully covered. Flexibility procurement costs are considered as any other controllable OPEX and thus subject to the efficiency requirement. Regarding CAPEX, the ex-ante allowed revenue calculation uses a list of standard investment prices and the DSO investment plan. The regulator sets the list of standard investment prices based on an external audit and considers the feedback from the DSOs [29]. The ex-ante CAPEX allowance is adjusted ex-post up or down to reflect the actual investments made [29], [30]. With this ex-post adjustment, the Swedish DSO remuneration scheme is leaning towards a cost-of-service approach for CAPEX.

In summary, the Swedish regulation encourages DSOs to reduce controllable OPEX and the incentives to reduce CAPEX may be limited.

The United Kingdom has a multi-year revenue trajectory with profit sharing for the Total Expenditure (TOTEX), this also includes the costs of flexibility. Ofgem, the energy regulator, sets the ex-ante revenue trajectory after evaluating the DSOs´ business plans. Business plans shall be based on a conservative low-growth-demand scenario. Ofgem conducts a cross-DSO benchmarking to assess cost-efficiency [31]. After evaluating their business plans, Ofgem fixes the capitalization rate and the incentive power ex-ante for each DSO. This capitalization rate is the percentage of the total expenditure that is included in the RAB and therefore recovered over time along with depreciation, referred as slow money. The portion that is not capitalized is recovered immediately, referred as fast money [32]. The incentive power is based on Ofgem´s confidence in the DSO business plan. This incentive is limited to a 50% maximum [33]. The UK regulation includes an uncertainty mechanism named load-related expenditures [31] to increase allowed revenue beyond the baseline if the need for additional investment materializes. As mentioned before, the allowed revenue baseline is based on a low-growth-demand scenario. However, the business plans should include the consequences of different scenarios in the foreseen investments [34]. Then, additional revenue allowances are recognized if demand grows to a point where additional investments were planned.

In conclusion, the UK regulatory framework encourages DSOs to reduce total expenditures where the bias between CAPEX and OPEX is mostly reduced since the capitalization rate is fixed ex-ante. The fact that this capitalization rate is affected by DSOs´ business plans may incentivize them to increase CAPEX in their plans. At the same time, this may be

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reasonable since fixing a capitalization rate without considering the business plan could put the financial situation of DSOs at risk.

It was already discussed at the beginning of this section 2.7, how cost-of-service approaches may not encourage cost efficiency, while the pure ex-ante multi-year revenue trajectory incentivizes cost-efficiency but may fail to share these achieved efficiencies with the final customer. And how a combination of both approaches resulting in a multi-year revenue cap with profit sharing may be desirable for incentivizing cost-efficiency while sharing part of the benefits derived from cost-efficiencies with the final customer.

In section 2.7.1, we discuss how the mechanisms to control unit investment price may not incentivize the selection of the best alternative when planning grid capacity upgrades.

2.7.1 Mechanisms to control unit price of investments and cost-efficiency

Some regulatory frameworks (e.g., Spain and France) use an incentive mechanism to control the unit investment price based on a pre-established reference (e.g., a price list or a reference unit cost model). These mechanisms reward companies that achieve lower price than the reference and penalize companies with actual costs higher than the reference. These incentives may result in not promoting overall cost-efficiency. For example, let´s consider a DSO facing potential capacity limitations in the distribution grid. The DSO has identified 2 upgrade alternatives with similar technical characteristics (additional capacity, useful life, etc.) but different costs. Alternative 1 costs 100k € and alternative 2 costs 92k €. In this case, any remuneration scheme should incentivize the DSO to choose alternative 2.

Let´s consider adding price lists to this example, see Table 2.3.

Table 2.3. Alternative selection using price lists incentive

	Reference unit cost	Actual unit cost year 0	Actual unit cost year 2
Alternative 1	102k €	100k €	102k €
Alternative 2	95k €	92k €	96k €

Table 2.3 shows two different situations for this case. In situation 1 (Actual unit price year 0), alternative 2 actual price (92k €) is lower than the reference unit price (95k €) by a margin of 3k €. Alternative 1 actual price in year 0 (100k €) is lower than the reference price (102k €) by a margin of 2k €. Thus, the incentive would reward more a DSO choosing alternative 2, the least cost alternative, than choosing alternative 1.

Now let´s consider a price evolution from actual unit price in year 0 to actual unit price in year 2, where prices rise from 100k € to 102k € for alternative 1 and from 92k € to 96k € for alternative 2. Additionally, the reference price list is still not updated to reflect this new situation. In this case alternative 1 would have a price equal to the reference unit price (102k €), while alternative 2 would exceed the reference price by 1k € (96k € vs 95k €). Thus, the unit price incentive would be neutral to alternative 1 and penalize alternative 2. In conclusion, the unit price incentive in this second situation would not be aligned with cost-efficiency.

A price list or a reference unit cost model may be an interesting complementary tool for regulators to estimate allowed revenue. In a revenue cap approach, the regulator has to establish an ex-ante allowed revenue, this amount may be based in different calculations, one bottom-up approach may be, to first analyze the expected necessary grid upgrades in the following years based on the reviewed/accepted investment plan. Then, calculate the necessary amount of money for these upgrades based on the reference price list. It may be interesting to complement these estimations with historical performance benchmarking or other approaches. However, establishing incentives based on a reference unit price may result in a misaligned incentive if the regulator is pursuing to encourage cost-efficiency.

France, Spain and Sweden currently use a unit cost reference as an incentive to control investment price, which may represent a barrier for promoting overall cost-efficiency. In section 2.7.2 we discuss how the CAPEX bias may also represent a barrier for flexibility procurement.

2.7.2 Flexibility and the CAPEX bias

As already described in the introduction, several researchers and some regulatory agencies have noticed that traditional regulatory regimes are biased towards CAPEX alternatives for solving grid capacity limitations. Next this section, we describe two characteristics of the regulatory regimes that may lead to a CAPEX bias.

First, some regulatory regimes treat CAPEX with a cost-of-service approach while encouraging OPEX reduction with price cap or revenue cap approaches. This is the case for Italy, Spain and Sweden. These schemes incentivize OPEX reduction while reducing CAPEX does not bring any monetary benefit for the DSO. This kind of framework introduces a bias towards CAPEX solutions and may discourage OPEX solutions. Therefore, discouraging the procurement of flexibility from third parties and the use of flexibility from DSO owned resources. First, because they both result in an OPEX increase compared to the traditional network reinforcement (not using/procuring flexibility), reducing the DSO´s net profit. Second, because they result in a reduction of the RAB (due to the investment deferral) for the DSO, also reducing the DSO´s net profit.

Sweden has already regulated that flexibility costs are treated as any other controllable OPEX with an ex-ante allowed revenue and a 50% profit sharing mechanism. This provides a clear incentive for DSO to opt for flexibility solutions vs. other OPEX solutions for operational purposes where it is more economically efficient for the power system, but may represent a barrier for the use of flexibility to delay network reinforcement in DNP, considering that CAPEX is recovered with a cost-of-service approach.

Italy and Spain have not defined yet how to include flexibility services in the remuneration schemes and incentives for DSOs (they are launching projects to develop specific regulation), but treating flexibility costs similar to the existing OPEX scheme and maintaining the CAPEX cost-of-service scheme may not provide incentives for the procurement of flexibility to delay network reinforcement, similar to the aforementioned Swedish case.

France presents a similar regime but treats flexibility procurement as a non-controllable cost and it is not included in the OPEX revenue cap. Flexibility costs are recovered ex-post and there is no direct incentive to reduce them. Still, CAPEX are treated with a cost-of-service approach, which may represent an incentive towards CAPEX as noticed by [35], since there is no direct incentive to reduce them plus they are funded over time with a rate of return, assuming that the rate of return is attractive considering the level of risk of the DSO regulated activity.

Second, a regulatory regime may separately encourage CAPEX and OPEX reductions. While this framework encourages cost-efficiency, it may still result in a CAPEX-bias. This is the case for Portugal, where there is a revenue cap for OPEX and a revenue cap for CAPEX. Different incentives for OPEX and CAPEX may distort alternative selection and represent a barrier for flexibility solutions (including both, the procurement of third party flexibility and the use of DSO owned flexibility), especially when CAPEX go to the asset base and as noticed in previous research "a dollar in reduced CAPEX will also involve a reduction in the utility's regulated asset base and thus a reduction in the allowed return on equity and a corresponding decline in net profit for the utility's shareholders. This decline in net profit will offset some portion of any efficiency-related income awarded by the regulator, distorting trade-offs between OPEX and CAPEX and potentially encouraging overinvestment in conventional network assets" [12].

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In the United Kingdom, Ofgem already noticed this effect and designed a TOTEX approach to minimize this bias [36], [37], using an ex-ante capitalization rate that affects the total expenditure along with a revenue cap approach. During the RIIO-ED1 the ex-ante capitalization rate is the same for all DSOs and fixed at 80%. In the current regulatory period, named RIIO-ED2, Ofgem establishes a different capitalization rate for each DSO after reviewing their business plans.

In section 2.7.3, we assess the alignment of the analyzed regulatory frameworks for DSO remuneration with the European regulation.

2.7.3 Alignment with European Union Electricity directive

Electricity Market Directive 944/2019 establishes common rules for the electricity sector in the member states. Regarding this study, we highlight the following requisites:

- First, there should be market-based procurement of flexibility. “All customer groups (industrial, commercial and households) should have **access to the electricity markets to trade their flexibility** and self-generated electricity.” *(EU directive 944/2019, whereas 39)*.
- Second, the DSO remuneration schemes should incentivize flexibility procurement when cost-efficient. So, there should be non-biased (grid investment vs. flexibility solutions) cost-efficiency incentives. “DSO remuneration schemes should **incentivize** the procurement of **flexibility** services as an alternative to grid reinforcement **when cost-efficient**.” *(Reference: EU directive 944/2019, article 32.1).*
- Third, the network development plans should be updated with a two-year frequency and they should cover a planning horizon of 5-10 years. These plans should also include the use of flexibility. “DSOs shall present **network development plans at least every two years to the regulatory authority**. The plan shall include the necessary 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.” *(EU directive 944/2019, article 32.3 and future Network Code on Demand Response)*

Table 2.4 shows how the current regulatory frameworks of the countries included in this analysis align with the directive based on the points already highlighted.

France, Sweden and the United Kingdom have already regulated market-based procurement of flexibility and have flexibility markets in place. These countries have already regulated how the DSOs recover the cost of flexibility procurement.

Italy, Portugal and Spain have not regulated the market-based procurement of flexibility and how DSOs may recover the flexibility costs. Portugal is running a pilot program with Picloflex with flexibility tendering [38].

Regarding investment plans only Sweden and the United Kingdom ask for estimates of flexibility needs in the Network Development Plans (NDP).

Regarding the frequency of network development plans, the European Directive establishes an update frequency of maximum 2 years, France is the only countries surpassing this barrier with 4 years.

Finally, regarding the incentive for non-biased cost-efficiency, France, Italy, Spain and Sweden present a cost-of-service regulation for CAPEX; this approach does not explicitly give a monetary incentive for cost-efficiency, and they also present unequal incentives for grid investments and the procurement of flexibility services, not being aligned with the beforementioned European directive. Portuguese regulation does incentivize cost-efficiency with revenue cap

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approaches for CAPEX and OPEX, still there are unequal incentives for OPEX and CAPEX, as explained in Section 1.3.3, so this regulatory approach may retain some CAPEX bias. The United Kingdom regulation has a TOTEX revenue cap incentive for cost-efficiency, where the TOTEX is capitalized with a fixed capitalization rate. This approach results in no observable bias while incentivizing cost-efficiency as the European directive requires.

Table 2.4. Alignment of national regulations with the Electricity Market Directive 944/2019 regarding DSO remuneration schemes.

	Is Market-based procurement of flexibility implemented?	Is flexibility procurement included in the investment plans?	NDP Frequency	Incentivize non-biased cost-efficiency
France	Yes	*Not in the investment plan.	4 years	Cost of service for CAPEX + different incentives for CAPEX and OPEX.
Italy	No	No	1 year	Cost of service for CAPEX + different incentives for CAPEX and OPEX.
Portugal	**Pilot	No	2 years	Revenue cap for OPEX and CAPEX + different incentives for CAPEX and OPEX.
Spain	No	No	1 years	Cost of service for CAPEX + different incentives for CAPEX and OPEX.
Sweden	Yes	Yes	2 years	Cost of service for CAPEX + different incentives for CAPEX and OPEX.
United Kingdom	Yes	Yes	2 years	Revenue cap for TOTEX + TOTEX capitalization rate fixed ex-ante

* The flexibility costs are covered by an ex-post adjustment mechanism through a expenses and revenues clawback account called CRCP.

** Tendering with Picloflex already in place during the pilot. https://prt.picloflex.com/dashboard

Green fill: aligned with EU directive / Yellow fill: partially aligned with EU directive / Red fill: Not aligned with EU regulation

2.7.4 Quality incentives

All the reviewed regulatory frameworks have quality of supply incentives in place. These incentives are focused on reducing frequency and duration of service interruptions. The regulator sets a reference value or formula for the evaluation and a penalty/reward applies based on DSO performance against the reference. Italy has an additional incentive for voltage quality while the United Kingdom includes an incentive for faster connections.

Any regulatory approach encouraging the DSO to pursue cost-efficiency should include quality of supply incentives; otherwise, it may incentivize the DSO to pursue excessive cost reduction while decreasing the quality of supply [21]. If quality of supply results below the desired levels, the relationship between the quality incentives and the cost-efficiency incentives should not be overlooked, it may be the case that saving a dollar results in higher earnings for the DSO, due to cost-efficiency incentives, than the earnings for investing a dollar in improving the quality of supply and receive corresponding incentive. Regarding compliance with service interruption standards, it is worth looking at the allocation of responsibilities between the DSO and the flexibility service provider, as non-delivered flexibility may result in service interruption, and in this case, liabilities may be applied to the flexibility service provider.

2.7.5 Incentive to reduce losses

All the reviewed regulatory frameworks have incentives to reduce losses, where power injections and withdrawals in the distribution network are considered to measure actual losses and a penalty/reward applies after comparison of the actual losses versus the reference values[8]. These incentives encourage DSOs to reduce technical power losses as well as energy theft.

2.7.6 Innovation incentives

The reviewed countries present different innovation incentives (e.g., sandboxes, pilot projects, innovation allowances for smart grid deployment or other specific challenges, and non-specific R&D budgets). These innovation incentives may help DSOs to find solutions to the challenges and uncertainties they will face in the near future, thus bringing efficiencies in the medium and long term.

As described in [39], innovation incentives can be categorized in direct innovation incentives (e.g. specific funding for a pilot project) and indirect innovation incentives (linked to incentives in the current regulatory framework, e.g., efficiency incentives, quality incentives, etc.). Direct and indirect innovation incentives should be aligned; otherwise, misaligned incentives may represent a barrier for innovation. For example, funding innovative OPEX solutions in a CAPEX bias regulatory framework may result in discontinuation of the innovation initiative as the funding ends, because the current regulatory framework may disincentivize the solution brought by the project. This would represent an institutional barrier to innovation. Other regulatory rules (e.g., minimum bid size in flexibility markets) may cause difficult market participation, representing an additional institutional barrier for flexibility-based OPEX solutions.

A different incentive for innovation in place in Sweden is the load factor incentive. This incentive rewards DSOs for reducing the (daily) peak-load in their grids with the aim of reducing the power contracted to the feeding upper grid, thus resulting in savings for final customers. The aim of this incentive is to promote innovation and smart grid technologies with potential to reduce peak load and the need for grid reinforcements (e.g., flexibility). On the other hand, a cost-of-service approach like the one implemented in Sweden, generally does not reward a DSO that reduces the need for grid reinforcement, because reducing the peak load and grid reinforcement results in a lower increase of the regulated asset base. This is another example of misaligned incentives that may represent a barrier for flexibility procurement. A possible solution for this is to incentivize the reduction of grid reinforcements with a multi-year revenue trajectory approach and profit sharing, rewarding the DSO for the achieved efficiencies, as motivated in the beginning of this results and discussion section.

2.8 Interim Conclusions

Distribution network planning is facing high uncertainties due to an unprecedented penetration of renewable generation and the unknown adoption pace for the increasing electrification of final end energy uses, such as transport, building climatization, and industry. Flexibility represents an opportunity for dealing with these uncertainties, avoiding over-commitment to traditional investment and accelerate the decarbonization of the power system. Flexible planning,

[8] In some countries this incentive is based on the procurement of losses by the DSO.

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where investment decisions are not fixed but rather react to unfolding information, may unveil additional economic value for flexibility (more specifically, long-term system services procurement).

The analysis of the current remuneration schemes for DSOs in 6 European countries (France, Italy, Portugal, Spain, Sweden, and The United Kingdom) highlighted that fostering flexibility solutions requires evolution in some European regulatory frameworks. Traditional CAPEX-biased regulatory frameworks are still in place in some of the reviewed countries. Improving those traditional schemes and promoting neutral incentives are key for pursuing cost efficiency. First, cost-of-service approaches (typically applied to CAPEX) where the DSO does not directly benefit from cost savings and second, remunerating CAPEX with an attractive rate of return while OPEX are treated differently, may represent barriers to flexibility procurement and cost-efficiency. The cost-of-service approach is still present in 4 of the 6 reviewed regulatory frameworks (France, Italy, Spain, Sweden). Portugal has a multi-year revenue trajectory approach promoting cost-efficiency, although the different treatment of OPEX and CAPEX may distort overall cost-efficiency objectives, and only the United Kingdom has a regulatory framework with equal treatment for OPEX and CAPEX. The European Union market electricity directive 944/2019 forces member states to overcome this challenge. Additionally, after promoting non-biased cost-efficiency and updating network development plans with a 2-year frequency as required by the directive, it may be interesting that regulatory regimes allow flexible planning as it has shown the potential to achieve additional cost-efficiencies.

Promoting cost-efficiency without proper quality incentives in place may lead to poor service quality and discourage long-term innovation. All the reviewed countries have quality incentives in their current regulatory frameworks. If regulators notice DSOs delivering low service quality, the relationship between cost-efficiency incentives and quality incentives could be one of the reasons and may be worth looking at. Innovation incentives may complement a regulatory framework promoting cost-efficiency and facilitating medium- and long-term innovation. Regarding innovation, misaligned direct and indirect incentives may represent a barrier to continuing innovation initiatives when the direct incentive is no longer in place.

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3 Regulatory framework for fostering flexibility deployment: roles, responsibility of new agents

This section describes the Task 1.1 activity on the characterization of the role and responsibilities of the two key emerging actors (i.e., energy communities and aggregators) and the two key enablers to foster the flexibility deployment (i.e., baselining and submetering).

3.1 Energy Communities

Energy communities are emerging as a transformative force in the landscape of energy policy, heralding a new era of decarbonization and decentralization of power systems, with a distinctive emphasis on the consumers driving forward sustainable energy transitions. Community-based energy production and consumption are gaining prominence in policy frameworks at both European and global levels. The European Union's Clean Energy for All Europeans package exemplifies this shift, positioning energy communities as key drivers in achieving energy and climate objectives [40]. Similarly, the United Nations' Sustainable Development Goals underscore the importance of localized, community-driven approaches in transitioning towards sustainable energy systems, aligning with broader environmental and socio-economic sustainability targets [41]. These policy directives reflect a growing recognition of the role of energy communities in fostering a more resilient, inclusive, and sustainable energy landscape.

Multiple reasons why citizens are keen to participate in energy communities, as identified by A. Hackbarth, and S. Löbbe through a literature review of 36 empirical studies carried out in Europe, the United States of America, and Australia [42], [43]: economic benefits, autonomy, self-sufficiency or energy autarky, environmental benefits, community spirit, regionality, convenience, and simplicity of participation.

The term "energy community" lacks a unified legal definition, leading to varied interpretations. Some authors, like G. Walker and P. Devine-Wright, view it as a locally initiated project with collective community benefits [44]. In contrast, D. Biggar and M.R. Hesamzadeh describe it as a group of electricity customers, both producers and consumers, who can redistribute their metered energy for billing purposes and manage internal financial transfers [45].

While the EU has legal frameworks potentially applicable to energy communities, it lacks a clear definition and service specification for them. This section analyses EU regulations on energy communities, examining their roles and responsibilities in the electricity sector. It covers the European political agenda's support for these communities, their integration into EU legislation, and the key aspects at the European level. The analysis also explores the implementation across Member States, addressing challenges and diverse national approaches. Additionally, it presents a classification of key concepts defining energy communities, based on a thorough review of relevant literature, to establish a unified understanding of their characteristics.

This section is designed to aid policymakers, researchers, and practitioners in understanding and advancing energy communities. By establishing a classification system for key concepts, it seeks to clarify their benefits and challenges, serving as a crucial tool for future research and policy development in this area.

3.1.1 European Union's regulatory framework for energy communities

This section examines the European regulatory framework for the five existing legal figures under European legislation, potentially classified as energy communities. Through a comparative analysis of the regulatory frameworks associated

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with these legal figures, conclusions are drawn, shedding light on similarities and differences in the approaches adopted by various countries. Key trends and issues arising from this analysis are also identified.

The procedure to analyse the European Union's concept of energy communities consists of three main steps.

1. **Analysis of the European strategy on energy communities:** the European strategy regarding energy communities is analysed through the different policies published by the European Commission to understand the objectives, goals, and initiatives of the European Union (EU) in promoting the development of energy communities.
2. **Analysis of the European regulation:** the European regulation is analysed to find the legal figures that may be considered as energy communities and extract the characteristics of those.
3. **Comparison among the different figures**: using the characteristics of energy communities extracted from the European legislation, a comparison between them is made. This helps to identify the similarities and differences among the different legal figures that can be considered as energy communities.

3.1.1.1 Analysis of the existing legal figures for energy communities in the EU regulation

Over the past decade, the European Union has embraced a series of policies aimed at transitioning the energy paradigm towards a more localized, renewable, and citizen-centric approach. These policies have been implemented though three packages: Clean Energy for all Europeans [46], European Green Deal [47], and Fit for 55 [48]. All of those political packages have been the basis for creating the legal figure of energy communities and developing all the relevant regulatory framework in Member States (MSs).

In the legislation of the European Union, there are, currently, five legal figures that could be considered energy communities: the jointly acting renewable self-consumers (JARSC), the renewable energy communities (REC), the jointly-acting renewable active consumers (JAAC), the citizen energy communities (CEC), and closed distribution networks (CDN). Table 3.1 resumes the legal acts that define the framework for those legal figures.

Table 3.1: Legal framework of the five figures that can be considered as energy communities in the European legislation.

Act	Jointly-acting renewable self-consumers (JARSC)	Renewable Energy Community (REC)	Jointly-acting active customer (JAAC)	Citizen Energy Community (CEC)	Closed distribution system
Regulation 2018/1999 [49]	-	Art. 2, and 20 Annexes I, and IX	-	-	-
Directive 2018/2001 [50]	Art. 2, and 21	Art. 2, 7, 15, 18, and 22	Art. 18	-	-
Directive 2019/944 [51]	-	-	Art. 2,15, 16, and 20	Art. 2, 6, 16, and 59	Art. 38

Each of the frameworks in Table 3.1 is defined independently and shares a certain number of characteristics with the others, but has also many differences.

The framework for Jointly-Acting Renewable Self-Consumers (JARSC) is mainly developed in articles 2, and 21 of Directive 2018/2001 [50] that defines the legal figure, and the latter its characteristics.

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The framework for Renewable Energy Community (REC) is mainly developed in articles 2, and 22 of Directive 2018/2001 [50]; the former defines REC, and, the latter, provides more characteristics of this legal figure. Other than those main articles, article 7 of the Directive 2018/2001 [50] specifies that the electricity produced by JARSC, and REC must be considered statistically, and, article 15, focuses on administrative procedures, regulations, and codes. Last, the Directive 2018/2001 [50] also specifies some obligations regarding the information, and training member states have to provide.

The framework for the Jointly-Acting Active Customers (JAAC) is mainly developed in Directive 2019/944 [51] following a similar structure to the renewable self-consumer defined in Directive 2018/2001 [50]. Nevertheless, as opposed to JARSC, this figure is only implicitly defined in article 2 of Directive 2019/944 [51]. Citizen Energy Community (CEC)

The framework for the Citizen Energy Community (CEC) has been developed mainly in Directive 2019/944 [51], which establishes common rules only for the electricity sector. The definition of the legal figure is presented in article 2 of Directive 2019/944 [51], and then, the article 16 expands the regulatory framework. Other than what has already been said, CEC are also cited in article 59 of the Directive [51], which indicates the duties, and power of the regulatory authorities.

The framework for Closed Distribution Networks (CDN), includes completely defined includen Article 38 of Directive 2019/944 [51].

In the ensuing discussion, an analysis is conducted on each of the regulatory frameworks. Drawing from the performed analysis, 30 common dimensions are identified, and this section utilizes them to provide a description of the frameworks. The enumerated dimensions include:

1. **Access to energy markets**: The ability of a legal figure to buy and sell energy products and services in energy markets.
2. **Activities**: Actions or operations that are performed by the legal figure, such as energy production, distribution, sale, sharing.
3. **Activities allowed for third parties**: Functions or activities that external parties may perform within the legal figure.
4. **Activities of the members**: Limits on the membership of the legal figure based on the activity performed by the participant.
5. **Cross-border participation**: The possibility for a legal figure to have participants and provide products or services in more than one country.
6. **Control**: Refers to the ability of a shareholder or member or a group of those to exercise a decisive influence over the strategic direction and management of the legal figure. Control can be achieved through ownership of a majority of the voting shares, or through special voting rights, board representation, or other contractual arrangements.
7. **Energy carrier**: Medium that may be used by the legal figure for any of its activities (energy storage, distribution, generation, sale…), such as natural gas, oil, electricity or heat.
8. **Geographical boundaries**: Geographical limits (distance, area…) for the members of the legal figure.
9. **Imbalances**: Differences or discrepancies between the supply and demand of energy within a particular market or system managed by the legal figure.
10. **Legal form**: The legal structure or type of organization that the legal figure takes (association, company…).
11. **Legal framework for the sale of energy**: Possible frameworks that, at least, the legal figure may use to sell the energy.

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12. **Member states must address**: Issues or challenges that member states must confront or deal with regarding the legal figure.
13. **Member states must assess**: Situations or issues that have to be evaluated or examined, by the member state, regarding the legal figure.
14. **Member states must develop**: Policies, regulations, aspects or programs that have to be evaluated or examined, by the member state, regarding the legal figure.
15. **Member states must ensure**: Aspects that have to be ensured by the member state, regarding the legal figure.
16. **Member states must provide**: Services, resources or information that have to be provided by the member state, regarding the legal figure.
17. **Members allowed**: Entities or individuals that are permitted to participate in the legal figure.
18. **National Energy and Climate Plans**: Whether the legal figure has to be somehow considered in the National Energy and Climate Plan of the country.
19. **Obligations as a DSO**: Responsibilities or duties that the legal figure has when acting as a DSO.
20. **Obligations**: General duties or responsibilities that must be fulfilled by the legal figure.
21. **Operation of the grid**: When acting as DSO, who operates the grid.
22. **Participation**: Whether the involvement or engagement in the legal figure is open and/or voluntary.
23. **Possible activities as a DSO**: Potential functions or services that, when acting as DSO, the legal figure may perform.
24. **Possible exemptions as a DSO**: Potential exemptions that, when acting as DSO, the legal figure may adopt.
25. **Possible members**: Kinds of entities or individuals who may join or participate in the legal figure.
26. **Purpose**: Reasons or objectives that may justify the creation of the legal figure.
27. **Regulatory authority**: Tasks (such as regulating and enforcing laws, rules, or standards) that the national regulatory authority must perform regarding a certain legal figure.
28. **Rights**: Legal entitlements or permissions that the legislation has to grant to that legal figure.
29. **Sharing of energy**: Exchange of energy between different entities or parties by or within the legal figure.
30. **Types of energy**: Whether the energy carriers managed (e.g. generated, sold, distributed…) by the legal figure are limited to renewable energy or any other type of energy.

Based on the analysis of frameworks in Table 3.1, Table 3.3 provides the comparison of the five different legal figures regarding the activities they can perform and applicable characteristics to each legal figure. To allow for this comparison, the symbols presented in Table 3.2 are used.

Table 3.2: List of symbols used in Table 3.3.

Symbol	Meaning
✕	Not allowed
◆	Only under certain circumstances
⁂	May be optionally considered by Member States

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Symbol	Meaning
✓	Allowed
	Not specified

For simplicity, the cross symbol (✕) is not reported in the cells in Table 3.3 unless it is specifically indicated by the regulation that a certain aspect should not be considered.

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Table 3.3: Comparison of the regulatory frameworks for the different legal figures that may be considered as energy communities in the regulation of the EU [49], [50], [51].

Dimension	Subdimension	Characteristic	Legal figures				
			JARSC	REC	JAAC	CEC	CDN
Motives	**Purpose**	Social		✓		✓	
		Environmental		✓		✓	
		Economic		✓		✓	
		Financial		✗		✗	
	Justification	For technical or safety reasons, the operations, or the production process of the users of the system is integrated					✓
		The energy is distributed to the owners or operators of the energy community and their related undertakings					✓
Membership	**Participation**	Open		✓		✓	
		Voluntary	✓	✓	✓	✓	
	Rights of the members	Right to leave		✓		✓	
		Maintain the same rights, and obligations as customers	✓	✓	✓	✓	
	Low-income members	Are explicitly considered		✓		✓	
	Geographic boundaries	Geographic boundaries do exist	✓	✓	✓		✓
		Cross-border participation is allowed		⁂		⁂	
	Possible types of members	Must be final consumers	✓	✓	✓		
		Households / physical persons	✓	✓	✓	✓	♦
		Microenterprises	♦	♦	♦	♦	✓
		Small enterprises	♦	♦	♦	♦	✓
		Medium enterprises	♦	♦	♦		✓
		Big enterprises	♦		♦		✓

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Dimension	Subdimension	Characteristic	Legal figures				
			JARSC	REC	JAAC	CEC	CDN
		Local authorities / Municipalities	✓	✓	✓	✓	
		Regional authorities	✓		✓		
		National authorities	✓		✓		
		Must be final consumers	✓	✓	✓		
Legal structure	**Control**	Autonomous		✓		✓	
	Legal-form	Agreement between the members of the community	✓		✓		
		Legal person		✓		✓	✓
Tecno-economic	**Possible activities**	Generation/production of energy	✓	✓		✓	
		Distribution of energy		✓		✓	✓
		Sale of energy	✓	✓	✓	✓	
		Supply of energy (retailer)		✓		✓	
		Consumption of energy	✓	✓	✓	✓	
		Aggregation of energy		✓		✓	
		Storage of energy	✓	✓	✓	✓	⁂
		Sharing among the members	✓			✓	
		Participate in flexibility schemes			✓		
		Participate in energy efficiency schemes			✓		
		Provision of energy efficiency services				✓	
		Provision of charging services for electric vehicles				✓	⁂
		Other services				✓	
	Types of energy	Only renewable energy	✓	✓	✓		

Dimension	Subdimension	Characteristic	Legal figures				
			JARSC	REC	JAAC	CEC	CDN
		Only electricity	✓		✓	✓	✓
	Framework for the sale of energy	Renewable Power Purchase Agreement (PPA)	✓	✓	✓		
		Peer-to-peer (P2P) agreement	✓				
		Contract with electricity suppliers	✓		✓		
		Aggregated access to energy markets		✓		✓	
		Individual access to energy markets		✓		✓	
	Regarding the installation, third parties may perform	Management	✓		✓		
		Installation	✓		✓		
		Maintenance	✓		✓		
		Management of data	✓		✓		
	Property of the distribution network	Own distribution networks				⁂	✓
		Stablish distribution networks				⁂	✓
		Purchase distribution networks				⁂	
		Lease distribution networks				⁂	
	Management of the distribution network	Autonomously manage the distribution network				⁂	✓
		May delegate their balancing responsibility				✓	
		May celebrate an agreement to the DSO/TSO about the management of the grid				✓	
	Exemptions as a DSO	May not have to procure the energy for losses or ancillary services transparently, without discrimination, and in a market				⁂	⁂
		May not have to approve the tariffs				⁂	⁂
		May not have to procure flexibility services				⁂	⁂
		May not have to develop the system in accordance to a development plan				⁂	⁂

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Dimension	Subdimension	Characteristic	Legal figures				
			JARSC	REC	JAAC	CEC	CDN
		May own, and operate storage facilities				⁂	⁂
		May own, and operate charging points for electric vehicles				⁂	⁂
Enabling framework	**DSO**	Must cooperate for the transfer of energy		✓		✓	
	Legal rights	Non-excessive or discriminatory technical requirements			✓	✓	
		Non-excessive or discriminatory administrative requirements	✓	✓	✓	✓	
		Non-excessive or discriminatory procedures	✓	✓	✓	✓	
		Non-justified cost for the administrative procedures	✓		✓	✓	
	Compulsory assessment of member states	Existing unjustified barriers	✓	✓			
		Potential of territory	✓	✓			
		Potential of the energy networks	✓	✓			
	NECP	Assessment of the implementation of policies, and measures	✓	✓			
	Storage	No double charges	✓		✓		
	Support	Tools to facilitate access to finance, and information		✓			
		Capacity-building support		✓			

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3.1.1.2 Gaps and challenges on the European regulatory framework for energy communities

This section presents the gaps and challenges identified from the analysis of the European regulation relevant for energy communities.

Need for clarification of definitions

Both Directive 2019/944 [51], and Directive 2018/2001 [50] use a set of terms that do not seem to be defined either in the directives themselves or in any of the European legislation. Some of those are the following:

- **Open**: this term might be defined as "*not restricted to a particular group or category of participants*" [52]. Objective definitions may include criteria such as the time required to become a participant, specific calls open to new participants, or capital and additional requirements.
- **Autonomous**: the term might be defined as *"undertaken or carried on without outside control"* [52]. However, considerations may arise regarding whether there should be a specific limit on the percentage of shares each member can hold. Some national TSOs in Europe already implement such limits [9] [53].

Compliance with the purposes defined in the Directives

Despite the need for clarification of certain terms, it is essential to specify how these terms are utilized. A significant challenge arising from this is determining the metric for assessing compliance with the various purposes outlined in the Directives (environmental, social, and economic).

Heterogeneity of organization types

As in Table 3.3, there is nothing but subtle differences among, on one side, the renewable energy communities, and the citizen energy communities, and, on the other side, the jointly-acting self-consumers, and the jointly-acting active customers.

- **Renewable Energy Communities, and Citizen Energy Communities**: the most evident difference is that the REC may use any type of energy as long as it is renewable, but CEC, as is mentioned in the directive for the electricity market (Directive 2019/944) [51], and it is not limited to renewable energy. Moreover, CECs do not have a proximity limit, and CEC might provide some services such as EV charging activities, and energy efficiency services.
- **Jointly-acting renewable self-consumers, and jointly-acting active customers**: both of them are thought as agreements between the members, and have most of the same characteristics, such as that they may only use renewable energy, only electricity.

Therefore, to simplify the legislative burden, we could try to fuse some of those legal figures, and leave just three of them, as shown in Table 3.4.

Table 3.4. Clustering of legal figures for energy communities as defined in the EU regulation

Definitions	Directive 2018/2001 [50]	Directive 2019/944 [51]
Definition A	Jointly-acting self-consumer	Jointly acting active customer (implicit definition)

[9] In Spain, no physical or legal person may own more than 5% of the capital of the TSO, and may not control more than 3% of the voting rights.

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Definitions	Directive 2018/2001 [50]	Directive 2019/944 [51]
Definition B	Renewable energy community	Citizen Energy Community
Definition C	-	Closed distribution network

Another possible option would be to use the freedom granted in art. 288 of the Treaty on the Functioning of the European Union to try to provide coherent definitions of both legal figures in each of the European countries [54]. Nevertheless, the European legislation still needs to include legal figures that cover non-electric renewable energy communities.

The notion of distance should be further defined

Some of the legal figures have a concept of boundary in their definition:

- **Jointly-acting renewable self-consumers**: art. 2 of Directive 2018/2001 specifies "*who are located in the same building or multi-apartment block*" [50].
- **Renewable Energy Community**: art. 2 of directive 2018/2001 indicates that it is "*controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned, and developed by that legal entity*" [50].
- **Jointly-acting active customers**: art. 2 of Directive 2019/944, defines it as a group of active customers "*who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises*" [51].
- **Closed Distribution Networks**: art. 38 of Directive 2019/944, indicates that it must be located "*within a geographically confined industrial, commercial or shared services site*" [51].

Nevertheless, two problems are identified considering the notion of distance:

- For the REC, the Directive 2018/2001 [50] only states that the communities should be near the renewable energy project. Setting aside the definition of the distance to be considered, one can easily envision a scenario where the renewable energy community spans multiple locations, covering a broader area than initially anticipated.
- For the CEC, the notion of distance exists, so, if not restricted, it could evolve into a medium or large company, covering the entire country or even multiple countries.

Therefore, some solutions can be proposed to solve this problem:

- **Geographic based**: set either a maximum distance among the consumers, a maximum spanning area, or an administrative division.
- **Grid based**: limit the extension of the community to a certain voltage level or based on the structure of the grid (in the same MV/LV transformer, for example).

The geographic-based option is easier to understand for the general population and is easier to apply for promoters. Nevertheless, it might generate a problem in some locations that have been administratively divided even if they form a natural town, and, in some situations, where the electrical grid might not be prepared or not electrically connected. As opposed to the geographic-based one, the grid-based option may already consider the capabilities of the grid but be less evident for the population or the participants of the energy grid. As a consequence, the notion of distance should be further developed.

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The type of legal person part of the energy community

Each country has a different legal framework, so it is tricky to define which type of legal entity should be an energy community in each MS at the European level. Nevertheless, it is interesting to note that for neither REC nor CEC, the primary purpose should be the provision of financial benefits. Therefore, it can be inferred that:

- **Non-for-profit associations and cooperatives** should be allowed to be energy communities, as their intention is not lucrative, and they are more focused on providing social, economic, or other kinds of benefits to their members.
- **Limited companies**, which are thought to provide a benefit for the shareholder, should generally not be allowed to become energy communities, unless there is a certain mechanism that specifies how the profits should be distributed among the members to comply with the rule that says that CEC and REC cannot have a financial intention.

As a consequence, this aspect should be considered in the national legislation, once the directives are transposed, to take into consideration the particularities of each legal framework.

REC regulation of the distribution role

When the possible activities of the REC are specified in Art. 22 of directive 2018/2001 [50], the article does not indicate that REC may distribute energy. Nevertheless, further on, Art. 22.4.e [50] specifies that these entities should not be discriminated when acting as distribution system operators, this is, when distributing energy:

> *"include renewable energy communities are not subject to discriminatory treatment with regard to their activities, rights, and obligations as final customers, producers, suppliers, distribution system operators, or as other market participants;" ~ Article 22.e, Directive 2018/2001*

Therefore, it can be inferred that RECs do have the right to become distributors, even if this activity is not indicated as one of the possible activities and is not regulated nowhere else in the article art. 22 [50].

This situation contrasts with the regulation of the distribution activity for the CEC, which is included among the possible activities that the energy community might perform, and even has a specific section to regulate this activity, art. 16.4 of Directive 2019/944 [51].

Therefore, it can be considered that Directive 2018/2001 [50] should be adapted to regulate adequately the activity for distribution. First, this Directive should include distribution of energy among the possible activities of the REC. Second as these entities may use all kinds of renewable energy (hydrogen, biogas, biomass…), to avoid duplicates, it would be better if the Directive referred to the Directives that regulate each of those energies.

As a single entity, energy communities may cover the roles typically assigned to different actors

Two of the types of energy communities might become DSO. Nevertheless, article 35 of Directive 2019/944 [51] defines the unbundling of DSO, which must be independent in terms of the legal form, organization, and decision-making from other activities. However, member states might exempt distributors with less than 100 000 clients from complying with this rule.

This generates a contradiction because Directive 2019/944 [51] and Regulation 2019/943 [55] unbundle the power system for the big power companies but does not establish a limit for energy communities, which might perform all activities without any limit on their size.

Consequently, we consider that the energy markets' directives should include limits concerning the roles that the energy communities may cover to avoid distortions. Furthermore, currently, European regulation does not include such a limit nor specifies that such a limit should be implemented at the national level.

Regulation of cross-border energy communities

Directive 2019/944 [51], and Directive 2018/2001 [50] allow member states for cross-border CEC, and REC, respectively. Nevertheless, the definition provided by those directives does not specify how those cross-border energy communities should be established.

Cross-border situations involving Community Energy Cooperatives (CEC) and Renewable Energy Communities (REC) may arise in various scenarios due to the complex nature of European borders. For instance, consider the case of Llivia, which is part of Spain but is entirely surrounded by French territory. Similar circumstances exist in Baarle Nassau, where it is one of the 22 Belgian cities that serve as enclaves within Dutch territory, and conversely, there are 8 Dutch enclaves within Belgian territory.

Given this, it might be interesting to set a common framework for this type of energy communities, rather than letting each member state to set its own framework. One possible option would be to consider Article 7 of Directive 2011/92/CE [56] as a reference and define a framework that either sets the common ground for these entities or set the rules of which state have to be prioritized, and which state has to authorize it.

Cross-subsidies in electricity tariffs

The peak power from a group of consumers is subadditive[10], as the addition of the peak power of multiple users is higher that the real peak power of the set of those users [11]. Moreover, grid charges are usually based on the contracted power of the users, which depends on the peak instantaneous consumption. As a result, if the users of an energy community aggregate a number of contracts into a single one, they will pay less charges for grid use. This is good for the users of the energy community, but as the cost for the power system might not be reduced, this behaviour shifts the cost to the other users. Figure 3.1 shows the difference between the real number of households and what has to be considered when aggregating them to design the installation for Spain.

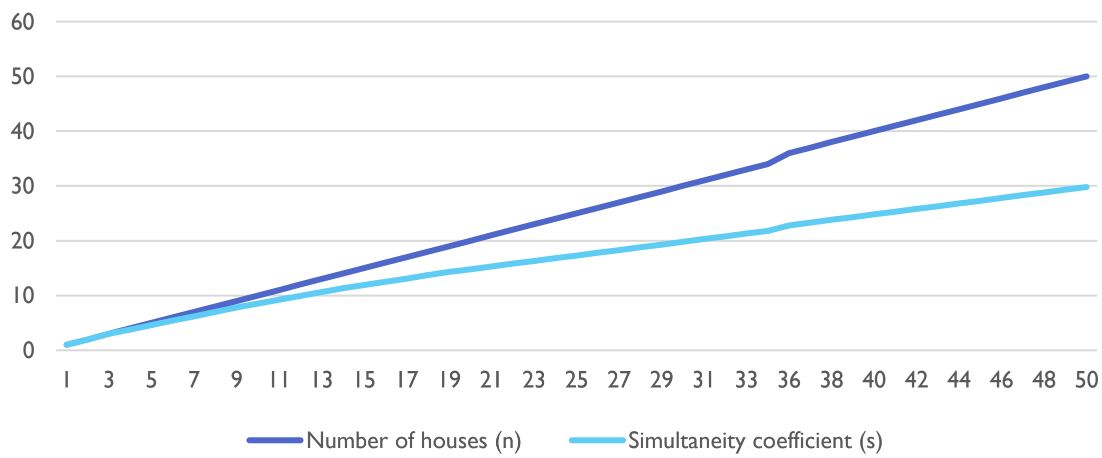

Figure 3.1: Simultaneity coefficient of the power for a set of houses, as specified in the Spanish electrical technical instructions from zero to fifty [57].

[10] In this context, the subadditivity means that the peak power of multiple consumers is less or equal to the peak powers of each of the consumers added.

[11] As an example of this, if we sum all power contracted by consumers in Spain, we obtained 174 273 MW in 2022 [57], but the peak instantaneous electricity consumption in Spain has never been more than 45 450 MW reached in 2007 [58], [59], [60], [61], [62], [63], [64].

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Therefore, the setup of the grid charges should be carefully done to reduce this type of behaviour.

3.1.2 Regulatory frameworks for energy communities at the national level

The purpose of this section is to analyse the national legal frameworks of several target countries, including France, Italy, Portugal, Spain, and Sweden, to understand the regulatory landscape for energy communities in each country.

To accomplish this task, the methodology for conducting the analysis will be defined initially, involving a comprehensive review of relevant legal and regulatory documents. Subsequently, the results of the survey for each of the target countries will be presented, comparing and contrasting the legal frameworks in each case. Finally, conclusions will be drawn based on the analysis, highlighting similarities and differences between the regulatory approaches of the different countries and identifying any key trends or issues that emerge from the analysis.

3.1.2.1 Methodology for the analysis of the national regulatory framework for energy communities

After the accomplishment of the revision and analysis of the European regulation, a regulatory survey was submitted to gather information on the regulatory framework of each of the countries. The regulatory survey, which may be seen in detail in section 3.1.2, covered multiple aspects:

1. **General overview**: a general understanding of how energy communities are managed in the country, and whether there is a legal framework for these entities.
2. **Enabling framework**: measures adopted to encourage energy communities in the country.
3. **Purposes**: which, and how different criteria are considered in the national regulation regarding the goals of energy communities.
4. **Legal entity**: type of legal form an energy communities might adopt, such as: cooperatives, associations, general partnerships, etc.
5. **Participation**: characteristics of the entity allowed to engage in.
6. **Membership**: different conditions that indicate what members of the community might be a part of it, such as distance, power, etc.
7. **Techno-economic** (general section): different services that might be provided by energy communities, considering both the economic, and the technical aspect, and how they are remunerated.
8. **Techno-economic** (electrical section): different techno-economic aspects of energy communities, which are specific for the electrical sector.
9. **Miscellaneous**: salient aspects not covered in any of the other sections of the document but that the respondents might have considered as important.

The survey was sent on February 16th, 2023, to different partners of the project to gather information about the focus countries of the project: France, Italy, Portugal, Spain, and Sweden. The surveys' responses were analysed, and completed as needed based on the references given in the surveys' response. The results of that analysis are presented in the section 3.1.2.2.

3.1.2.2 Analysis of the national regulatory survey on energy communities

This section presents the results of the national regulatory survey on energy communities. They are summarized according to structure of the survey and trying to compare the different aspects in the five countries. Nevertheless, not much information was available about the Swedish regulation, as most of it has not already been transposed.

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General overview of the energy communities' deployment in the target countries

Table 3.5 reports the total, and per capita number of energy communities (legal persons) for the analysed target countries.

Table 3.5: Total, and per capita number of energy communities (legal persons) by country analysed.

	France	Italy	Portugal	Spain	Sweden
Number of energy communities[12] [65]	343	198	11	235	329
Inhabitants (in millions) [66]	67.9	59.0	10.3	47.4	10.4
EC per million inhabitants	5.1	3.4	1.1	5.0	31.6

Some countries, such as Sweden, have more than 30 ECs per million inhabitants, while others, such as Portugal, have almost one energy communities per million inhabitants.

As can be seen in Table 3.6, all the articles related to energy communities in Directive 2019/944 [51], and Directive 2018/2001 [50] should already have been transposed to the national legislation by December 31st, 2020 and June 30th, 2021 respectively.

Table 3.6. Final date for the transposition of the articles regarding REC, JARSC, CEC, and JAAC.

Directive	Publishing date	Transposition limit for the articles related to energy communities
Directive 2018/2001	December 21st, 2018	June 30th, 2021 [50]
Directive 2019/944	June 14th, 2019	December 31st, 2020 [51]

The French government is adapting European laws into national legislation, with many already in the French Energy Code. However, some definitions, like that of an "active customer," are still missing.

Italy was one of the first countries to enact a full framework for REC. In fact, not long after Directive 2018/2001 was approved, the country enacted Decree-law 162/2019, which already allowed the creation of RECs, even if they had important restrictions [67] . After that first Decree-law, the country approved Decree-law 199/2022, and Decree-law 210/2022, which include or regulate the definition, and regulation of the five legal figures, and opens them [68], [69].

In Portugal, the enaction of Decree-Law 162/2019, of October 25th, encouraged distributed production, and self-consumption of energy from renewable sources. This framework allows collective self-consumption, and the formation of REC [70]. Some years later, the Government approved another Decree-Law 15/2022, which clarifies certain aspects, and includes the definitions, and rules of CEC, REC, and CDN [71]. However, as for France, it does not include some definitions, such as the definition of "active client" [71].

[12] The data source does not include all the organizations considered as energy communities in this document.

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Spain has only transposed and included the definition of REC in the Law for the Electrical Sector[13] through the Royal Decree-Law 23/2020[14] [72]. The definition is exactly the one provided in Article 2 of Directive 2018/2001 [72], and no other clarification or modification has been provided. Therefore, the Government has still to include other legal figures. As an exception, the region of Navarra, which has a special status, has included the definition of CEC in Law 4/2022, of March 22nd, of Climate Change, and Energy Transition[15] [73]. In the autonomous region of Navarra, a CEC is defined as a legal entity that focuses on producing electricity on a small scale, with open, and voluntary participation, located near the renewable energy project [73]. It can integrate physical, and legal persons, both public, and private, but cannot participate in the Iberian power pool [73]. The CEC is effectively controlled by its members and aims to provide environmental, economic, and social benefits to the community where it operates, rather than financial benefits. It can generate, distribute, consume, aggregate, and store energy, and provide energy efficiency services, electric-vehicle charging services, and other services to the community members [73].

As reported in Table 3.7, the transposition process is not homogenous among the analysed target countries.

[13] Ley 24/2013, de 26 de diciembre, del Sector Eléctrico.
[14] Real Decreto-ley 23/2020, de 23 de junio, por el que se aprueban medidas en materia de energía y en otros ámbitos para la reactivación económica.
[15] Ley 4/2022, de 22 de marzo, de Cambio Climático y Transición Energética.

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Table 3.7: Transposition status of the different legal figures for energy communities defined in the European legislation.

Exception	France	Italy	Portugal	Spain
REC (Directive 2018/2001) [50]	Yes [74]	Yes [68]	Yes [70]	Yes [72]
JARSC (Directive 2018/2001) [50]	No [16]	No [17]	No [18]	No [19]
CEC (Directive 2019/944) [51]	Yes [74]	Yes [69]	Yes [70]	No [20]
JAAC (Directive 2019/944) [51]	No	Yes [69]	No	No
CDN (Directive 2019/944) [51]	Yes [75], [76]	Yes [69]	Yes [70]	No

Other than the figures defined in the European legislation, some other countries had already created the figure of *collective self-consumption* (CSC) before neither Directive 2018/2001 nor Directive 2019/944 were enacted. This figure is quite similar to the JARSC.

In France, for example, the Energy Code[21] defines CSC as a set of one or multiple producers, and one or multiple final consumers linked inside the same legal person[22] [74]. It also classifies it into two types, depending on where the self-consumers are located [74]: simple (inside the same building), and extended (the producers and consumers must be connected to the low-voltage grid, and respect the criteria fixed by the government).

Furthermore, since 2019, some kinds of companies, established to carry out a biogas production project, could offer a portion of their capital to individuals, particularly residents living in the vicinity of the project site, as well as to territorial collectivities and their groups located on or near the project site, during the incorporation or capital increase process [77]. Those societies might also offer these same individuals the opportunity to participate in financing the biogas production project [77]. This article was abrogated in 2022 and widen to any renewable energy project [78].

In Spain, CSC was first mentioned in the Spanish Electrical Law in 2018 through Article 18, two months before Directive 2018/2001 was published [79]. Currently, there are three ways of organizing the self-consumption in Spain [80]: without surplus but with compensation (the installations under this regime have a system that impedes feeding surplus energy into the public grid), with the surplus, and with compensation (only allowed for installations that have less than 100 kW that are connected through an internal network, this regime allows compensating the energy feed into the grid with a reduction in the monthly cost of energy), and with surplus but without compensation (they are not compensated but paid for the electricity they feed into the grid). In the CSC with surplus but without compensation, producers, and consumers must be connected through the internal grid of a building or through the public distributor grid [80] . For the

[16] Collective self-consumption exists since 2016.
[17] Collective self-consumption is included in Decreto-legislativo 8 novembre 2021, n. 199
[18] Collective self-consumption has been defined in the Decreto-Lei n.º 162/2019, de 25 de outubro.
[19] Collective self-consumption exists since 2018.
[20] Only transposed in the autonomous region of Navarre.
[21] *Code de l'Énergie*.
[22] *Personne morale*.

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latter, either the distance in the orthogonal projection in a plane cannot be higher than 500 m (or 2 000 m for PV installations on rooftops, industrial areas, or other infrastructures) or the participants must have the same property code [80]. Other than this, there is a law[23] in the Balearic Islands that aims to incentivize local participation in renewable energy projects [81]. Projects will be considered as having local participation if at least 20% of the project's ownership is offered to individuals or entities located in the municipality where the project is located or neighbouring municipalities (if the project is led by a company, 20% ownership will be defined as 20% of the company) [81]. Moreover, if the project is located on the ground and has a capacity of 5 MW or more, local participation is mandatory [81]. Other than that, the Balearic Government has to create a land bank for renewable energy projects [81].

Finally, Portugal has also included this figure of CSC in both Decree-law 162/2019 [70], and Decree-law 15/2022 [71].

As exposed by CEER, regulatory sandboxes, and regulatory experimentation stand as one the tools used by regulators for dynamic regulation without compromising the efficacy of other regulatory tools [82].

In France, regulatory sandboxes[24] have been created in 2019 [77], and regulated by the French Regulatory Authority (CRE) a year later, in 2020 [83]. In those sandboxes, the Regulator allows derogating some dispositions regarding the transport, distribution, access, and connection to the grid, and some specific ones for electricity [83]. The Regulator is in charge of calling for applications to use this mechanism [83].

Following the creation of these sandboxes, 41 projects were presented to the first call, some of which were focused on energy communities [84]. However, only 20 projects were eligible, none of which was focused on energy communities [84].

Regulatory sandboxes for electricity are not currently regulated in Italy. Nevertheless, a partial, anticipated transposition of Directive 2018/2001, allowed for experimentation with some of those EC, as small ones could already be created before the full transposition of the Directive was carried out [67]. Those energy communities should have less than 200 kW from renewable energy which started producing energy after May 1st, 2020, connected to a low voltage grid depending on the same transformer, and use the existing electrical grid to share the energy [67]. For collective self-consumption, the producers, and consumers should be located in the same building [67] Finally, if the energy was shared or taken from the existing grid, the current tariffs should apply [67]

In Italy, virtual RECs had a certain number of limitations such as [67] having to be under the same secondary substation, new generation facilities being limited to 200 kW, and there were explicit incentives on the shared energy, which could be shared through the public grid

In Portugal, the Government has created the concept of *free technological zones*[25] to ease the research, and testing, in real, technologies, products, services, procedures, innovative models, concepts, business models, and specific regulatory models in multiple activities related to the energy sector as electricity production, storage, and self-consumption, and electric mobility [71]. Any pilot project might be tested in those zones but, regardless of these zones being created specifically to test new concepts, energy communities have to be licensed as if they were anywhere else [71]. Last, none of these *free technological zones* defined by the Portuguese regulation focuses specifically on energy communities [71]. Nonetheless, the regulatory authority has approved the four pilot projects that may be seen in Table 3.8 which may somehow concern aspects related to energy communities.

[23] *Ley 10/2019, de 22 de febrero, de cambio climático y transición energética*
[24] *Bacs à sable règlementaires*.
[25] Zonas Livres Tecnológicas

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Table 3.8: Pilot projects in Portugal approved by the regulatory authority [85].

Promoter	Name of the project	Description
Agência de Energia do Porto	Comunidade de Energia Renovável – Agra do Amial	Dynamic part of self-consumption production, development of management and optimization platforms, aimed at combating energy poverty.
Capwatt Services, S.A.	Sonae Campus, Maia	Dynamic part of self-consumption production and storage management.
EDP New	POCITYF, Évora	Dynamic sharing of production for self-consumption and energy exchanges between peers.
Cooperativa para a Sustentabilitdade a Ilha Culatra	CER na Ilha da Culatra	Dynamic part of self-consumption production, development of an optimized energy management system that considers the prevention of local network congestion.

In Spain, the Government has recently published a Decree allowing regulatory sandboxes [86]. Furthermore, it has published an Order that regulates the subsidies for the testing of new business models in the regulatory sandboxes [87]. Nevertheless, no regulatory sandbox focused on energy communities seems to exist in Spain.

Finally, in Sweden, there are some pilot projects for energy communities, for example, the Örebro project. Nevertheless, with the current legal framework, it is not clear whether or not it is a sandbox for energy communities.

To summarize, the current status of the regulatory sandboxes may be seen in Table 3.9.

Table 3.9: Status of the regulatory sandboxes by country.

Exception	France	Italy	Portugal	Spain	Sweden
Sandboxes are regulated	Yes	No	Yes	Yes	No
Sandboxes focused on energy communities	No	No	No	No	Yes

Purposes

European directives specify that REC and CEC should have social, environmental, and/or economic purposes, rather than financial ones [50], [51]. Nevertheless, they do not specify how these purposes have to be taken into account in the national legislation nor how their 62greements has to be measured [50], [51].

That said, at present, French law does not impose any restrictions or obligations to prove the purposes of EC. However, the French Government has been developing a decree that will regulate the functioning of these communities, and impose limitations on the types of legal entities they can adopt [88], [89]. Based on the available information from the French regulatory body (CRE), and the National Council for the Evaluation of Norms, the forthcoming decree will require REC, and CEC to include specific provisions in their bylaws stating that their primary objective is to generate environmental, social, or economic benefits for either their shareholders or their community members [88], [89].

In Italy, the bylaws of the foundational act of the CECs must identify the main purpose of pursuing environmental, economic, or social benefits for its members, the community or the territory where it operates, and that financial profits cannot be its primary goal [69]. The REC decree [90] defines that the primary goal of a REC is to provide environmental,

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economic, and social benefits to its members or shareholders and the local areas in which it operates, through the self-consumption of renewable energy.

Neither Portugal nor Spain seem to have gone further in specifying the criteria to measure the accomplishment of those goals. Nevertheless, a new draft regulation in Spain defines that the CEC or REC must primarily be directed towards reducing the energy cost of its participants, developing actions related to its corporative purpose, or making environmentally friendly investments [91].

Table 3.10 compares the situation of France, Italy, Portugal, and Spain regarding whether the bylaws of the energy communities must include some of the purposes defined in the directives.

Table 3.10: Comparison on whether the bylaws of the energy communities must include the purposes of the energy community and the percentage of profits that must be invested in the purposes of the community.

Exception		France [26]	Italy [68], [69]	Portugal	Spain [72] [27]
CEC	Bylaws must include the purposes	No	Yes	No	Not defined
	Minimum percentage of profits has been used for the purposes	No	No	No	Not defined
REC	Bylaws must include the purposes	No	No	No	No
	Minimum percentage of profits has been used for the purposes	No	No	No	No

Legal entity

Member states have different legal frameworks and, within those, they define and characterize differently the kinds of existing legal persons in those. Even if the European legislation does not define them, both Directive 2018/2001 and Directive 2019/944 specify that REC and CEC should be legal entities, but their articles, do not limit the legal entities to certain kinds [50], [51]. Nevertheless, as Vega Labella highlights, the introduction of Directive 2019/944 does indicate that member states should be allowed to assign CEC to any kind of legal entity, such as associations, co-operatives, small or medium enterprises, and non-profit organizations, as far as it may have both exercise rights, and have obligations [50], [93].

Currently, French legislation limits the types of legal forms that REC and CEC should have. The energy code indicates that both a CEC and a REC should be: limited partnerships, simplified limited partnerships, cooperatives, or associations [74].

In Portugal and Italy, the national legislation does not specify any limits to the kinds of legal forms for an EC, only saying that it must be a legal entity, as specified in the national regulation [67], [71].

[26] A legislative proposal specifies that they must include those benefits.
[27] The new draft regulation does specify that CEC and REC must invest most of their benefits on their purposes and must specify their purposes in the bylaws [92].

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The Spanish legislation, like both the Portuguese and the Italian ones, does not specify what kind of legal form energy communities should have. Given this absence of regulation, the kinds of entities that have received the subsidies for the creation of energy communities range between private limited companies, co-operatives, and associations [92]. Moreover, Vega Labella considers that, based on what has been indicated in the introduction of Directive 2019/944, energy communities should be allowed to be associations, private limited companies, co-operatives, and general partnerships [93].

On April 21st, 2023, the Spanish Government opened a public hearing period for a new decree for CEC and REC [94]. The draft specifies that Ecs should be allowed to be any kind of legal person as long as they respect the other conditions specified in the decree, such as [91]: the corporate purpose must be in line with the definition of CEC and REC, its access must be open and voluntary, autonomous (no partner or member may have more than a 51% of the votes or have the power to control more than a 51% of the council), must have a minimum of 5 partners or members, and must use most of their profits to reduce energy costs to its members, develop social actions related with its corporative purpose, invest in the increase of the environmental quality of the municipalities and develop socially the municipalities where they are.

As we may see in Table 3.11, the type of legal entities that are allowed to be either REC or CEC differs between the different countries.

Table 3.11: Types of legal entities allowed to be either REC or CEC.

Country	REC	CEC
France [74]	Limited partnership, simplified limited partnership, cooperative or association	Limited partnership, simplified limited partnership, cooperative or association
Italy	Not limited	Not limited
Portugal	Not limited	Not limited
Spain	Not limited	Not limited

Participation

The shareholders or members of both RECs, and CECs in France may include individuals, small, and medium-sized enterprises, provided they are autonomous, territorial communities or their groupings, joint-stock companies participated by local government, and small, and medium-sized enterprises or associations whose purpose is the development of renewable energies, benefiting from the label “solidarity enterprise of social utility” [95]. The associations authorized to participate in a renewable energy community are those whose members are individuals, small, and medium-sized enterprises, territorial communities or their groupings, or joint-stock companies participated by municipalities.

The label “solidarity enterprise of social utility” is an accreditation for social, and solidarity economy enterprises that pursue social utility as their main objective, directed towards vulnerable populations or territories or aimed at preserving and restoring social, and territorial cohesion, education for citizenship, sustainable, and solidarity-based development, or international solidarity [96]. To be eligible, companies must demonstrate that their pursuit of social utility has an impact on their financial results, and must have a fair remuneration policy that respects certain conditions. Specifically, the average amount paid to the five highest-paid employees or executives, including bonuses, must not exceed an annual ceiling set at seven times the minimum wage, and the remuneration paid to the highest-paid employee must not exceed an annual ceiling set at ten times the minimum wage. Finally, companies must keep their capital shares out of financial markets, allowing them to prioritize their social goals, and invest in their communities.

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In Italy, participation in REC is limited to small, and medium enterprises, local authorities (including municipalities), research, and training entities, religious entities, third sector, and environmental protection associations [67], [90]. Participation in an REC can be in the capacity of: a renewable energy producer, a self-consumer of renewable energy, an electricity consumer. Participation in CEC seems not to be limited, as no entity is indicated in the regulating norm [69].

In Portugal, they have transposed the European legislation both for REC, and CEC without many changes. In fact, members or shareholders may be either physical or legal persons, the latter might be both public, and private, including, in particular, SMEs, and municipalities [71].

In Spain, only the definition of the REC has been transposed, and uses the same expression as in the European Directive 2018/2001, allowing only physical persons, local authorities, and small, and medium enterprises [72]. The new draft published by the Spanish Government offers some clarification on the kind of authors allowed to participate in REC and CEC and states that no partner or member may have more than a 51% of the votes or have the power to control more than a 51% of the council [91]. For REC, other than the participants indicated beforehand, the draft also includes associations of SMEs, local entities, and physical persons as long as they respect the same limits as if they were directly a partner of the REC. For CEC, the sum of the participation of legal persons cannot be more than 51% of the votes or the capacity to elect more than 51% of the council. The new draft also specifies a minimum number of five members or shareholders.

A comparison between the characteristics of REC and CEC considering the national regulatory frameworks analysed may be seen in Table 3.12.

Table 3.12: Types of legal entities allowed to participate in CECs and RECs.

Country	REC	CEC
France	Physical persons, autonomous SMEs, local authorities, and their companies, and SMEs or associations whose purpose is the development of renewable energies which benefit from the label "solidarity enterprise of social utility" [97], [98]	
Italy	SMEs, local authorities, research, and training entities, religious entities, third sector, and environmental, and protection associations [68]	Not limited [69]
Portugal	Physical persons, public, and private legal persons, and in particular, municipalities, and SMEs [71]	
Spain	Physical persons, local authorities, and SMEs [72] [28]	Not transposed [28]

Membership

Directives 2019/944, and 2018/2001 specify that all energy communities but CEC should be restricted to a certain area, but do not give any more hints on how this should be done [50], [51]. That said, France, Italy, Portugal, and Spain have defined a set of boundaries that limit the extent of some EC.

As we may see in Table 3.13, countries have been defining a set of boundaries for energy communities based on: the grid (based on the voltage of the connection point or limited to a single distributor, substation, or transformer), the

[28] Draft on new regulation, transposing this new figure from Directive 2019/944, indicates that any public or private person and creates limits on the maximum percentage of shares and control into the community.

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maximum power generating capacity (both the individual consumers, and the total power of the energy community), and the distance or the surface of the area covered by the community.

Table 3.13: Conditions taken into account in the national legislation to bind energy communities.

Country, and legal figure		Grid-related	Maximum power capacity	Distance or surface
France	CSC [97], [98]	Yes	Yes	Yes
Italy	REC, JARSC, CEC and JAAC [68], [69]	Yes[29]	No	No
Portugal	CSC [71]	Yes	No	Yes
Spain	CSC [80]	Yes	No	Yes
	REC [72]	No	No	No
	REC and CEC [99]	No	No	Yes
	CDN [72] [30]	Yes	No	Yes

As Table 3.13 shows, the boundaries based on the voltage level also vary widely between the different countries. While some countries, such as Portugal, allow the members of energy communities to share electricity even on the high-voltage grid, others limit this option to the low-voltage grid. Furthermore, there is a discrepancy in the distance allowed between members, with Spain allowing up to 500 meters for CSC while Portugal and France (with government authorization) permit distances up to 20 kilometers.

[29] They have to be in the same market zone.
[30] It refers to a proposal. It has not been approved.

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Table 3.14: Distance between the members of the EC, to share electrical energy, based on the voltage of the grid.

Country, and legal figure		Distribution grid		Transmission grid	
		Low voltage	**Medium voltage**	**High voltage**	**Very high voltage**
France	CSC [97], [98]	Single distributor, and < 2 km (or 20 km[31])	*Not allowed*	*Not allowed*	*Not allowed*
Italy	JARSC, CEC and JAAC [68], [69]	Same market area		*Not allowed*	*Not allowed*
	REC [90].	Same primary electrical substation			
Portugal	CSC [71]	Less than 2 km or connected to the same transformer between the producer, and consumer	Same substation, and less than 4 km between the producer, and consumer	Same substation, and less than 10 km between the producer, and consumer	Same substation, and less than 20 km between the producer, and consumer
Spain	CSC [80]	Same substation, same building, or < 500 m (or 2 000 m [32]) between members	*Not allowed*	*Not allowed*	*Not allowed*

[31] Exceptionally, and only in the continental territory, the Ministry for Ecologic Transition might authorize an increase in the limit to 20 km.
[32] The 2 000 m limit only applies if the electricity is being produced by photovoltaic panels located on the rooftop of a building.

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In France, currently, for the extended CSC, there are three necessary conditions. First, the distance between the connections point of the members must be lower than 2 km unless the Ministry for Ecologic Transition, exceptionally, and only in the continental territory, authorizes it to be as high as 20 km. This exception must be based on the isolation, the dispersed, and the low population density of the place where the project is being done. Second, the aggregated power of all the electricity generating installations cannot exceed 3 MW in the continent, and 0,5 MW in the non-connected grids. Third, the connection points must be connected to a single distributor.

In Italy, electricity sharing is allowed for JARSC, CEC, and JAAC provided that the following conditions are met: the electricity is shared within the portion of the distribution network that falls under the same market area[33]; the amount of shared electricity is equal, for each hour, to the minimum value between the electricity produced and injected into the network by the generation facilities and the electricity taken from the set of associated customers; electricity can also be shared through storage facilities; and, finally, the electricity generation and storage facilities subject to sharing among participants in the energy communities must be available and under the energy community control. For RECs, all consumers and producers must be located within the geographical area where their connection points to the national electricity grid (POD) are served by the same primary electrical substation [90].

In Portugal, the proximity between the production units and the consumption facilities in the CSC scheme is limited. In low volage, the sharing of energy is limited to being connected to the same transformer or within 2 km. Otherwise, consumers must be connected to the same substation at less than 4 km for medium voltage grid, 10 km for high voltage grid, and 20 km for very high voltage grid. Additionally, the Government may assess proximity on a case-by-case basis, considering technical elements and energy optimization criteria, within the scope of essential public services or regional and municipal development strategies.

In Spain, CSC has some limits regarding the distance at which they may share their energy (between 500 m and 2 000 m, depending on the situation and on whether is it generated by a PV power plant on a rooftop) and have to be connected to a low-voltage grid. As a consequence, the regulation is not technology neutral, and it also takes into account the location of the installation. Other than those limits for CSCs, a limit regarding distance does not apply to RECs.

Furthermore, the new draft published by the Spanish Government, specifies which may be the members of a CEC or a REC depending on the population of the municipality where the energy communities is located. The members of the energy community have to live in a given municipality or the surrounding ones if the municipality has 5 000 or fewer inhabitants and the sum of its population and that of the surrounding municipalities has less than 50 000 inhabitants. If the population of the municipality has 5 001 or more inhabitants and 50 000 or fewer, the members have to live in that municipality. Last, if the municipality has 50 001 or more inhabitants, the members have to be located 5 km around the energy communities. Moreover, the new draft specifies that ECs should be allowed to be any kind of legal person as long as they respect the other conditions specified in the decree, such as, the ones presented in Table 3.15.

Table 3.15: Limits to the members defined in the Spanish draft decree for CEC and REC [99].

Conditions on the population of the municipality		Conditions on the sum of the population of the municipality and the surrounding ones	Criteria about the possible members of the REC
Minimum	**Maximum**		
0	5 000	Less than 50 000	Members have to live in the municipality of the energy

[33] Italy is divided in multiple bidding zones for electricity markets.

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Conditions on the population of the municipality		Conditions on the sum of the population of the municipality and the surrounding ones	Criteria about the possible members of the REC
Minimum	**Maximum**		
			communities or in the surrounding ones
5 001	50 000	-	In the municipality of the project
50 001	-	-	Limited to 5 km around the EC

One of the options allowed in European legislation is the creation of cross-border CEC or REC. Nevertheless, none of the four countries have included such provisions in their regulation.

Distribution activity for CEC and REC

Table 3.16 compares the distribution capabilities for the different countries analysed.

Table 3.16: Kinds of energy distribution allowed for energy communities CEC and REC.

Energy Carrier	France [78]	Italy [68], [69]	Portugal [71]	Spain [72]
Electricity	No	Only CEC	Only CEC	No
Gas	No	No	No	- [34]
Heat or cold	Yes	No	No	-

In France, neither RECs nor CECs are allowed to own or operate an electricity or natural gas distribution network. Nevertheless, they might only create, manage, and own a heating or cooling network subject to prior notification of the competent local authority for the relevant territories.

In Italy, among RECs and CECs, only CECs are allowed to participate distribution of electricity. The shared electricity produced by the CECs can be distributed through the existing distribution network or, in specific cases, through newly constructed networks. If the community manages the distribution network, it must obtain authorization from the Government and enter into a sub-concession agreement with the DSO. The distribution networks managed by the community energy entity are considered public distribution networks, with the obligation to connect third parties, regardless of network ownership. The community energy entity, as a sub-concessionaire of the electricity network used, is subject to the same obligations and conditions as the concessionaire. The lease or sub-concession fees charged by the DSO must be fair and are subject to evaluation by the regulatory authority.

In Portugal, the Electricity Act allows for CECs to distribute energy, and they are not cited in other documents. Nevertheless, the act does not specify any other aspect of the distribution activity.

In Spain, CSC agreements cannot manage the distribution grid, and the definition of REC does not include the possibility to distribute energy.

[34] The definition of REC was only included in the Electrical Act.

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Exceptions for closed distribution networks

Table 3.17 reports the limits defined for the CDN in each of the countries and Table 3.18 compares the exemptions allowed for CDN in each of the countries analysed. In France, CDNs, which may be authorized by the regulatory authority for a maximum of twenty years (may be renewed) if certain technical, and security criteria are met, are in charge of designing, and building the network without discrimination, maintaining, and securing the network, ensuring the balance of electricity flows, and maintaining a reserve capacity, providing transparent, and non-discriminatory access to third parties, promoting energy efficiency, and renewable energy, and potentially managing metering activities for users connected to the network, unless the users are involved in electricity markets or mechanisms that require contracts with public network managers.

Table 3.17: Limits defined for the CDN in each of the countries.

Limit for	France [75], [76]	Italy [69]	Portugal [71]	Spain [35] [72]
Maximum period for the authorization	20 years	No	No	No
The maximum surface	No	2 municipalities	No	8 km^2
The maximum number of households	No	No	0	100

Table 3.18: Exemptions allowed for CDN in Directive 2019/944, as applied in each country.

Exempt for…	France [75], [76]	Italy [69]	Portugal [71]	Spain [72]
May produce energy	No	No	Yes	No
Procuring energy for losses or system services transparently, without discrimination, and in a market	Yes	Yes	No	Yes
Approving the tariffs by the regulator	Yes [36]	Yes	Yes	Yes
Procuring system services	Yes	Yes	No	No [37]
Developing the grid based on a development plan	No	Yes	No [38]	Yes
Not being allowed to own, and operate storage facilities	Yes	Yes	Yes	Yes
Not being allowed to own, and operate charging points for EV	Yes	Yes	Yes	Yes

[35] This information comes from a regulatory proposal which has not been approved.
[36] Has to be authorized by the regulatory authority (CRE).
[37] The procurement of flexibility services on behalf of the DSO has not been included in the Spanish legislation.
[38] The regulation does not specifically say that CDN are exempted.

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In order to ensure the balance of electricity flows, efficiency, safety, and security of the closed electricity distribution network, as well as to cover electricity losses and maintain reserve capacity, the closed electricity distribution network operator negotiates contracts freely with producers, suppliers, or other market players of its choice, for losses coverage, auxiliary and flexibility services, and reserve capacity maintenance on the network, according to competitive, transparent, and non-discriminatory procedures. Other than that, prior to their entry into force, the tariffs for the use of closed electricity distribution networks must be approved by the Energy Regulatory Commission, which has a four-month period from the date of receipt of a complete file to make its decision. At the end of this period, the tariffs are deemed approved.

Nevertheless, CDNs may request an exemption from certain obligations and prohibitions, including prior approval of the tariffs, negotiating contracts for loss coverage, auxiliary services, and reserve capacity, as well as possessing or operating energy storage facilities and electric vehicle charging points. The conditions of these exemptions are determined by decree after consultation with the regulator.

Italy, following the European regulation, allows for the creation of CDN for the distribution of electricity to shared industrial, commercial, or service consumption units within a geographically limited area, under specific technical, safety, or functional conditions, or if the system mainly distributes electricity to the owner or operator of the system, and their related businesses in an area of no more than two adjacent municipalities. To create a CDN, the operator of the closed distribution system must hold a sub-concession for distribution from the DSO and must obtain authorization from the Ministry of Ecological Transition. The system cannot supply electricity to civil customers, except in the case of a limited number of households that are linked to the system's owner through a professional or employment relationship and located within the area served by the system. CDNs are considered public distribution networks with an obligation to connect with third parties, and the operator of the closed distribution system must comply with the same obligations and conditions as the DSO.

Other than that, CDNs are exempt from certain obligations, including the approval of tariffs or pricing methodologies by the regulator, the procurement of non-frequency system services, and energy loss coverage services through transparent, non-discriminatory, and market-based procedures, the procurement of services necessary for the operation of the network, and the submission of a development plan for the electricity distribution network. Furthermore, CDNs are free to develop, and manage electric vehicle charging points, provided that they ensure open, and non-discriminatory access to them, and also to create, and manage electricity storage systems.

Regarding the CDNs, the regulatory authority must also prepare standard agreements for the issuing of sub-concessions, approve guidelines for compliance with conditions related to the operation of closed distribution systems, and set specific conditions for the geographical delimitation of sites where closed distribution systems may be established. Additionally, the authority is responsible for adjusting regulations related to connection, measurement, transmission, distribution, dispatching, and sales services, in accordance with principles of proportionality, and simplification, and for determining the procedures through which users of a closed distribution system can request approval of the rates charged by the system operator or the methods used to calculate these rates.

In Portugal, CDNs[39] must be integrated into domains or infrastructures excluded from the scope of electricity distribution concessions, such as networks that distribute electricity within geographically circumscribed industrial, commercial, or shared service sites, railways, ports, airports, and campsites that do not supply domestic customers and meet one of the following requirements: for specific technical or safety reasons, the operations or production process of users of that network are integrated; or that network essentially distributes electricity to the owner or operator of the network or to companies connected to them. The installation and operation of CDNs are subject to the licensing

[39] Redes de Distribución Fechadas (RDF).

procedure for private service electrical installations and depend on the prior registration of the operator to be carried out with the Portuguese Government on an electronic platform provided for this purpose.

CDNs are permitted to engage in various activities. Among those activities, the production of electricity from renewable sources, owning, and managing electric vehicle charging points, owning, and operating energy storage facilities, and supplying electricity to its members when constituted as a REC are included.

In December 2018, the Spanish Government published a Royal Decree-Law[40] that allowed the Government to regulate CDN and gave a maximum delay of 6 months to publish the requirements, and the applicable procedure. Among the requirements, to provide the compulsory authorization, the Government should consider the financial, and economic sustainability of the electrical system, the operation security, avoiding the fragmentation, and redundancy of grids, non-discrimination among consumers with similar characteristics, and the minimization of the environmental impact.

Consequently, on June 10th, 2021, the national Government started an open hearing period regarding the project of the Royal Decree[41] that regulated the closed distribution networks. The project of the Royal Decree in Spain aimed to reduce the price of electricity for large industries by specifying certain characteristics that CDN must follow. These included supplying electricity to industrial zones confined to less than 5 km^2, with production somehow related between different companies, and admitting a maximum of 100 non-industrial clients provided they have a commercial or labor relationship with the grid owners and do not represent more than 1% of total consumption. CDNs must belong to a limited company or cooperative specifically for that purpose, follow the same rules as a distributor, and not be connected to another closed distribution network. Additionally, clients could not cascade, and the owner of the grid would be responsible for charging the charges, fees, and any other cost of the network to the users connected to the grid. Electrical consumption would be individual for each client, and they would maintain the right to be supplied through a retailer or directly in the market. The owners of CDN must justify legal, technical, and economic capacities to be authorized, and the regulator must approve the CDN while ensuring that the economic, and financial viability of the electrical system is not compromised. It was estimated that the administrative cost to become a CDN would be €2 505 and that the annual cost would be €114 /year. Nevertheless, it did not estimate the impact on the electric system. It just stated that the reduction in the number of charges paid to distributors would have been compensated by a reduction in the investment that they would have to perform. This Royal Decree has been recently approved, on April 26th, 2023. The final version increases the surface to 8 km^2 and limits the possible activities to certain kinds.

The network coefficients

The network allocation coefficients stand as the set of coefficients used to split the generated energy between the different members of the EC. The following types of coefficients might be defined based on how the energy is split among the members:

- **Fixed**: allocated proportionally to a set of coefficients that remain the same regardless of the moment of the day.
- **Variable**: allocated proportionally to a set of coefficients which are defined *ex-ante*, and might vary based on some kind of time variable (hour of the day, an hour of the year, season, weekday…).
- **Dynamic:** the allocation of the energy is done *ex-post* based on a given set of rules.

These different kinds of coefficients, which are mutually exclusive and collectively exhaustive, might be used by the distributors or the suppliers to already discount the amount of energy consumed by the other members of the community.

[40] Legal proclamation issued by the National Government that is approved in Congress a month later, and that, if approved, becomes a Law.
[41] Legal proclamation issued by the national Government of Spain.

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Using the definitions given at the beginning of this section, the types of coefficients allowed in each country may be found in Table 3.19.

Table 3.19: Types of electrical network coefficients allowed.

Country	The default option has been defined	Types of network coefficients		
		Fixed	Variable	Dynamic
France [100]	Yes	Yes	No	Yes
Italy	No	For CEC and JARSC, the law does not define a fixed set of options but indicates that it has to be internally decided by the community		
Portugal	Yes	Yes	Yes	Yes
Spain	No	Yes	Yes	No

In France, the law has defined three possible options for the allocation coefficients: *fixed*, *dynamic*, and *default dynamic*. For the first one, the allocation of the generated energy among the different consumers remains always the same. In the second, a specific calculation method might be defined. In the third, the default one if no option is specified to the DSO, the energy generated is split *pro rata* based on the consumption of the members.

Italy has not defined a set of methodologies to share electricity for CEC and REC but rather indicated that the methodology has to be indicated by decided by the members of the energy community. The relationships between individuals belonging to either of those two configurations are governed by a private law contract that [101], [102]: ensures the maintenance of end customer rights, including the right to choose their own supplier; uniquely identifies a delegated entity responsible for the distribution of shared electricity, and to which individuals may delegate the management of payment and collection transactions with sales companies and the GSE[42]; allows individuals to withdraw from the configuration at any time, subject to any agreed compensation in case of early termination for shared investment participation, which must be fair and proportionate. In the case of condominiums, for example, the contract can also be constituted by the assembly resolution signed by the condominium owners who join the group of renewable energy self-consumers who act collectively. In the case of renewable energy communities, the above-mentioned contents are an integral part of the statute and/or the constitutive act of the same community. After the installation of the plant, the community requests the incentives provided by the GSE. Each member of the community will still receive an electricity bill from their own supplier, but they will also receive an amount from the CER for the shared energy use.

Portugal has defined four different types of methodologies to share the energy produced [71]: *fixed*, *variable*, any *mix of the two* previous, and the *dynamic management system*. The first of those is similar to the French one but may vary both by type of day (weekdays, weekends, and public holidays), and by season. The second uses the consumption measured in the period defined by the DSO to allocate the produced energy. In the last option, which is called Specific Systems for Dynamic Management, the allocation coefficients are calculated ex-post according to any mechanism the members of the self-consumption agree on. However, even if the law specifies that this mechanism must be regulated by the DSO, it has not regulated it yet.

[42] Gestore de Servizi Energetici is a public Italian society that is in charge of promoting, incentivizing and developing renewable energy.

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In Spain, consumers may either use *fixed* or *variable* coefficients [103]. Using the former, the energy is distributed always using a fixed set of coefficients between the different members of the community [80]. Using the latter, the energy is distributed using a set of defined *ex-ante* for each of the hours of the year. Dynamic coefficients have not been implemented yet, but are mentioned in the legislation, and other documents as the *Self-consumption Roadmap* [104].

Participation in electricity markets

In general, the analysed countries have implemented the provisions of the European regulation that indicate that ECs must be able to access all markets. Nevertheless, some barriers might subsist in the countries.

For example, Italy has indicated that the regulatory authority must adopt measures that aim to ensure that CEC can participate, directly or through aggregators, in all electricity, and related services markets, while respecting network security constraints in a non-discriminatory manner [69]. CECs will be financially responsible for any imbalances they cause in the system, assuming the balancing responsibility, or delegating it to a third party.

Portugal has also indicated that energy communities are allowed to access any electricity market [71]. Moreover, it has also specified that they should be allowed to access all system services markets.

In Spain, access to certain energy markets is only allowed to limited companies[43], which may be a problem if the energy community has been created, e.g., as an association or a cooperative [105].

National Energy and Climate Plans (NECPs)

Regulation 2018/1999 specifies that member states might include information about the current situation of energy communities in the country, future targets, and measures that will be taken to incentivize the creation of energy communities in the country [49]. The final French NECP only states that [106]: new opportunities and funding will be developed for collective self-consumers, the regulatory framework both for REC, and CEC will be established, and a target of 200.000 PV individuals, and 50 collective self-consumers for 2050 has been set.

Based on its NECP, Portugal intended to promote the installation of distributed energy resources, and the creation of energy communities by [107]: promoting distributed energy generation, and self-consumption from renewable energy sources, removing obstacles to its extension, promoting the creation, and development of energy communities, promote the creation of energy communities in collaboration with municipalities, boost the registration service for self-consumption, and energy communities, and create a website with information about distributed generation, self-consumption, and energy communities.

The Spanish NECP cites energy produced by cities, energy communities, and self-consumers as one of the priorities to reduce GHG emissions [108]. In particular, the document explains that it is necessary to rationalize both economic and administrative requirements. Moreover, it considers that for communities and citizens to use the full potential of these figures, it is necessary to promote educational programs that provide the necessary skilled workforce.

The Italian NECP indicates that REC would be promoted by utilizing the existing electricity network to support local economies and enable renewable energy production, and consumption [109]. These communities are expected to facilitate local consensus on energy plant and infrastructure development and aid families facing energy poverty. The plan includes direct support mechanisms for locally produced and consumed energy, granting privileged access to these communities. It also proposes standard tools for managing RECs and encourages the use of thermal energy from renewable sources. Additionally, the plan suggests examining the relationship between RECs and Citizen Energy Communities (CECs) to enhance cooperation in renewable energy production, consumption, and related services. Other measures include reorganizing and rationalizing self-consumption arrangements and supporting these arrangements.

[43] (*sociedades anónimas) S.A.* or *(sociedades limitadas) S.L.*

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The Swedish NECP only states that the Swedish Energy Market Inspectorate should have delivered, to the Swedish Government, a report by February 2020 on how to implement both collective self-consumption and renewable energy communities [110].

Administrative barriers and simplifications

Administrative simplifications for the creation of energy communities have not been identified. However, since solar PV is a primary energy source for these communities, regulations related to this technology significantly impact their development.

In France, the authorization process for ground-mounted solar power plants under the urban planning code depends on three factors: peak power, location, and maximum height above ground [111], [112]. The peak power is particularly important as it determines whether or not an environmental assessment of the project is necessary. The location of the project determines the applicable authorization process and whether it falls within a protected area, such as a historical monument, nature reserve, or future park. E.g., for installations with a peak power of less than 3 kW and a maximum height of less than 180 cm above ground, no formalities are required. The full extent of the exceptions might be seen in Table 3.20.

Table 3.20: Administrative simplifications regarding the construction permit for solar PV power plants in France [111], [112].

Peak power (P)	Non protected area		Protected area
P ≤ 3 kW	Not controlled if it is under 180 cm	Prior notification if higher than 180 cm	Prior notification
3 kW < P ≤ 1 MW	Prior notification		Construction permit
P > 1 MW	Construction permit and environmental impact assessment		

Other than that, the French Agency for Ecological Transition, ADEME, has also published a report in 2017 that explains how to create a self-consumption installation [113]. Nonetheless, no analysis on the barriers faced by energy communities in France was found.

In Italy, there are certain “ideal areas” that are automatically designated for the installation of solar PV installations [114]. These areas include agricultural areas which are enclosed within a perimeter no more than 100 meters away from industrial, artisanal, and commercial areas, including national interest sites, quarries, and mines. Additionally, areas within industrial plants and facilities, as well as agricultural areas enclosed within a perimeter no more than 500 meters from the same plant or facility, are eligible for solar PV installation. Finally, areas adjacent to the highway network within a distance of no more than 300 meters are also deemed suitable for solar PV installations. These guidelines are in place to encourage the expansion of solar energy infrastructure and to make it easier for individuals and businesses to invest in renewable energy. Furthermore, PV power plants until 200 kW located in a building, there is a simplified administrative form to construct, connect and produce energy. PV power plants with less than 20 MW in the ground in agricultural areas located next to industrial or commercial zones are also approved through a simplified procedure. Furthermore, if the power plant has less than 1 MW, only sworn statement indicating the beginning of the works to the municipality is needed. If the area is affected by cultural elements, the cultural authorization is still needed. In Italy, the GSE has published some guides to explain professionals and citizens the advantages and the procedures to create an energy community or have self-consumption. Nonetheless, Italy does not have analysis of the barriers faced by energy communities in the country. Other than that, the DSO have to publish maps with the perimeter of each primary substation, so that energy communities know their limits [68]. Furthermore, some regions are providing both technical support and financing for the creation of [115].

In Portugal, normally, electricity production and storage installations require production and exploitation licenses [71]. Nevertheless, the country has simplified some procedures for the installation of renewable energy sources. First, some types of electricity production, storage, and research activities only require prior registration and an exploitation certificate. These include renewable energy production with a capacity of up to 1 MW for injection into the grid, electricity production for self-consumption with a capacity between 30 kW and 1 MW, autonomous electricity storage with a capacity of up to 1 MW, and research and development projects related to innovative production, storage, and self-consumption technologies with a capacity exceeding 30 kW. Furthermore, some others only require prior notification. A summary of these exceptions might be seen in Table 3.21. Portugal has also published a report which includes the current legislation in REC and self-consumption to promote the creation of those [116].

Table 3.21: Administrative simplifications in the authorization process in Portugal [71].

Peak power (P)	Requirements
P ≤ 700 W	Not controlled
700 W < P ≤ 30 kW	Only prior notification is required
30 kW < P ≤ 1 MW	Only require prior registration and an exploitation certificate
P > 1 MW	Normal procedure

As the legislation has been mostly not transposed yet, in Spain, currently, there is no specific procedure in place for creating an energy community as defined in European directives. However, there is a process for collective self-consumption [117]. This process involves several steps, including writing a project memoire, obtaining necessary licenses, and permits, executing the installation, certifying its completion, registering as a self-consumer, and signing a representation agreement. Additionally, in some cases, an activity permit may also need to be signed. After completing these steps, the DSO must verify, and approve the energy-sharing agreement. In this process, Spain has created some exceptions that simplify the authorization or generating facilities. Table 3.22 describes the administrative simplifications in the process in Spain. Spain has also some administrative simplifications for self-consumption projects. First, projects of less than 10 kW might be elaborated and signed by an authorised electrician [118]. Second, self-consumption projects of less than 100 kW are exempted of paying the endorsement, which ascends to €40 /MW [119]. Then las projects of less than 15 kW located in an urbanized area do not require grid access permit [79]. Other exceptions exist but are not applicable to CSC.

Table 3.22: Administrative simplifications in the process in Spain.

Peak power (P)	Non-urbanized area	Urbanized area
P ≤ 10 kW	No endorsement needed. Simplified engineering project [44] Grid access permit is needed.	No endorsement is needed. Simplified engineering project [44] No grid access permit is needed.
10 kW < P ≤ 15 kW	No endorsement is needed. Grid access permit is needed.	No endorsement is needed. No grid access permit is needed.
15 kW < P ≤ 100 kW		No endorsement is needed. Grid access permit is needed.

[44] May be elaborated by an electrician. Normally it has to be signed by an engineer.

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Peak power (P)	Non-urbanized area	Urbanized area
100 kW < P	Grid access permit and endorsement are needed.	

Some administrative barriers for CEC and REC might be that Spanish legislation requires that, to be a supplier, the entity has to be a limited company [105], [120]. Therefore, it cannot be a cooperative or an association. Other than that, organizations that want to generate electricity must provide technical, legal, and economic capacity. For small self-consumption installations, it is not necessary to provide those capacities, but especially the technical capacity might be a limit for bigger entities, as for electricity, the technical capacity is proven by being an entity that has produced, distributed, or transported electricity for more than 3 years, have at least a 20% of shares belonging to such a company or have an agreement with such society. As indicated in the European Legislation, the new proposal of a decree to regulate energy communities indicates that the IDEA[45], a governmental agency in charge of the energy efficiency and diversification, must analyse the existing barriers and potential development for energy communities in Spain [91]. This agency has been publishing a report that keeps track of the procedures and the exceptions nationwide to promote self-consumption [121]. Furthermore, it has also created an office for technical assistance [117].

Last, as specified in Section 3.1.2.2, Sweden has included on its NECP that it must analyse the existing barriers to the promotion of energy communities in the country [110].

A comparison of the simplification measures is provided in Table 3.23.

Table 3.23: Administrative exemptions for the installation of distributed energy resources.

	France	Italy	Portugal	Spain
Exceptions in the permitting for low power installations	Yes	Yes	Yes	Yes
Guide for self-consumption	Yes [46]	Yes	Yes	Yes
Analysis of the barriers has been performed	No	No	No	No

Network fees and national tax exceptions

In France, the regulator has defined specific fees for self-consumers [122]. For example, as can be seen in Table 3.1, self-consumers are charged more annually for the management of their connection point.

Table 3.24: Different management tariffs for the electrical networks in France for users with less than 36 kVA based on the whether the user is a self-consumer.

Situation	Access contract with the DSO [€/year] [47]	Single-contract [€/year] [47]
Other users	15,72	14,64
Collective self-consumers that are not individual self-consumers	19,44	18,36

[45] Instituto para la Diversificación y Ahorro de Energía
[46] Has not been updated since 2017.
[47] Tariffs are different whether the user has a single contract with the supplier or also a contract with the DSO.

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Situation	Access contract with the DSO [€/year] [47]	Single-contract [€/year] [47]
Individual self-consumer that injects electricity	22,92	

Furthermore, a reduced VAT rate of 10% applies to equipment and installation costs for photovoltaic systems with a maximum power of 3 kW [123]. However, this rate cannot be applied to homes that are less than 2 years old. The 20% VAT rate applies to all other equipment with a power greater than 3 kW. In the income tax, revenues generated by a photovoltaic installation of 3 kW or less are exempt, including from some social contributions.

In Italy, the NRA, ARERA, determines the value of regulated tariff components that should not be applied to shared energy within the portion of the distribution network underlying the same primary substation, and instantaneously self-consumed [101]. The coefficient of avoided network losses is a measure of the percentage of avoided energy losses in the distribution network due to shared electricity generated by connected production systems. In the case of electricity shared due to the electricity produced by production systems connected to the medium voltage distribution network, the coefficient is 1.2%. However, for electricity shared due to the electricity produced by production systems connected to the low voltage distribution network, the coefficient is higher, at 2.6%. In Italy, the income tax includes reductions for the installation of PV power plants [124]. In 2022, an important incentive for those who install a photovoltaic system is the reduced VAT. For all works that allow energy savings, the value-added tax is reduced from 22% to 10% for existing houses. For new houses, the VAT is set at 4% [125].

The Portuguese Government has exempted self-consuming units from paying certain fees [48], which are normally included in the access tariff [71]. These exemptions have to be approved yearly by the energy ministry. Furthermore, there is an exemption until €1 000 for the profits of the electricity feed-in by small renewable energy power plants up to 1 MW, both for self-consumption and not [126]. Furthermore, the acquisition and installation of solar systems is charged with a reduced quota on the VAT [127].

Since 2018, self-consumers in Spain are exempt from paying fees or charges for self-consumed energy generated from renewable sources, waste, or cogeneration [79]. Some years before, a tax had been created for self-consumed energy but never applied [128]. This legislation also permits the feeding of self-generated energy back into the grid, as well as the sharing of this energy with nearby consumers, without paying network fees. Other than that, in general, grid charges are only applied to consumed energy, so there are no double charges for the stored energy and stand-alone storage is exempted of paying network charges [129]. Finally, citizens benefit from a 20% deduction when installing renewable energy sources on its house [130].

In Sweden, small-scale electricity generation (1 500 kW or less) is exempted from paying the general tax on generation [131]. In fact, the amount charged is limited to the annual cost incurred by the network operator for measuring, recording, calculating, and reporting. This fee is in place to cover the expenses associated with monitoring, and reporting small-scale electricity generation, but it is limited to the actual costs incurred by the network operator.

Table 3.25: Tariffs and tax exceptions for self-consumption.

Aids, tax or rates exception …	France	Italy	Portugal	Spain
Reductions in the income tax	Yes	Yes	Yes	Yes

[48] *Custos de política energética, de sustentabilidade e Interesse Económico Geral* (CIEG)

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Aids, tax or rates exception ...	France	Italy	Portugal	Spain
Reductions in the value-added tax	Yes	Yes	Yes	No
Different fees for self-consumed energy	Yes	Yes	Yes	Yes

State aids and capacity-building support for energy communities

In France, both the national Government and some regions have provided funding to an association[49] that promotes the distributed generation, and energy communities along the French territory [132]. Moreover, some regions are also promoting energy communities through technical support and financing [133].

In Italy, the JARSCs and RECs is entitled to a premium tariff for a period of 20 years from the date of commercial operation of each facility whose electric energy is detected for the configuration, which is [102]: €100 /MWh in case the energy from the production plant belongs to a JARSC and €110 /MWh in case the energy from the production plant comes from a CER. To access incentives, renewable energy production facilities must have been operational from March 1, 2020, until the adoption of relevant measures by the Italian Government and the regulatory authority to update the regulatory framework. Additionally, these facilities must have a power output of no more than 200 kW. For JARSCs, the connection points for final customers and/or producers and production facilities must be located within the same building or condominium area. For RECs, connection points for member entities must be under the same medium-to-low-voltage transformation substation. In this context, shared energy refers to the minimum hourly amount of electricity that is fed into the grid by production facilities and consumed by consumers as detected by the configuration, which is the one that receives the subsidy. On January 23, 2024, the decree promoting the establishment and development of RECs and widespread self-consumption in Italy was published [90]. This decree officially came into effect on January 24, 2024. Incentives for all RECs are provided for self-consumed energy in two different forms:

- An incentive tariff on energy produced by Renewable Energy Sources (RES) and virtually self-consumed by REC members. This tariff, calculated by the GSE (Gestore dei Servizi Energetici) – which also calculates the virtually self-consumed energy – is recognized for a period of 20 years from the start-up date of each RES plant. The tariff ranges between 60 €/MWh and 120€/MWh, depending on the plant's size and the market value of energy. For photovoltaic plants, an additional increase of up to 10 €/MWh is provided based on geographic location.
- A compensation for valorisation for self-consumed energy, defined by ARERA – Regulatory Authority for Energy, Networks, and Environment. This compensation is approximately 8 €/MWh.

Furthermore, all renewable electrical energy produced but not self-consumed remains available to the producers and is valued at market conditions. For this energy, it is possible to request from the GSE access to the economic conditions of dedicated withdrawal. Finally, for RECs whose production plants with less of 1MW of power located in municipalities with a population of less than 5,000 inhabitants, a capital grant is provided, covering 40% of the investment cost, funded by the resources of the PNRR (National Recovery and Resilience Plan).

Portugal is financing the creation of REC and CSC through the Environmental Fund[50] with the Recovery and Resilience Facility funds. The program aims to finance measures that promote the production of electricity from renewable sources under CSC and REC regimes. Specifically, the supported measures should lead to an average reduction of at least 30% in primary energy consumption in the benefited buildings and strengthen the capacity for self-consumption and/or REC

[49] Energie Partagée
[50] Fundo Ambietal

in the residential, central public administration [134]. The first are issued €10 million, the second €10 million and the third €10 million.

Table 3.26: Subsidy limits per type of investment [134].

Type of action	Maximum subsidy intensity in relation to total costs	Maximum incentive per consumer	Maximum inventive per CSC or REC
Residential buildings	70 %		
Central public administration	100 %	€200 000	€500 000
Commercial buildings	50 %		

In Spain, the Government has also allocated some of the funds of the European Recovery, and Resiliency Facility to promote energy communities. In particular, has published two subsidy programs. The first of those, known as *CE Implementa*, intends to promote the creation of energy communities in the country. The funds granted through the *CE Implementa* program have been distributed through four calls, two of them for projects with an investment of more than €1 million, with a total budget of € 80 million, and the other two for projects with an investment lower than that amount [135], [136], [137], [138]. The *CE Implementa* program promotes the five types of investments presented in Table 3.27.

Table 3.27: Maximum subsidy intensity in relation to total costs [139].

Area of actuation	Description	Maximum subsidy intensity in relation to total costs
Electrical renewables	Biomass, biogas or other renewable gases, wind, hydro, and solar PV.	60 %
Thermal renewables	Air, water, and ground source heat pumps, biomass, biogas, biomethane or other renewable gases, and solar thermal	60 %
Energy efficiency	Increase of energy efficiency in the thermal envelope	30 %
Mobility	Vehicle charging infrastructure, and hydrogen or battery electric vehicles	40 %
Demand management	Storage behind the meter, and regulation using hydro or other storage systems.	(Same as the area to which it is related)

The Spanish Government has also published a subsidy program focused on the creation of offices for the promotion of energy communities [137]. This program has been funded by €20 million from the European Recovery, and Resiliency Facility. In total, the Spanish Government has been authorized by the European Union to allocate €400 million to these two programs, between December 27th, 2021, and December 31st, 2025 [140].

The proposal for regulate energy communities in Spain, also includes a reserve in the power auctioned for distributed generation with a focus on local characteristics in the auctions for renewable energy subsidies [91].

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3.1.2.3 Gaps and challenges about the analysis of the national frameworks

This section presents the conclusions after having analysed the relevant national regulation for energy communities in France, Italy, Portugal, and Spain.

Purposes of the energy communities

The countries analysed have incorporated the "purposes" from European directives into their national laws, but without further elaboration on these "purposes". This means that simply including these purposes in national legislation doesn't provide clear guidance on the actions or functions of energy communities.

Therefore, it is suggested that national regulations should specify measurable requirements for energy communities. This ensures they fulfil the objectives of European regulation. Member states need to set up methods to evaluate if energy communities are actually pursuing the goals outlined in their bylaws.

Spain and the United Kingdom have implemented specific regulatory approaches for organizations serving the public interest. In Spain, associations recognized as providing "public benefit" must submit annual financial statements and activity reports within six months after the year's end, along with any information requested by the public administration [141]. Their statutes must outline specific objectives, and their activities should benefit more than just their members. In the UK, charities must have charitable purposes and annually report on their work. If a charity's gross income exceeds £500,000, a detailed report is required [142]. This report is made public if submitted to the Charity Commission, which is mandatory for charities with a gross income over £25,000. However, among the countries analysed, only Spain's new draft regulation specifies that the purposes of energy communities must be detailed in their bylaws.

Regulation of multi-energy carriers

RECs have been created for all renewable energy sources, and not only for electricity. Moreover, Directive 2018/2001 defines renewable energy as "*energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas*".

Nonetheless, only France has included on its legislation that RECs are not allowed to distribute gas and that they might distribute heat and cold. Portugal has included both REC and CEC and Spain only REC exclusively in the Electricity Act, so the regulation only applies for electricity. Italy, even if does not explicitly limit REC, does not regulate other possible services.

Therefore, we consider that member states should also consider other types of energies carriers, as biogas, hydrogen, or heat networks, when regulating REC.

Define the type of legal entities energy communities can take

The European legislation defines energy communities in such a way that limits public participation in the energy communities and links these organizations to a given set of purposes (social, environmental, and economic, but not financial).

José Ignacio Vega Labella considers that, based on the European regulation, for Spain, it should be considered [93]: associations, limited companies, cooperatives, specific purpose societies, and civil societies.

France, which has stablished limits, considers that the entities that might become energy communities are *limited partnership*, *simplified limited partnership*, *cooperative* or *association*. Furthermore, based on the limits on the European legislation, it is evident that, for example, public institutions are not allowed to be energy communities.

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Consequently, the French approach to defining specific legal entities for energy communities can be viewed as a good practice. Further legal analysis is recommended for other countries in this regard.

Dynamic and default coefficients for energy sharing among participants

The network allocation coefficients are a key aspect of the regulation on energy communities, as they define how the energy is going to be shared among the members of the community itself.

As a result, on the one hand, the availability of default options for allocating the electricity produced by energy communities' systems, as seen in the case of France and Portugal, might provide a simplified approach to energy sharing that is accessible to a wider range of communities. On the other hand, the implementation of dynamic allocation coefficients, as seen in the case of Portugal, can allow for more flexible and efficient distribution of energy and allow for the creation of new business models. One of those might be the creation of local electricity markets managed or not by energy communities themselves. The impact of this measure requires to be further analysed.

Wide range of boundaries to define energy communities

Even if directives 2019/944 and 2018/2001 specify that some energy communities should be distance bound, European legislation does not provide any criteria on how to do so.

Based on the reviewed countries regulations, it is evident that energy communities have varying boundaries and conditions across different countries in Europe, such as distance limitations, power capacity restrictions, and connection requirements. The maximum distance, for example, differs from only 500 m to the whole market area.

Therefore, it can be concluded that a further analysis would be necessary to determine the best option for implementing energy communities in each specific case. Factors such as population density, distribution network characteristics, and available resources could affect the feasibility and efficiency of implementing energy communities. Thus, it is essential to assess the local conditions and regulations to ensure that the implementation of energy communities is optimal for the given region.

Administrative simplifications

All the countries analysed have enacted administrative simplifications for the installation of electricity generation units which favour energy communities' development. These simplifications focus, mainly, on exempting certain kinds of installations, based on their power, on requesting a permit and almost never focus exclusively on energy communities. Other countries focus on specifying a list of locations to install PV electrical generation systems.

The impact of these strategies should be further analysed, but it can significantly impact the number of energy communities and self-consumers.

Grid tariffs

Each country has established certain exceptions in the electrical grid tariffs for EC. Some of the countries have opted for a full exemption in certain tariffs or taxes, while other have just applied certain premiums. The impacts of these policies require further analysis to avoid, on one hand, double charging effects but on the other hand cross-subsidies among customers.

3.1.3 Characterization of the energy community actor

In this section of the document, the characterization to the energy community actor is provided based on the systematic analysis of the relevant literature.

3.1.3.1 Methodology for characterising the energy community actor

The analysis of the literature to provide the characterization to the energy community actor is based on the concept of taxonomy [143]: "*a set of n dimensions* D_i *(i=1, …, n) each consisting of* k_i *(*k_i*≥2) mutually exclusive, and collectively exhaustive characteristics* C_{ij} *(j=1, …,* k_i*) such that each object under consideration has one, and only one* C_{ij} *for each* D_i". A taxonomy 83greeme the five following properties [143]:

- **Concise**: the number of dimensions must be meaningful without being unwieldy or overwhelming (there is no consensus on the right number of dimensions).
- **Robust**: the differentiation among the different types of objects is sufficient.
- **Comprehensive**: all possible objects within the domain can be classified.
- **Extendible**: new characteristics of any existing dimension can be easily included.
- **Explanatory**: not every single detail of the object is described, but rather provides useful detail.

Furthermore, no perfect taxonomy exists, but rather useful implementations of them [143].

Nickelson, Varshney, and Muntermann propose two different methodologies (sets of steps) to elaborate a taxonomy, based on whether the concept (conceptual-to-empirical) is known or there are many examples of its application (empirical-to-conceptual) [143]. To elaborate this taxonomy, the conceptual-to-empirical approach is chosen as we have analysed quite some legislations, and know how it has been implemented, and which are its characteristics. The procedure used in this analysis to elaborate it is presented in Figure 3.2.

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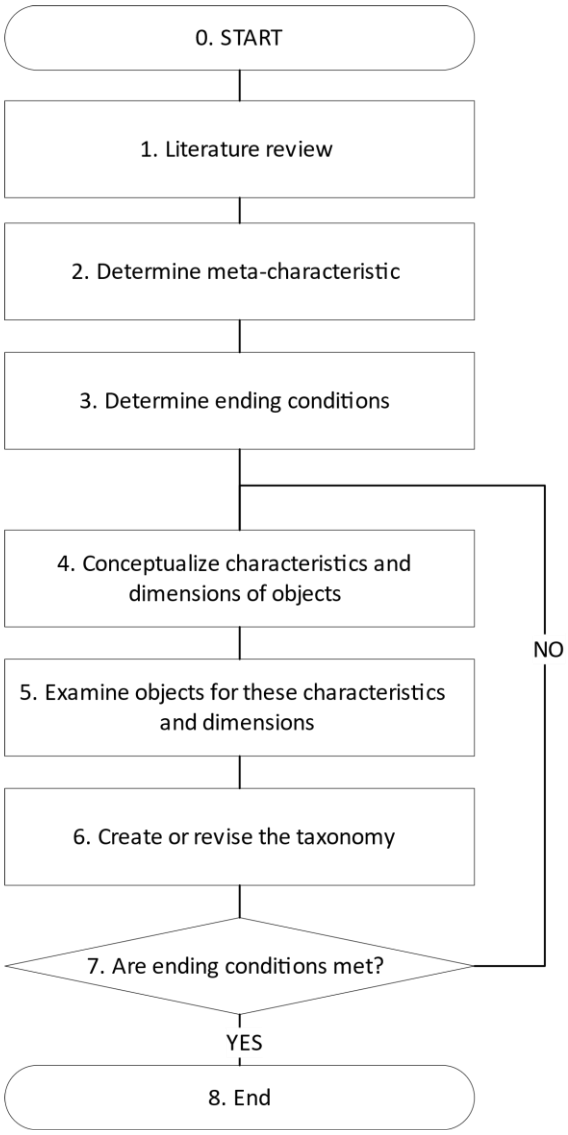

Figure 3.2: Procedure to create the taxonomy (conceptual-to-empirical).

In what follows, a detailed description of the steps in Figure 3.2 is provided. While existing literature lacks a comprehensive taxonomy of energy communities that encompasses all aspects discussed in the preceding sections, several attempts have been made to classify energy communities based on various criteria. Hence, as a first step a literature review is addressed. A systematic literature revision of the taxonomies that have been performed following the SPAR-4-SLR procedure defined in [144]. Following this procedure, a search for other taxonomies in the Scopus database has been done with the statement "*TITLE-ABS-KEY (({energy communities} OR {energy community}) AND {taxonomy})*". As a result of this search, four articles, two chapters in books, and a conference have been found. One of those, written by F. Bovera, and L. Lo Schiavo, is discarded, as it presents a taxonomy for regulatory experimentation, and not for energy communities [145].

The methodology continues by defining the meta-characteristic of the taxonomy as 'high-level description of energy communities in the European Union'. Following Nickerson, Varshney, and Muntermann's guidelines, both objective and subjective ending conditions are established. The eight objective conditions include: a representative sample of energy communities examined, no splitting or merging of communities in iterations, classification of at least one community under every characteristic, no new additions in the last iteration, uniqueness of every dimension, subdimension, and characteristic, and no duplication of cells. Subjectively, the taxonomy should be concise, robust, comprehensive, extendible, and explanatory.

Concision is key, and despite Miller's suggested limit of 5 to 9 dimensions, this taxonomy, due to the complexity of energy communities, will exceed that range but remain concise through grouping into subdimensions and dimensions. This grouping is based on the researcher's knowledge and ensures logical consistency with the meta-characteristic. The examination stage involves verifying if actual energy communities possess the conceptualized characteristics. Inappropriate subdimensions are re-evaluated or eliminated to maintain mutual exclusivity and collective exhaustiveness.

The taxonomy is created or refined by verifying the eight objective and five subjective conditions. If met, the taxonomy is concluded; otherwise, the process returns to the examination stage for further refinement. As Nickerson, Varshney, and Muntermann suggest, the aim is to develop a useful taxonomy rather than a perfect one.

3.1.3.2 Literature review

While existing literature lacks a comprehensive taxonomy of energy communities that encompasses all aspects discussed in the preceding sections, several attempts have been made to classify energy communities based on various criteria.

To find all of them, a systematic literature revision of the taxonomies that have been performed following the SPAR-4-SLR procedure defined in [144]. Following this procedure, a search for other taxonomies in the Scopus database has been done with the statement "*TITLE-ABS-KEY (({energy communities} OR {energy community}) AND {taxonomy})*". As a result of this search, four articles, two chapters in books, and a conference have been found. One of those, written by F. Bovera, and L. Lo Schiavo, is discarded, as it presents a taxonomy for regulatory experimentation, and not for energy communities [145].

G. Walker, and P. Devine-Wright (2008) elaborated a database of the community renewable projects conducted in the United Kingdom between 2004, and 2006, interviewed policymakers, and analysed 6 projects that used different renewable energy technologies [44]. After that analysis, the article concludes that two dimensions classify the initiatives analysed, and that represent the concept of policymakers, administrators, activists, project participants, and local residents: process and outcome. The former dimension explains who a project is developed and run by, which may adopt the characteristics *open and participatory* (developed through an open and participatory process, with input from a diverse group of stakeholders, including local residents) or *closed and institutional* (developed and run by closed institutions, with limited involvement or influence from local people). The latter, instead, how the outcomes of a project are spatially and socially distributed. This dimension might adopt the characteristics *distant and private* (distant institution that develops energy project for grid, not for local use or benefit, with remote shareholders and no local involvement) or *local and collective* (undertaken by a community group and generates communal advantages for the local populace). In the end, the article explains that the ideal energy community would be the one that is *open and participatory*, and *local and collective*.

The characteristics of this taxonomy do not fully comply with the mutually exclusive, and collectively exhaustive (MECE) principle, as we might have an organization that is local but not collective, and public but distant. Accordingly, the taxonomy needs to be slightly adapted either by including four dimensions (local, collective, public, and distant) with yes / no characteristics or include two more characteristics in each of the dimensions to make them collectively exhaustive.

S. Becker, C. Kunze, and M. Vancea (2017) analysed the purpose, the organization, and the embeddedness of social entrepreneurship in three energy communities [146]: Machynlleth, Somenergia, and Retenergie, and Berlin Roundtable.

They concluded that all of them exhibited collective ownership, embeddedness in the local communities, and/or social movements, and a motivation linked to environmental, and/or social purposes. As done for the precedent article, the dimensions are divided for the purpose of simplifying the comparison with other frameworks.

M. Koltunov, and A. Bisello (2021) published a conference paper in which they analyse the motives for creating an energy community through a literature survey first, and an interview to two energy communities in the Italian Alps [147]. The authors analyse all the impacts, and conclude that there are four dimensions which allow classifying both all the positive, and all the negative impacts of energy communities: economic, health, and psychological, environmental, and social.

The problem of this classification includes that an energy community might have multiple of the characteristics of each dimension. Therefore, the characteristics do not comply with the mutually exclusive, and collectively exhaustive principle presented in section 3.1.2.1, and the taxonomy, and its dimensions need to be slightly adapted. To do so, the characteristics of the dimensions are converted to positive, negative, both positive, and negative, and neither positive nor negative.

J. Hicks, and N. Ison (2018) analysed the different motivations that drive the creation of renewable energy communities, and the context in which they are created [148]. In that analysis, the authors start by listing a set of energy communities as the case study, and classify them using the following parameters: country, technology (technology used to produce electricity), scale (rated power of the energy community), legal structure, attribution of voting rights, and primary motivation (main motivation behind the community). Then, the article groups the motivations, and concludes that that there are four kinds of motivations: physical, institutional, technological, and political or policy. They also conclude that there are four contextual factors: physical, technological, institutional, and community.

As for the other situations, some of these dimensions are not MECE. First, regarding the tale used to present the characteristics of an energy community, it has to be noted that an energy community might be in multiple countries (not just in one), and the number of options is excessively wide to include it in a taxonomy. This problem also impacts the dimensions technology, and primary motivation. Moreover, the scale of the energy community does not have a limited number of choices. Accordingly, we keep the dimensions category of motivations, contextual factor, legal structure, and attribution of voting rights. The dimensions category of motivations, and contextual factor are also adapted to make them comply with the MECE principle.

S. Moroni, V. Alberti, V. Antoniucci, and A. Bisello (2019) developed a taxonomy with two dimensions [149]: place-based, and purpose. The former refers to a correspondence of the energy communities to a specific area. In other words, the members of an energy community may or may not be concentrated in a specific area (building block, condominium, area, city…). The latter of the dimensions describes whether the energy community manages the generation, purchase, and consumption of energy (single-purpose), or if the entity provides other services (multi-purpose).

N. Rossetto, S. F. Verde, and T. Bauwens (2022) classify energy communities in nine business models, which are defined based on the main value proposition of the community. Those nine business models are, at the same time, classified by the main function performed in the following five types [150]: support provision to energy consumers, and prosumers (joint-purchasing groups, and assistance providers), energy production, and supply (community energy producers, community-energy retailers, and energy-sharing communities), energy delivery via networks, and deployment (utility cooperatives), and management of distributed energy resources (shared-electric-mobility community providers, community aggregators, and community microgrids).

The characteristics of this taxonomy do not comply with the MECE principle. On the one hand, they are not mutually exclusive, as there are energy communities that manage a distribution network, and produce their energy, for example. On the other hand, they are not collectively exhaustive, as those energy communities are not limited to only those activities. Therefore, to make the classification MECE, we convert the characteristics to dimensions, and we modify the adapt the vocabulary to make it compliant with European regulations 2018/2001, and 2019/944. Moreover, we split some of the new dimensions, as previously done for the article by G. Walker, and P. Devine-Wright. As a result, we obtain the following dimensions with yes / no characteristics: energy support-provision, energy production, energy supply, energy distribution, and distributed-energy-resources management.

Other than those articles found in the Scopus database, and even if they are not specifically focused on energy communities, the principles of the International Cooperative Alliance have also been considered, as they are widely cited by many associations, e.g., Renewable Energy Sources Cooperatives (REScoop.EU) [151]. This organization defines the following seven dimensions (principles) [152] (voluntary, and open membership (participation must be voluntary, and open to anyone willing to accept the obligations of membership), democratic member control (members must be responsible for making the decisions, and setting the policies;, and the organization must be democratic, which may imply that each member has equal voting rights), member economic participation (the contribution to the cooperative's capital is equitable, members might receive compensation for the capital subscribed, any profit is allocated to developing the cooperative, setting reserves, benefiting members in proportion to their transactions with the cooperative, and supporting other activities), autonomy, and independence (the organization's control is held by the members, and remains autonomous regardless of any agreement with other organizations, including governments), education, training, and information (cooperatives provide education, and training to their members, and also information to the general public, and political leaders), cooperation among cooperatives (they participate in local, regional, national, and international structures to strengthen the cooperative movement, and better serve their members), and concern for the community (cooperatives collaborate in the sustainable development of the communities where there are).

As in the precedent situations, some of these dimensions are not MECE. First, some organizations might be open but not voluntary, as an energy community formed by the neighbours of a building might be open to all the members of the building but be compulsory (no neighbour of a building might be entitled to not own the proportional part of the shared property). Second, an entity might be autonomous (right to decide by itself) but not independent (belong to a higher entity or is constrained by some other kind of relationship). Full public limited corporations are an example of this situation, as their executive officers might usually adopt the strategic choices, they consider but they still belong to the government. Last, an entity that provides education might provide neither training nor information. Accordingly, the last dimensions are transformed in: voluntary membership (yes/no), open membership (yes/no), democratic control (yes/no), economic participation (equal / not equal), autonomous control (yes/no), independent control (yes/no), provides education (yes/no), provides training (yes/no), provides of information (yes/no), and cooperates with other cooperatives (yes/no).

Table 3.28 compares the dimensions, and subdimensions included in each of the articles found in the literature survey. To allow for a proper comparison, some of the dimensions retrieved have been grouped based on their meaning.

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Table 3.28: Comparison of the dimensions presented in each of the documents found in the literature survey.

Dimension	Subdimension	Moroni, Alberty, Antoniucci, and Bisello [149]	Gordon Walker, and Patrick Devine-Wright [153]	S. Becker, C. Kunze, and M. Vancea [146]	M. Koltunov, and A. Bisello [147]	Rossetto, Verde, and Bauwens [154]	Hicks, and Ison [148]	International Cooperative Alliance's principles [152]
Purpose	Environmental			X	X		X	
	Social			X	X		X	
	Economic				X		X	
	Health, and psychological				X			
	Technical						X	
	Political or Policy						X	
Contextual factor	Physical						X	
	Institutional						X	
	Technological						X	
	Communal						X	
Activities	Multiple activities	X						
	Support provision					X		
	Energy production					X		
	Energy supply					X		

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Dimension	Subdimension	Moroni, Alberty, Antoniucci, and Bisello [149]	Gordon Walker, and Patrick Devine-Wright [153]	S. Becker, C. Kunze, and M. Vancea [146]	M. Koltunov, and A. Bisello [147]	Rossetto, Verde, and Bauwens [154]	Hicks, and Ison [148]	International Cooperative Alliance's principles [152]
	Energy distribution					X		
	DER management					X		
Ownership, and participation	Open		X					X
	Voluntary							X
	Equal economic value of the participations							X
	Embedded in local community			X				
	Embedded in social movement			X				
	Collective ownership			X				
Control, and governance	Distant		X					
	Attribution of voting rights / democratic						X	X
	Autonomous							X
	Independent							X
	Legal structure						X	
Outcome	Local or place-based	X	X					
	For the collective or community		X	X	X			

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Dimension	Subdimension	Moroni, Alberty, Antoniucci, and Bisello [149]	Gordon Walker, and Patrick Devine-Wright [153]	S. Becker, C. Kunze, and M. Vancea [146]	M. Koltunov, and A. Bisello [147]	Rossetto, Verde, and Bauwens [154]	Hicks, and Ison [148]	International Cooperative Alliance's principles [152]
	Provides training							X
	Provides education							X
	Provides information							X
	Collaborates with other cooperatives							X

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3.1.3.3 Dimensions classifying the energy communities actor

Based on the analysis of the European regulation that may be read in Table 3.3, and the literature analysis that may be seen in Table 3.28, and on the analysis of the national implementations performed in Section 3.1.2.2 of this document, a conceptualization of the characteristics, and the dimensions of the objects is elaborated.

Given the amount of information already presented in those sections, and tables, a wide amount of information is already considered to have been analysed, objective condition 1 is considered as fulfilled.

Many of the subdimensions were not included as individual characteristics within a single subdimension because they are not mutually exclusive. Additionally, it cannot be guaranteed that such structure is comprehensive or fully representative of all possible contextual factors.

The final taxonomy is presented in Table 3.29, and an explanation about each of the sections is given in the sections that follow.

Purpose

The dimension "purpose" refers to the different possible intentions to be attained by a given energy community. The list of subdimensions is the following:

- **Economic purpose**: indicates whether the purpose of the energy communities is focused on aspects such as employment, income, and economic growth.
- **Environmental purpose**: indicates whether the purpose of the energy communities is focused on aspects such as air quality, water quality, biodiversity, ecosystem services, and climate change.
- **Financial purpose**: indicates whether the purpose of the energy communities is focused on aspects such as profit maximization or capital investment.
- **Health and psychological purpose**: indicates whether the purpose of the energy communities is focused on aspects such as physical health, mental health, and quality of life.
- **Political or policy purpose**: indicates whether the purpose of the energy communities is focused on aspects such as regulatory frameworks, legal compliance, stakeholder engagement, and governance.
- **Social purpose**: indicates whether the purpose of the energy communities is focused on aspects such as equity, social cohesion, cultural heritage, and community involvement.
- **Technical purpose**: indicates whether the purpose of the energy communities is focused on aspects such as design, construction, operation, maintenance, and safety.

In particular, this section includes both the dimensions that may be found in Table 3.3 referring to the European legislation, and in Table 3.28 referring to the literature analysis and Table 3.10.

Contextual factor

The dimension "contextual factor" refers to external factors that provide a background or framework for understanding and interpreting the creation of the EC. The subdimensions are the following:

- **Communal**: refers to the social relationships, and networks that exist within a community. It includes shared values, norms, and beliefs that shape social interactions, as well as community resources, and institutions.
- **Economical**: deals with the production, distribution, and consumption of goods, and services within a society or economy. It encompasses issues such as economic growth, trade, and taxation.

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- **Institutional**: pertains to the rules, regulations, and systems that govern social, economic, and political activities. It includes the formal, and informal structures of organizations, government, and society.
- **Organizational**: concerns the management, and operation of organizations, including businesses, non-profits, and government agencies. It includes issues such as leadership, decision-making, and communication within organizations.
- **Physical**: refers to the tangible, and material aspects of the environment. It can include the natural or built environment, infrastructure, and resources such as land (islands), water, and air.
- **Technological**: relates to the application of science, and engineering principles to create new tools, machines, and systems to solve problems or improve performance.

The subdimensions of this dimension have been based on Table 3.3 referring to the European legislation, and in Table 3.28 referring to the literature analysis.

Access and membership

The dimension "access and membership" refers to the status or condition of being a member of the "energy community" and who and how a potential member bay be a part of it. The subdimensions included in this dimension are:

- **Cross-border membership**: focuses on whether the energy communities allows members from and offers services to two or more countries.
- **Open membership**: relates to the accessibility and inclusivity of the membership criteria, meaning that anyone who meets the requirements can join the community, regardless of their background or affiliation.
- **Physical persons membership**: refers to the eligibility of individuals to become members of the energy community.
- **Private lucrative entities membership**: refers to the permission granted to lucrative organizations, as partnerships or limited companies, to join the energy community as members.
- **Private non-profit entities membership**: relates to the eligibility of non-profit organizations, such as charities or foundations, to become members of the energy community.
- **Public entities membership**: indicates whether or not public institutions, such as local governments or municipalities, are permitted to be members of the energy community.
- **Restrictions based on the distance or area**: relates to the geographical location of members and whether or not there are restrictions or preferences based on proximity to other members.
- **Restrictions based on the electrical generation power**: relates to the type and capacity of electricity generation that members are allowed to have, such as solar or wind power, and the size of the power system they can operate.
- **Restrictions based on the grid**: indicates whether or not there are specific requirements or limitations based on the structure or voltage of the grid.
- **Restrictions based on the number of members**: refers to the size of the community and whether there are any restrictions or preferences based on the number of members in the community.
- **Voluntary membership**: refers to the willingness and choice of individuals or entities to join the community, rather than being coerced or forced to do so. There might be EC, as some condominiums, where if a person belongs to the condominium it must belong to the energy community.

These subdimensions have been extracted from the ones found in Table 3.3 referring to the European legislation, and 3.1.2.2 about the conditions considered by the different countries to bind ECs.

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Organization and control

The dimension "organization and control" refer to the way in which the community is structured and managed and encompasses a wide range of activities, including decision-making processes, governance structures, and management systems. The subdimensions herein included are the following:

- **Autonomous entity**: refers to an energy community that has a high degree of independence, and self-governance. An autonomous energy communities may have the ability to make decisions independently of external authorities or other organizations and may have its own governance structures, and decision-making processes.
- **Independent entity**: related to whether the energy communities operate separately from other organizations or groups, and is not subject to their control or influence. An independent entity may have its own governance structure, decision-making processes, and resources, and may pursue its own goals, and objectives without interference from external parties.
- **Legal form**: refers to the legal structure of an organization, such as a corporation, partnership, or non-profit. This legal form determines the organization's rights, liabilities, and responsibilities under the law, as well as its tax status, and other regulatory requirements.
- **Voting rights**: focuses on the distribution of the right to participate in the decision-making process of the EC. This can include the right to elect leaders or representatives, approve budgets or policies, or make other important decisions.

In particular, this section focuses both in the dimensions that may be found in Table 3.3 referring to the European legislation, Table 3.11 about the kind of legal persons that are allowed to represent the concept of EC, and in Table 3.28 referring to the literature analysis.

Electricity activities

The dimension "electricity activities" includes all the activities related exclusively to electricity. The subdimensions here included are:

- **Aggregation**: function performed by an energy community to combine multiple customer loads or generators for sale, purchase or auction in any electricity market
- **Generation of electricity**: indicates whether the energy communities may produce electricity
- **Operation of the electrical distribution grid**: responsible for operating the electrical distribution system in a given area and, where applicable, its interconnections with other systems.
- **Ownership of the electrical distribution grid**: owns the electricity distribution grid, ensuring the maintenance of, and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems.
- **Provision of electric-vehicle charging services**: refers to the provision of infrastructure and services to enable electric vehicles to be charged. This can include the installation and maintenance of charging stations, billing and payment services, and customer support.
- **Sharing of electricity among members**: refers to the sharing of electricity between individuals or organizations belonging to the EC, often facilitated by a platform or system that enables the exchange of electricity between producers and consumers. This can include peer-to-peer trading, community-based renewable energy projects, or virtual power plants.

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- **Storage of electricity**: refers to 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 electrical energy or use as another energy carrier.
- **Supply of electricity**: refers to the sale or resale of electricity to final consumers, such as households, businesses, and other organizations, for their consumption.
- **Wholesale market participant for electricity**: refers to the ability to purchase or sell electricity or other kinds of gases in wholesale organized or non-organized markets.

This section focuses both on the dimensions that may be found in Table 3.3 referring to the European legislation, and Table 3.28 referring to the literature analysis.

Where possible, the definitions for the activities were based on or extracted from Directive 2019/944.

Gas activities

- The dimension "gas activities" includes all the activities related exclusively to gas. The subdimensions are the following:
- **Operation of the gas distribution grid**: responsible for operating the gas distribution system in a given area and, where applicable, its interconnections with other systems.
- **Ownership of the gas distribution grid**: owns the gas distribution grid, ensuring the maintenance of, and, if necessary, developing the transmission or distribution system in a given area and, where applicable, its interconnections with other systems.
- **Production of gas**: production of gases such as hydrogen, biogas, biomethane, and syngas, both renewable and not.
- **Storage of gas**: carries out the function of storage and is responsible for operating a storage facility.
- **Supply of gas**: indicates the ability to sell or resell gas to final consumers, such as households, businesses, and other organizations, for their consumption.
- **Wholesale market participant for gas**: refers to the ability to purchase or sell natural gas or other kinds of gases in wholesale organized or not organized markets.

This section was developed based mainly on the French regulation of energy communities, which refers to the kinds of energy distribution activities that might be done by energy communities. French regulation, as explained in that section, states that REC and CEC cannot distribute gas [74]. It also regulates the participation in local biogas production projects [155]. Directive 2018/2001 does not limit REC to electricity, but for any energy it manages, it has to be renewable. Where possible, the definitions for the activities were based or extracted from Directive 2009/73/EC and Directive 2019/944 [51], [156].

In the production of gas, to make it collectively exhaustive, even if REC cannot make it, the production of non-renewable gases (gasification) was included.

Heat and cold activities

The dimension "heat and cold activities" refer to the provision of heating and cooling to homes and buildings within an energy community. The subdimensions are the following:

- **Distribution of heat or cold**: relates to the ownership, responsibility for operating, ensuring the maintenance of, and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution heat and cold.

- **Generation of heat or cold**: refers to the production of heat and cold for thermal uses (industry, climatization…).
- **Supply of heat or cold**: process of selling or reselling heat or cold to end-users, such as households, businesses, and other organizations, for their consumption.

This section was developed based on the French regulation of energy communities, which refers to the kinds of energy distribution activities that might be done by energy communities.

Other energy activities

The dimension "other energy-services" refer to any services related to energy that are not directly related or specifically focused on electricity, gas, heat, or cold. The subdimensions are the following:

- **Energy efficiency consulting services**: services related to advising and consulting on energy efficiency measures and practices for buildings, appliances, or transportation.
- **Energy management services**: services related to managing and optimizing energy use, such as demand response services or energy management systems for buildings.
- **Transportation services**: services related to sustainable transportation options, such as electric vehicle charging stations, bike-sharing programs, or carpooling services.

This dimension was based in the literature revision in Section 4.2, the revision of the European regulation in Table 3.3, and the possible investments for the Spanish aids in Table 3.27.

Outcome

The dimension "outcome" refers to the result or impact of the community's activities or initiatives. The subdimensions are the following:

- **Investments part of its benefits on its purpose**: refers to the practice of allocating a portion of an organization's profits or earnings towards achieving its intended purposes.
- **Collaborates with other communities**: refers to the EC's efforts to collaborate with other communities, organizations, or stakeholders on energy-related initiatives, such as sharing best practices.
- **Community outcome**: refers whether energy communities impact focuses on the members itself.
- **Local outcome**: refers whether energy communities impacts the local community.
- **Provides education**: refers to the EC's efforts to educate its members or the local community on energy-related topics, such as the benefits of renewable energy, energy conservation, or the role of energy in climate change.
- **Provides information to citizens**: relates to the EC's efforts to provide information to its members or the local community on energy-related topics, such as energy policies, regulations, or programs, or the availability and cost of different energy sources.
- **Provides training**: indicates whether the energy communities is providing practical training to its members or the local community on energy-related topics, such as energy efficiency, renewable energy, or energy management.

This dimension was based mainly in the literature revision in Section 3.1.3.2 and in the analysis of the national regulation in Section 0.

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Table 3.29: Proposed taxonomy.

<table>
<tr><th>Dimension</th><th>Subdimension</th><th colspan="6">Characteristics</th></tr>
<tr><td rowspan="7">Purpose</td><td>Economic purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Environmental purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Financial purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Health and psychological purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Political or policy related purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Social purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Technical purpose</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td rowspan="6">Contextual factor</td><td>Communal</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Economical</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Institutional</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Organizational</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Physical</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Technological</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td rowspan="5">Access and membership</td><td>Cross-border membership</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Open membership</td><td colspan="3">Yes</td><td colspan="3">No</td></tr>
<tr><td>Physical persons membership</td><td colspan="2">All</td><td colspan="2">Only some kinds</td><td colspan="2">None</td></tr>
<tr><td>Private lucrative entities membership</td><td colspan="2">All</td><td colspan="2">Only some kinds</td><td colspan="2">None</td></tr>
<tr><td>Private non-profit entities membership</td><td colspan="2">All</td><td colspan="2">Only some kinds</td><td colspan="2">None</td></tr>
</table>

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Dimension	Subdimension	Characteristics					
	Public entities membership	All	Only some kinds	None			
	Restrictions based on the distance or the area	Both area and distance	Only area	Only distance	None		
	Restrictions based on the electrical generation power	Both on the type and the capacity	Only on the capacity	Only on the type	None		
	Restrictions based on the grid	Only based on the structure of the grid	Only based on the voltage	Based on both	Based on none		
	Restrictions based on the number of members	Yes	No				
	Voluntary membership	Yes	No				
Organization and control	Autonomous entity	Yes	No				
	Independent entity	Yes	No				
	Legal form	Simple agreement	Association or foundation	Enterprise or profit association	Public administration	Religious entity	Other
	Voting rights	Per share or equity percentage	Per member of shareholder	Per client	Other		
Electric activities	Aggregation	For everyone	Only for members	Only for non-members	No		
	Generation of electricity	Both	Only non-renewable	Only renewable	None		
	Operation of the electrical distribution grid	Yes	No				
	Ownership of the electrical distribution grid	Yes	No				
	Provision of electric-vehicle charging services	For everyone	Only for members	Only for non-members	No		

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Dimension	Subdimension	Characteristics			
	Sharing of electricity among members	Using fixed coefficients	Using variable coefficients (ex-ante)	Using dynamic coefficients (ex-post)	No
	Storage of electricity	Yes		No	
	Supply of electricity	For everyone	Only for members	Only for non-members	No
	Wholesale market participant of electricity	Bilaterally and in organized markets	Only bilaterally	Only in organized markets	No
Gas activities (includes hydrogen, biogas…)	Operation of the gas distribution grid	Yes		No	
	Ownership of the gas distribution grid	Yes		No	
	Production of gas	Both renewable and non-renewable	Only non-renewable	Only renewable	None
	Storage of gas	Yes		No	
	Supply of gas	For everyone	Only for members	Only for non-members	No
	Wholesale market participant for gas	Bilaterally and in organized markets	Only bilaterally	Only in organized markets	No
Heat and cold activities	Distribution of heat or cold	Both	Only heat	Only cold	None
	Generation of heat or cold	Both	Only heat	Only cold	None
	Supply of heat or cold	For everyone	Only for members	Only for non-members	No
Other energetic activities	Energy efficiency consulting services	For everyone	Only for members	Only for non-members	No
	Energy management services	For everyone	Only for members	Only for non-members	No

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Dimension	Subdimension	Characteristics			
	Transportation services	For everyone	Only for members	Only for non-members	No
Outcome	Investment part of its benefits on its purpose	Yes		No	
	Collaborates with other communities	Yes		No	
	Community outcome	Yes		No	
	Local outcome	Yes		No	
	Provides education	Yes		No	
	Provides information to citizens	Yes		No	
	Provides training	Yes		No	

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3.1.4 Interim conclusion

This report provides a comprehensive analysis of the European legal framework for energy communities, highlighting gaps and challenges that exist in the current regulatory landscape. The second chapter provides an in-depth examination of the European legal framework for energy communities, outlining the methodology used to conduct the analysis, identifying the relevant legal figures and the main characteristics to describe, compare and contrast the legal frameworks at national level. The analysis identifies the five legal figures that currently exist under European legislation, which may be considered as energy communities, and get their respective characteristics and requirements, identifying commonalities among them. The chapter draws conclusions based on the analysis, highlighting similarities and differences between the approaches taken by different countries, and identifying any key trends or issues that emerge from the analysis.

The third chapter analyses the national legal frameworks of several target countries, including France, Italy, Portugal, Spain, and Sweden, to understand the regulatory landscape for energy communities in each country. The analysis identifies gaps and challenges in the regulatory frameworks of these countries, highlighting the need for specific measurable requirements to ensure compliance with the purposes of the European regulation. The chapter emphasizes the importance of considering other types of energy carriers, such as biogas, hydrogen, or heat networks, when regulating energy communities, and notes the potential benefits of dynamic allocation coefficients to create new business models such as local electricity markets. The chapter concludes that further analysis is necessary to determine the best option for implementing energy communities in each specific case, considering factors such as population density, distribution network characteristics, and available resources.

The fourth chapter provides a comprehensive overview of the taxonomy and its application in the context of European energy communities. A taxonomy is a hierarchical classification system that organizes and categorizes information or entities based on their characteristics or relationships. In this report, it is applied to energy communities to provide a structured framework that helps in understanding, organizing, and managing the corresponding complex information in a systematic and efficient manner. The chapter defines the concept of taxonomy and outlines the five subjective conditions necessary for its development. The chapter reviews existing literature on taxonomies for energy communities and compares the different dimensions and characteristics used to classify energy communities. The conceptual-to-empirical approach proposed by Nickelson, Varshney, and Muntermann is employed to create the taxonomy, resulting in ten dimensions and 56 subdimensions, with each subdimension being mutually exclusive and collectively exhaustive. The taxonomy includes dimensions such as purpose, contextual factor, access and membership, organization and control, electric activities, gas activities, heat and cold activities, other energetic activities, and outcome. The chapter notes that the taxonomy is not intended to be static and could be modified in the future to include new dimensions, subdimensions, and/or characteristics.

Overall, this report provides a useful tool for researchers and practitioners to understand and classify energy communities in Europe, facilitating the development of future research and policy initiatives in the area of energy communities. The report identifies gaps and challenges in the regulatory landscape and provides recommendations for addressing them, emphasizing the need for specific measurable requirements, the consideration of other types of energy carriers, and the potential benefits of dynamic allocation coefficients. The report concludes that further analysis is necessary to determine the best option for implementing energy communities in each specific case, considering factors such as population density, distribution network characteristics, and available resources.

3.2 Aggregators

Unlocking the potential of aggregation in the context of distributed resources is a compelling goal in modern energy systems. The ability to harness the collective power of numerous decentralized energy sources holds tremendous promise for achieving sustainability, efficiency, and grid resilience. However, realizing this potential requires a clear understanding of the roles and responsibilities involved, along with careful examination of the challenges that must be overcome.

The purpose of this section is to outline the aggregator's role to fully unlock the potential of aggregation for distributed resources. By delineating the responsibilities of various stakeholders, we aim to analyse the aggregation schemes that maximizes the societal benefits of aggregated energy resources while addressing the challenges that exist within the current landscape.

This section addresses key challenges in aggregating distributed resources, focusing on establishing effective contracts with Flexibility Service Providers (SP) to ensure transparent and fair operations. It also explores coordination with retailers for market participation of aggregated resources, emphasizing efficient energy utilization and market growth.

Additionally, this section highlights the importance of a robust baseline methodology for accurately measuring the impact of aggregated resources on power system operation and value. It aims to develop a standardized approach for baselines to ensure comparability and reliability in the aggregated energy market.

Lastly, it examines balance responsibility in aggregated energy systems, crucial for maintaining grid stability, and proposes strategies for fair and efficient distribution of this responsibility among stakeholders.

For this analysis, this section first analyses the literature on aggregation. This document provides an extensive analysis of the conceptual and regulatory frameworks for DERs aggregation, exploring the various theoretical perspectives, methodologies, and best practices. By delving into the existing body of knowledge, this analysis aims to establish a comprehensive foundation for understanding the key concepts and principles that underpin the aggregation of distributed energy resources.

3.2.1 Analysis of the European regulation

The European regulatory framework provides rules and guidelines for the operation of the electrical grid, including the integration of aggregators into operations. Based on what has been identified by ACER in [157], a list of relevant regulations and directives is included in Table 3.30.

Table 3.30: Most important regulations regarding the provision of aggregation services [157]

Regulation	Legal text	Relevant titles and sections in the regulation based on the guidelines	Articles which cite "demand response" or "aggregation"
Electricity Market Regulation	Regulation 2019/943	Titles I and II	1, 3, 6, 7, 12, 13, 18, 23, 30, 57 and 59
Electricity Market Directive	Directive 2019/944	Chapters I to V	2, 3, 8, 12, 13, 15, 16, 17, 20, 23, 27, 31, 32 and 40
Electricity Balancing	Regulation 2017/2195	Titles I, II, III and V	3, 18 and 60
Operational Operation	Regulation 2017/1485	Sections 2 and 3 on title II; sections 1 through 6 on title III; and section 5, 6, 7 and 10 on title IV	2, 3 and 54
Demand Connection Code	Regulation 2016/1388	Section III.1	1, 2, 3, 4, 10, 27, 28, 29, 31, 32, 34, 35, 36, 41 …
Capacity allocation and congestion management	Regulation 2015/1222	Section 2 on title III	-

3.2.1.1 Principles on aggregation

This first subsection on European regulation analyses how the basic concepts of demand response, aggregation, and independent aggregators are included in European regulation.

Demand response

Article 2 of Directive 2019/944 defines *demand response* as "*the change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including in response to time-variable electricity prices or incentive payments, or in response to the acceptance of the final customer's bid to sell demand reduction or increase at a price in an organized market […], whether alone or through aggregation*" [158].

Aggregation and independent aggregator

Article 2 of directives 2019/944 and 2018/2001 provide the following definitions [158]:

- **Aggregation**: 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.
- **Independent aggregator**: market participant engaged in aggregation who is not affiliated to the customer's supplier.

Therefore, we might understand that, in the European regulation, an *independent aggregator* stands as "*a market participant engaged who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market, and who is not affiliated to the customer's supplier*". Other than that, *demand aggregation* designates *"a set of demand facilities or closed distribution systems which can operate as a single facility or closed distribution system for the purposes of offering one or more demand response services*" [158].

Among others, Directive 2019/944 is motivated by the aim to provide all customer groups, including industrial, commercial, and households, with access to electricity markets for trading their flexibility and self-generated electricity [158]. The directive encourages the utilization of aggregation, allowing customers to leverage benefits across larger

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regions and promoting cross-border competition. Market participants engaged in aggregation are envisioned to act as intermediaries between customer groups and the market [158].

Regarding Article 17 on demand response through aggregation, Member States are required to facilitate the participation of demand response through aggregation. They must also establish transparent and non-discriminatory rules that clearly define the roles and responsibilities of all electricity undertakings and customers in this process [158].

Last, Article 27, also states that Member States have the freedom to enhance the market position of household customers and small and medium-sized non-household customers by facilitating voluntary aggregation of representation for this customer group [158]. This provision recognizes the potential benefits and opportunities that can arise from allowing customers to join together and collectively engage in the energy market [158].

Implementation model for independent aggregation

The motivation of Directive 2019/944 acknowledges the importance of allowing Member States the flexibility to adopt suitable implementation models and governance approaches for independent aggregation while adhering to the principles outlined in the directive [158]. These models can encompass market-based or regulatory principles that comply with the directive, such as settling imbalances or introducing perimeter corrections [158]. It is essential for the chosen model to incorporate transparent and fair rules that enable independent aggregators to fulfil their intermediary roles effectively and ensure that end customers receive adequate benefits [158].

Furthermore, Article 17 of the same Directive emphasizes the need for Member States to establish non-discriminatory and transparent rules that clearly define the roles and responsibilities of all electricity undertakings and customers in relation to demand response through aggregation [158].

Balancing responsibility and imbalance settlement

Article 17 of Directive 2019/944 states that market participants involved in aggregation have the financial obligation to account for any imbalances they create in the electricity system [158]. As a result, they must either assume the role of balance responsible parties themselves or assign their balancing responsibility to another entity [158].

As indicated in the Framework Guidelines on Demand Response, the new rules will provide clarity and guidance for market participants, including service providers, regarding demand response implementation behind the metering point(s) of a connection point [159]. These rules will allow multiple market participants, including service providers, to be active simultaneously behind the metering point(s) of a connection point [159]. They will cover all aspects of imbalance settlement, including the calculation of position, allocated volume, imbalance adjustment, and imbalance for activations by system operators (SOs) and market participants, considering different aggregation models [159].

The metering point(s) of a connection will assign withdrawal and/or injection to the responsible Balance Responsible Party (BRP) for imbalances on that connection [159]. In addition, the new rules will distinguish between the imbalance adjustment of BRPs of market participants behind the metering point(s) of the connection point and the adjustments to the allocated volume of BRPs responsible for imbalances on the connection point [159]. These calculations will be differentiated based on the applicable aggregation model, ensuring consistency among the volumes involved to prevent free-riding [159].

Compensation

Other that what has already been said, Article 17 of Directive 2019/944, as part of the Electricity Market Directive, establishes that Member States have the option to mandate financial compensation from electricity companies or participating end customers to other market participants or their balance responsible parties in cases where demand response activation directly affects them [158]. However, this compensation should not create obstacles for market participants engaged in aggregation or hinder flexibility[158].

The financial compensation should be limited to covering the specific costs incurred by the suppliers of participating customers or their balance responsible parties during the demand response activation [158]. The calculation method for determining the compensation may consider the benefits brought about by independent aggregators to other market participants. If such benefits exceed the direct costs incurred, the aggregators or participating customers may be required to contribute to the compensation, but only to the extent that the benefits do not outweigh the costs [158].

The regulatory authority or another competent national authority must approve the calculation method for the compensation. This ensures that the process is transparent and regulated [158].

Contract for aggregation

A contract might be defined as an "*an agreement between two or more parties that creates in each party a duty to do or not do something and a right to performance of the other's duty or a remedy for the breach of the other's duty*" [52].

Article 13 of Directive 2019/944 includes some specific provisions for aggregation contracts. Within that article, Member States bear the responsibility of ensuring that customers enjoy the freedom to independently purchase and sell electricity services, including aggregation, regardless of their existing electricity supply contract or chosen electricity provider [158]. Furthermore, customers are entitled to enter into an aggregation contract without requiring the consent of their electricity provider [158].

Market participants engaged in aggregation are obligated to provide customers with comprehensive information about the terms and conditions of their contracts [158]. Furthermore, customers have the right to obtain relevant data on demand response, as well as information regarding the electricity they receive and sell. This information must be provided free of charge at least once during each billing period, upon customer request [158].

These rights must be granted to customers in a fair and unbiased manner, without any form of discrimination [158]. Suppliers are prohibited from imposing discriminatory technical and administrative requirements, procedures, or charges on customers based on whether they have a contract with a market participant involved in aggregation [158].

The Directive 2019/944 defines a *switching-related fee* as "*a charge or penalty for changing suppliers or market participants engaged in aggregation, including contract termination fees, that is directly or indirectly imposed on customers by suppliers, market participants engaged in aggregation or system operators*" [158].

That said, in addition to what has already been stated, Article 12 of Directive 2019/944 contains provisions concerning consumers' rights to switch aggregators [158]. Specifically, it stipulates that the process of switching market participants engaged in aggregation should be completed as quickly as possible [158]. Member States are responsible for ensuring that customers who wish to switch suppliers or market participants engaged in aggregation, while adhering to contractual conditions, are entitled to make such a switch within a maximum of three weeks from the date of their request [158].

Member States may also allow market participants engaged in aggregation to charge customers contract termination fees if customers voluntarily terminate fixed-term, fixed-price electricity supply contracts before their maturity [158]. However, these fees must be explicitly communicated to the customer prior to entering into the contract, and they should be proportionate to the direct economic loss incurred by the supplier or market participant engaged in aggregation as a result of the customer's contract termination [158]. This includes the costs of any bundled investments or services that have already been provided to the customer as part of the contract [158].

The market participant engaged in aggregation has the responsibility to demonstrate the direct economic loss, and the permissibility of contract termination fees should be overseen by the regulatory authority or another competent national entity [158].

Member States must ensure that the right to switch suppliers or market participants engaged in aggregation is granted to customers in a non-discriminatory manner concerning cost, effort, and time [158].

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Last, the Directive 2019/944 also defines *contract termination fee* as a "*charge or penalty imposed on customers by suppliers or market participants engaged in aggregation, for terminating an electricity supply or service contract*" [158]. That said, market participants engaged in aggregation may be allowed by Member States to impose contract termination fees on customers who voluntarily terminate fixed-term, fixed-price electricity supply contracts before their maturity [158]. These fees must be included in a contract that the customer willingly entered into and clearly communicated to the customer prior to signing the contract. The fees should be reasonable and proportionate, not exceeding the direct economic loss incurred by the supplier or market participant engaged in aggregation due to the customer's contract termination [158]. This includes costs related to any investments or services already provided to the customer as part of the contract [158]. It is the responsibility of the supplier or market participant engaged in aggregation to demonstrate the direct economic loss [158]. The regulatory authority or another competent national authority will monitor the permissibility of contract termination fees [158].

Aggregation models

The new rules described in the Framework Guidelines on Demand Response aim to establish comprehensive guidelines for different aggregation models in the electricity sector [157]. These models must be categorized based on the number of BRPs per connection point and per metering point, as well as the type of compensation mechanism applied [157].

The rules must also define the roles, responsibilities, and interactions of market participants under each aggregation model, including data exchange with system operators (SOs) for accessing wholesale markets, verification of SO service provision, communication with BRPs after service activation, and settlement of provided services [157]. The rules will also address financial compensation, ensuring that it is separate from imbalance settlement corrections and that the energy activated for the service is correctly attributed to the respective BRPs [157].

The specific requirements and direction of financial compensation for each aggregation model type will be specified, with consideration given to correction actions taken during imbalance settlement [157]. The rules will ensure that financial compensation does not create barriers for market participants engaged in aggregation [157]. They will provide a list of resulting costs incurred by suppliers and a description of benefits brought by independent aggregators to other market participants [157].

Additionally, a European-wide process will be established to further specify and harmonize the elements of aggregation models based on gained experience and the functioning of integrated balancing markets [157]. The process will include monitoring reports and proposals for the EU methodology to assess the need for further harmonization and achieve the aims of the Electricity Regulation [157].

Conflict resolution mechanism

Article 17 of Directive 2019/944 includes the need for a conflict resolution mechanism between market participants engaged in aggregation and other market participants, including responsibility for imbalances [158].

Active customers and energy communities

Directive 2019/944 includes provisions related to active customers and citizen energy communities, with a specific focus on aggregation [158]. In Article 15, Member States are required to ensure that final customers can become active customers without facing disproportionate or discriminatory technical requirements, administrative burdens, procedures, or non-cost-reflective network charges [158]. These active customers have the right to operate directly or through aggregation [158].

Similarly, Article 16 emphasizes that citizen energy communities should have equal access to all electricity markets, either directly or through aggregation, without facing discrimination [158]. These communities should be treated fairly and proportionately in terms of their activities, rights, and obligations as final customers, producers, suppliers, distribution system operators, or market participants engaged in aggregation [158].

Last, Directive 2018/2001 also allows the participation of renewable energy communities in aggregation and the non-discrimination of those actors [50].

3.2.1.2 Participation in markets

Regulation 2019/943 [55], Regulation 2017/2195 [160], and Directive 2019/944 [158] give specific provisions on how demand response and demand response through aggregation should be treated in markets. This subsection provides an overview on the underlying principles.

Principles

Regulation 2019/943, set fundamental principles for well-functioning, integrated electricity markets, which allow all resource providers and electricity customers non-discriminatory market access, empower consumers, ensure competitiveness on the global market as well as demand response, energy storage and energy efficiency, and facilitate aggregation of distributed demand and supply, and enable market and sectoral integration and market-based remuneration of electricity generated from renewable sources [55]. Furthermore, the purpose of Directive 2019/944 is to encourage the establishment of products in all electricity markets, encompassing ancillary services and capacity markets, with the aim of facilitating the integration of demand response [158].

In this context, the Regulation defines *market participant* as a "*natural or legal person who buys, sells or generates electricity, who is engaged in aggregation or who is an operator of demand response or energy storage services, including through the placing of orders to trade, in one or more electricity markets, including in balancing energy markets*" [158]. Based on the directive, we might also define the term *market participant engaged in aggregation* as a "*natural or legal person who buys, sells or generates electricity, who is engaged in aggregation, in one or more electricity markets, including in balancing energy markets*".

Indeed, Regulation 2019/943, as outlined in Article 1, aims to establish core principles for efficient and integrated electricity markets [55]. These principles include non-discriminatory market entry for resource providers and electricity customers, empowerment of consumers, global market competitiveness, promotion of demand response, energy storage, and energy efficiency, and facilitation of aggregated distributed demand and supply [55].

Furthermore, the motives of Regulation 2019/943 highlight the significance of demand response in the electricity market [55]. It emphasizes that electricity prices should be determined through the interplay of demand and supply, creating market-based incentives for investments in flexibility sources such as flexible generation, interconnection, and energy storage [55]. The regulation acknowledges that decarbonization and the integration of renewable energy require the removal of existing barriers to cross-border trade and the promotion of investments in supporting infrastructure [55]. This includes demand response, which plays a crucial role in enabling the efficient operation and planning of the electricity network and providing effective price signals for new generation capacity and transmission infrastructure [55]. Furthermore, the regulation advocates for targeted measures instead of broad derogations to encourage the development of demand response solutions and achieve efficient market-based decarbonization processes [55].

The principles outlined in Article 3 of the Regulation 2019/943 emphasize the importance of enabling market participation for final customers and small enterprises through the aggregation of generation and demand response facilities [55]. These facilities can provide joint offers and operate together in the electricity system, adhering to competition law [55]. Market rules should also incentivize investments in generation, energy storage, energy efficiency, and demand response to support a decarbonized and sustainable electricity system [55]. Furthermore, the principles highlight the need for fair competition and equal participation of safe and sustainable generation, energy storage, and demand response in the market [55]. Finally, the market rules should facilitate the efficient dispatch of generation assets, energy storage, and demand response [55].

Among others, Directive 2019/944, in Article 3, emphasizes the importance of promoting competitive, consumer-centred, flexible, and non-discriminatory electricity markets [158]. It requires Member States to ensure that their national laws do not unreasonably obstruct, among others, consumer engagement (including through demand response), investments in variable and flexible energy generation, energy storage, as well as the adoption of electromobility [158]. Additionally, the directive emphasizes the need for electricity prices to accurately reflect the actual demand and supply in the market [158].

Article 17 of Directive 2019/944 requires Member States to ensure the equal participation of final customers, including those involved in demand response through aggregation, in all electricity markets [158]. It also grants each market participant engaged in aggregation, including independent aggregators, the right to access electricity markets without the need for consent from other participants [158].

Day ahead and intraday markets

According to Article 7 of Regulation 2019/943 [55], the provisions regarding day-ahead and intraday markets stipulate that these markets must be structured to enable all participants, either individually or through aggregation, to have access to the market.

Dispatch and redispatch

Article 12 of Directive 2019/944 emphasizes that the dispatching of power-generating facilities and demand response should adhere to certain principles. The dispatching process should be non-discriminatory and transparent [158]. However, there might be some exceptions for renewable and high-efficiency cogeneration installations [158].

Regarding the redispatch, article 13 of the same Directive states that the redispatching of generation and demand response should be carried out based on fair, transparent, and non-discriminatory criteria [158]. All generation technologies, energy storage, and demand response resources should be eligible for participation, including those located in other Member States if technically feasible [158].

Market-based mechanisms should be used to select the resources for redispatching, and these resources should be financially compensated [158]. The pricing of balancing energy bids should not determine the balancing energy price [158].

Non-market-based redispatching of generation, energy storage, and demand response may be used only when no market-based alternatives are available, all available market-based resources have been utilized, the number of available facilities is insufficient for effective competition, or when congestion occurs regularly and predictably with strategic bidding concerns [158]. When non-market-based redispatching is implemented, the system operator requesting the redispatching must provide financial compensation to the operator of the redispatched demand response facility [158]. This compensation requirement applies unless the producer has accepted a connection agreement without a firm energy delivery guarantee [158].

The financial compensation should be at least equal to the higher value between the following elements or a combination of both, considering that applying only the higher value should not result in unreasonably low or high compensation [158]:

- Additional operating costs incurred due to the redispatching, such as extra fuel expenses in the case of upward redispatching or backup heat provision for downward redispatching of power-generating facilities using high-efficiency cogeneration.
- Net revenues that the demand response facility would have generated from the sale of electricity on the day-ahead market if there were no redispatching request. If the facility receives financial support based on the volume of

electricity generated or consumed, the financial support that would have been received without the redispatching request is considered part of the net revenues.

Balancing market

As explained in Article 3, Regulation 2017/2195 aims to facilitate the participation of demand response, including aggregation facilities and energy storage, in the electricity balancing market [160]. The regulation ensures that these participants can compete fairly with other balancing services and, if required, operate independently when serving a single demand facility [160].

Indeed, Articles 18, 30, and 32 of Regulation 2017/2195 establish pricing methods for balancing energy that incentivize market participants, including demand response, to maintain their own balance or restore system balance [55]. The pricing approach aims to economically utilize demand response and other balancing resources while ensuring operational security limits are respected [55].

Title V of the Regulation aims to create balance in the energy system by providing incentives to market participants, including demand response aggregators, for their contribution to maintaining or restoring system balance [55]. Imbalance prices should reflect the real-time value of energy, accommodating the integration of variable renewable energy. All market participants, including demand response aggregators, are financially responsible for the imbalances they cause, based on allocated volume compared to their final position in the market [55]. The allocated volume for demand response aggregators is determined by the physically activated energy from participating customers, following defined measurement and baseline methodologies [55].

Regulation 2017/2195, Article 18 outlines the terms and conditions related to balancing services [160]. These terms and conditions should define reasonable requirements for providing balancing services and allow the aggregation of demand facilities, energy storage facilities, and power generating facilities within a scheduling area to offer balancing services, subject to certain conditions particular conditions defined in the Regulation [160].

Furthermore, this regulation also specifies that the terms and conditions should include rules for the qualification process to become a balancing service provider, as well as rules, requirements, and timescales for the procurement and transfer of balancing capacity [160]. They should also specify the rules and conditions for aggregating demand facilities, energy storage facilities, and power generating facilities within a scheduling area to become a balancing service provider [160].

Other than that Regulation, in accordance with Article 6 of Regulation 2019/943, the organization of balancing markets, including prequalification processes, should adhere to the following principles [55]:

- Guarantee effective non-discrimination among market participants, taking into consideration the diverse technical requirements of the electricity system and the varying technical capabilities of generation sources, energy storage, and demand response.
- Ensure that services are transparently defined in a technologically neutral manner and procured through transparent and market-based processes.
- Provide non-discriminatory access to all market participants, whether individually or through aggregation, including those generating electricity from variable renewable energy sources, engaging in demand response, and utilizing energy storage.
- Accommodate the growing share of variable generation, increased demand responsiveness, and the emergence of new technologies.

Technical requirements for demand response

Directive 2019/944 also specifies that Member States must ensure that regulatory authorities and, where applicable, TSOs and DSOs (where applicable), in cooperation with market participants and final customers, establish technical participation requirements for demand response in all electricity markets [158]. These requirements should be tailored to the unique characteristics of each market and the capabilities of demand response and aggregated loads [158].

Prequalification

The new rules outlined in Section 3 of the Framework Guidelines in Demand Response aim to establish principles, requirements, and processes for the prequalification of service providers and products in the electricity system [157]. These rules ensure that the delivery of services is technically supported by the grid and that service providers have the necessary qualifications and capabilities [157].

The prequalification processes should be user-friendly, non-discriminatory, transparent, and standardized where possible [157]. The rules should consider the specific requirements for different services and products [157]. They should also define the criteria for grid prequalification, service provided qualification, and product prequalification, as well as the roles and responsibilities of different system operators [157].

The burden of the prequalification process should be proportionate, and activation tests should be minimized for small units [157]. Framework Guidelines in Demand Response does not consider always product prequalification as a requirement, in some cases system operators might opt for ex-post verification. Ex-post product verification processes are required for specific balancing products and local system operator services, and shall be the default process instead of an ex-ante prequalification if not any of the deviation criteria applies [157]. The rules also address data availability, switching of small units between service providers, and the simplification of prequalification processes [157].

To avoid duplications, a table of equivalences is established, mapping the technical requirements for each product and facilitating the harmonization of prequalification processes [157]. This table will be kept up to date and made public by system operators [157].

3.2.1.3 Grids

Regulation 2019/943 [55] and Directive 2019/944 [158] state some provisions on the management of the grids.

Non discrimination

Based on article 8 of Regulation 2019/943, to provide for a level playing field between all market participants, network tariffs should be applied in a way which does not positively or negatively discriminate between production connected at the distribution level and production connected at the transmission level [55]. Network tariffs should not discriminate against energy storage, and should not create disincentives for participation in demand response or represent an obstacle to improving energy efficiency [55].

Implementing acts stablishing network codes

In accordance with Article 59 of Regulation 2019/943, the Commission has the authority to issue implementing acts to ensure consistent implementation of the Regulation [55]. These acts establish network codes that cover various aspects of demand response, such as aggregation, energy storage, and demand curtailment rules [55].

Furthermore, the European Commission is authorized to adopt delegated acts that supplement this Regulation, specifically in relation to the establishment of network codes in certain areas [55]. These areas include network connection rules, which encompass guidelines for connecting transmission-connected demand facilities, transmission-connected distribution facilities, and distribution systems [55]. Additionally, the connection of demand units used for providing demand response is also covered by these delegated acts [55].

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New capacity

Directive 2019/944, specifically Article 8, outlines the requirements for the authorization process of new generating capacity [158]. Member States are required to establish an authorization procedure that adheres to objective, transparent, and non-discriminatory criteria [158]. These criteria should be defined by Member States to grant authorizations for the construction of generating capacity within their territories [158]. When determining these criteria, Member States must take into account alternatives to new generating capacity, including solutions such as demand response and energy storage [158].

Elaboration of the long-term transmission and distribution network development plan

Lastly, in the network development plans for the transmission system operator (TSO) and the distribution system operator (DSO) is required to thoroughly consider the potential utilization of demand response or other resources as viable alternatives to expanding the system. Moreover, the Directive 2019/944, the Electricity Market Directive states the mandatory requirement to perform national flexibility assessments.

3.2.1.4 Data

The rationale behind Directive 2019/944, the Electricity Market Directive, is to encourage consumer involvement by providing them with the necessary incentives and technologies. Smart metering systems play a crucial role in empowering consumers by offering accurate and timely information about their energy usage or production. This enables consumers to effectively manage their consumption, participate in demand response programs, access additional services, and ultimately reduce their electricity expenses.

Smart meters

Article 20 of Directive 2019/944 sets the rules for the deployment of smart metering systems in the European Union [158]. The goal is to promote energy efficiency and empower customers to participate actively in the electricity market [158]. The deployment may be subject to a cost-benefit assessment[51], and if it is positively assessed, Member States shall deploy smart meters according to the applicable Union data protection rules [158]. Member States must ensure that the functional and technical requirements of the smart metering systems are met. Member States shall also ensure the interoperability of the smart metering systems and their ability to provide output for consumer energy management systems [158]. Final customers must contribute to the associated costs of the deployment in a transparent and non-discriminatory manner [158]. The provisions of this Directive concerning smart metering systems apply to future installations and to installations that replace older smart meters [158]. The text also describes the minimum functionalities of smart metering systems, which should accurately measure actual electricity consumption and securely provide information on actual time of use to customers [158].

Data management

Article 23 of Directive 2019/944 specifies that the security of smart metering systems and data communication must comply with relevant Union security rules, while the privacy of customers and protection of their data must comply with relevant Union data protection and privacy rules [158]. Meter operators must ensure that the meters of active customers who feed electricity into the grid can account for electricity fed into the grid from their premises [158]. Data on the electricity customers fed into the grid and their electricity consumption data shall be made available to them or a third party acting on their behalf [158]. The text also requires appropriate advice and information to be given to customers prior to or at the time of installation of smart meters, in particular concerning their full potential with regard

[51] Process used to evaluate whether the expected benefits of a proposed project, policy, or investment outweigh the expected costs. It involves identifying and quantifying all the costs and benefits associated with the project, policy, or investment, and comparing them to determine whether the net benefits are positive or negative.

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to the management of meter reading and the monitoring of energy consumption, and concerning the collection and processing of personal data in accordance with the applicable Union data protection rules [158]. Smart metering systems must enable customers to be metered and settled at the same time resolution as the imbalance settlement period in the national market [158].

Data exchange

Article 17 of Directive 2019/944 emphasizes the need for fair and transparent regulations regarding data exchange between market participants involved in aggregation and other electricity companies [158]. These rules should facilitate easy access to data on equal and non-discriminatory terms, while also safeguarding commercially sensitive information and protecting the personal data of customers [158].

3.2.1.5 System operators

This subsection focuses on how the system operators have to consider demand response and demand response aggregation in their activities.

Usage of demand response

Articles 17, 31, 32 and 40 of Directive 2019/944 focus on the usage of demand response and aggregation by TSO and DSO. In particular, aims to enable DSOs to efficiently operate their networks and avoid costly expansions by utilizing services from distributed energy resources such as demand response and energy storage. It emphasizes the importance of treating market participants engaged in demand response and aggregation on equal terms with producers based on their technical capabilities [158].

The directive requires member states to establish non-discriminatory regulations for the procurement of ancillary services by TSOs, including those provided by demand response and energy storage facilities. It emphasizes the participation of all qualified market participants, including those offering energy from renewable sources and engaged in demand response and aggregation [158].

Member states are also required to provide a regulatory framework that incentivizes DSOs to procure flexibility services, including congestion management, from providers of distributed generation, demand response, and energy storage [158]. The framework should support the efficient operation and development of the distribution system, promote energy efficiency measures, and reduce the need for capacity upgrades [158].

Both DSOs and TSOs are responsible for ensuring the availability of necessary ancillary services, including those provided by demand response and energy storage [158]. They are required to establish transparent, non-discriminatory, and market-based procedures for procuring these services [158]. The specifications for flexibility services and non-frequency ancillary services should be developed through a transparent and participatory process, ensuring the effective and non-discriminatory participation of all market participants, including those involved in demand response and aggregation [158].

Finally, according to Article 57 of Regulation 2019/943, DSO and TSO are required to collaborate with each other [158]. The purpose of this cooperation is, among others, to ensure coordinated access to resources like distributed generation, energy storage, and demand response [158]. These resources can effectively meet the specific requirements of both the distribution system operators and the transmission system operators [158].

Baselining

In the context of demand response, the concept of baseline has two applications [157]:

- Between the customer and the aggregator.
- Between the aggregator and the system operator.

The guideline on demand response, which exclusively focuses on the second one, explains that the new rules clarify that alternative methods can be used instead of baselining for validating the activation, such as using the final position of the service provider's BRP as a reference, although, the baseline methodology should follow general principles defined at the national level, ensuring transparency, accuracy, and ease of implementation [157].

Gaming opportunities should be prevented by using objective calculation methods, although forecast by service providers can be considered if accuracy checks are in place [157].

The baseline methodology may vary depending on the products and timeframe, but a minimum content for the terms and conditions of service providers should be defined [157]. The validation of the baseline should align with the actual resource profile, potentially involving ex-post analysis and adjustments based on real-time measurements [157].

Sub-metering can be used for measurement, and the rules should cover roles, data collection, accuracy verification, and compliance with standards [157].

For settlement purposes, provisions should ensure data exchange between service providers and the SO, including baseline data, with real-time validation and communication of errors [157]. The data should include activated energy volumes for different products and services [157].

Report on balancing

In Regulation 2017/2195, specifically Article 60 on TSO reporting on balancing, there is a requirement to analyse the costs, benefits, potential inefficiencies, and distortions associated with having specific products in terms of competition and market fragmentation [160]. The analysis also encompasses the participation of demand response and renewable energy sources, the integration of balancing markets, and the potential side-effects on other electricity markets [160].

Consideration in the European analysis

In compliance with Article 30 of Regulation 2019/943, the ENTSO for Electricity is obligated to consider the advancement of demand response as it carries out its responsibilities [55].

Furthermore, article 23 of the same Regulation states that the European resource adequacy assessment should rely on a transparent methodology [55]. This methodology should ensure that the assessment takes into consideration the contribution of all resources, including existing and future options for generation, energy storage, sectoral integration, demand response, and import and export [55]. It recognizes the importance of these resources in enabling flexible system operation [55].

Electricity system operation

Article 3 of Regulation 2017/1485 defines *reserve providing unit* as a "*single or an aggregation of power generating modules and/or demand units connected to a common connection point fulfilling the requirements to provide FCR, FRR or RR*" [161]. It also defines a *reserve providing group* as a "*aggregation of power generating modules, demand units and/or reserve providing units connected to more than one connection point fulfilling the requirements to provide FCR, FRR or RR*" [161].

Moreover, Article 2 of Regulation 2017/1485 on electricity transmission system operation establishes that the rules and requirements outlined in the regulation apply to Significant Grid Users (SGUs) who provide redispatching of power generating modules or demand facilities through aggregation [161].

Last, Article 54 of Regulation 2017/1485 on Operational Operation outlines the responsibilities of SGUs as follows [161]:

1. SGUs must inform the Transmission System Operator (TSO) or Distribution System Operator (DSO) to which they are connected about any planned modifications to their technical capabilities that could impact their compliance with the requirements of Regulation 2017/1485 before implementing such modifications.

2. SGUs must promptly notify the TSO or DSO to which they are connected about any operational disturbances in their facility that could affect their compliance with the regulation.
3. SGUs are required to inform the TSO or DSO about the planned test schedules and procedures to assess the compliance of their facility with the regulation's requirements. The TSO or DSO should approve these schedules and procedures in advance and without unreasonable delay. If the SGU interacts solely with the DSO, the TSO has the right to request compliance testing results from the DSO if they are relevant for the operational security of the transmission system.
4. Upon request from the TSO or DSO, SGUs must carry out compliance tests and simulations in accordance with the regulation's requirements throughout the lifetime of their facility. This includes conducting tests after any faults, modifications, or equipment replacements that could impact the facility's compliance regarding declared values, time requirements, and the availability or contracted provision of ancillary services. Third parties providing demand response directly to the TSO, providers of redispatching of power generating modules or demand facilities through aggregation, and other providers of active power reserves must ensure that the facilities in their portfolio comply with the regulation's requirements.

3.2.1.6 Promotion of demand response

This subsection explores the promotion of demand response and aggregation as a key element in various sectors, including storage and electric vehicles, renewable energy sources, and district heating.

Storage and electric vehicles

The motivation of Directive 2019/944 emphasizes the significance of demand response in facilitating smart charging of electric vehicles and the efficient integration of electric vehicles into the electricity grid [158]. This integration plays a vital role in the decarbonization of the transport sector. Additionally, the directive highlights the importance of empowering consumers to consume, store, and sell self-generated electricity while actively participating in all electricity markets [158]. Consumers can contribute to system flexibility through energy storage, including electric vehicle storage, demand response, and energy efficiency schemes [158].

Renewable energy sources

Article 15 of Directive 2018/2001 highlights the importance of incorporating demand response measures in the integration and deployment of renewable energy sources [50]. Member States are required to ensure that competent authorities at various levels include provisions for demand response in their planning and infrastructure development activities. This includes considering demand response programs and their impact on energy efficiency, as well as specific provisions related to renewable energy self-consumption and renewable energy communities [50]. Additionally, the directive encourages consultation with network operators to reflect the role of demand response in balancing the electricity system and utilizing surplus electricity from renewable sources efficiently [50].

District heating

In the context of district heating systems, Article 24 also of Directive 2018/2001 emphasizes the assessment of these systems' potential to offer demand response services and contribute to system balancing [50]. Member States are tasked with evaluating the capabilities of urban heating and cooling operators in terms of demand response, storage of surplus electricity, and other system services [50]. The objective is to ensure that the utilization of these systems for demand response is resource-efficient and cost-effective compared to alternative solutions [50]. By focusing on demand response, the directive aims to promote flexibility and optimize the integration of renewable energy sources in the energy system [50].

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3.2.2 Analysis of the target countries' national regulation

The purpose of this section is to analyse the national legal frameworks of several target countries, including France, Italy, Portugal, Spain, and Sweden, in order to understand the regulatory landscape for aggregators.

To accomplish this task, we first define the methodology that we used for conducting the analysis, which involved a comprehensive review of relevant legal and regulatory documents. Second, we present the results of our survey for each of the target countries, comparing and contrasting the legal frameworks in each case.

3.2.2.1 Methodology

After the accomplishment of the literature revision, and analysis of the European regulation, a regulatory survey was created to gather information on the regulatory framework of each of the countries. The regulatory survey, which may be seen in detail on section 8.4.

As it may be seen in Table 3.31, the survey was sent on February 16th to different partners of the project to gather information about the focus countries of the project: France, Italy, Portugal, Spain, and Sweden. Other than those countries, we have also received answers from Lithuania and the Netherlands, so, those results are also considered.

Table 3.31: Project partners responsible of the regulatory analysis by focus country, and the countries that have answered on behalf of EDSO (shadowed).

Country	Partners
France	Comillas
Italy	Terna
Lithuania	ESO
Netherlands	Enexis
Portugal	RSE
Spain	INESC-TEC
Sweden	Iberdrola Clientes

The results of that analysis are presented in the section 3.2.2.2.

3.2.2.2 Analysis of the target countries' landscape considering aggregation

This subsection, which is divided in 9 parts, includes an analysis and a comparison of the regulation for aggregators in each of the target countries of the project: France, Italy, Portugal, Spain and Sweden.

General overview of the target countries

In France, even if the largest DSO, Enedis, covers around 95% of the territory and only 6 distributors have more than 100 000 clients (SER in Strasbourg, Réséda in Metz, Gérédis in Deux-Sèvres, SRD in Vienne and GEG in Grenoble) [162], there is a total of 144 distributors[52] in country [163], [164]. The reason for this lies in the nationalization law of electricity

[52] Most of them are "Entreprise Locale de Distribution" (Local Distribution Companies).

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and gas on April 8, 1946, recognized the right of municipalities to retain a role in the public distribution of electricity and gas by maintaining their existing distribution networks under their own management [163], [165]. As a result, in 1946, certain companies, municipalities, or groups of municipalities declined the nationalization proposal and established autonomous public distribution authorities [163]. That said the ownership is largely national and the of the private part, is largely domestic [166]. Last, based on the information provided by RTE, there are 15 aggregators currently providing demand response services [167]. The aggregators in France have been included in the regulation for many years.

In Italy, both the number of suppliers and distributors stands at 122 [168]. Of those, only 10 distributors (e-distribuzione, Unareti, Areti, Ireti, Edyna, Set Distribuzione, Inrete Distribuzione Energia, Megareti, Deval and AcegasApsAmga) have more than 100 000 consumers [166]. The ownership of the companies is largely private and the shareholding is largely domestic [166]. From the survey, even if there is no specific register for aggregator, based on the auctions from 2020 to date, we can infer that there are 30 aggregators. The activities of aggregators first started with the UVAM pilot project[53] about the provision of global ancillary services by DERs.

From the survey, in Lithuania, there are 11 DSO, but most of the distribution grid is managed by one of those (the remaining ones take less than 1% of the grid). The ownership of the distributors is mainly public and the shareholding 100% domestic [166]. There are also 32 suppliers that have been authorized, but only 4 are currently active. Also based on the survey, there are also 10 BSP.

From the survey, the Dutch regulation formalized the role of congestion service provider, which may be seen as an aggregator providing congestion management services. As part of a formal recognition procedure, congestion service providers (CSPs) are registered by the Dutch [169]. Not all CSPs are also BRP [170]. In Netherlands three are dynamic tariffs, as least in pilots, and there are 6 DSO, 3 of which have less than 100 000 clients.

In Portugal, the distribution sector is highly concentrated since E-REDES manages most of the grid, including all the high and medium voltage grid [171]. The remaining 10 distributors, which are almost all of them co-operatives, only manage low voltage grids with less than 100 000 clients [171]. The ownership of the distributors is largely private and the shareholding largely domestic [166]. Nevertheless, there is a high number of suppliers, with 48 suppliers considering both normal ones and last resort suppliers [172]. Last, based on the results of the survey, we don't have information if there are already aggregators legally constituted.

In Spain, even if there are 321 DSO [173], most of the electricity distribution grid is managed by five companies, which are the only ones that have more than 100 000 clients (I-DE, E-Distribution, E-REDES, UFD and Viesgo Distribución) [166]. That said, the ownership of the distributors is largely private and the shareholding largely domestic [166]. Nonetheless, with half a thousand, Spain has a high number of suppliers [174]. There is no official register for aggregators, so we do not have a precise number of the number of organizations that are either providing those services or planning to do so. Nonetheless, there is an association promoting independent aggregation that has 19 members [175].

In Sweden, there are 170 distributors, most of them with less than 100 000 clients [166]. That said, only 6 of those are legally unbundled (E.ON, Vattenfall, Fortum, Göteborgs Energi, Lunds Energi and Mälarenergy) [166], [176]. The

[53] The UVAM (Mixed Enabled Virtual Units) project aims to enable a group of sites, through an aggregator, to modulate their electricity production and consumption, effectively forming a virtual generation/consumption plant. The goal is to allow different types of resources, including residential photovoltaic systems with energy storage, to participate in the dispatch services market. Enel X has initiated a pilot UVAM project in Lombardy, Italy, involving owners of residential storage systems, offering tertiary reserve services and balancing. The project seeks to demonstrate the technology's effectiveness, expand it to other assets like electric vehicles, and highlight the potential of batteries to provide flexibility services and participate in the energy market. Enel X aims to commercialize UVAM and offer aggregation-ready batteries to a wide customer base.

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ownership of the distributors is largely public (municipalities) and the shareholding largely domestic [166]. Based on the answers to the survey, currently there are 9 aggregators in the country.

Table 3.32 shows the main indicators on each of the target countries, and Figure 3.3 and *Figure* 3.4 provide a comparison among the main metrics shown in the Table 3.32.

Table 3.32: Main indicators of the electrical system in each of the countries

	France	Italy	Portugal	Lithuania	Spain	Sweden
Number of aggregators [167], [175]	15	30	0 [54]	6	(19)[55]	9
Number of suppliers [168], [172], [174]	93	122	48 [56]	32	504	100 [57]
Number of distributors [166], [168], [171], [173]	144	122	11	11	321	170
- Of which, legally unbundled [166], [176]	6	10	1	1	5	6
Raw yearly consumption in 2022 [TWh] [64], [177], [178], [179]	452.8	316.8	50.4		250.4	
Historic consumption peak [MW] [179], [180], [181], [182]	103.0	56.8	9.9		45.5 [58]	
- Year of the consumption peak	2010	2007	2021		2009	
Generation capacity in 2022 [GW] [183]	141.0	93.2	18.8	3.7	112.4	43.7
- Nuclear [GW]	61.4	0	0	0	7.1	6.9
- Fossil, biomass and waste [GW]	19.5	55.0	5.2	1.7	34.5	0
- All hydro [GW]	25.6	22.2	7.2	1.0	25.9	16.3
- Wind, both onshore and offshore [GW]	19.5	10.7	5.4	0.7	27.7	12.1
- Solar [GW]	13.1	5.1	1.0	0.3	14.6	0

[54] As far as the respondent of the survey know, there are not currently aggregators in Portugal.
[55] Number of companies that are members of the association *ENTRA Agregación y Flexibilidad*.
[56] Considering both normal ones and last resort suppliers.
[57] From the survey.
[58] As an example of this, if we sum all power contracted by consumers in Spain, we obtained 174 273 MW in 2022, but the peak instantaneous electricity consumption in Spain has never been more than 45 450 MW reached in 2007.

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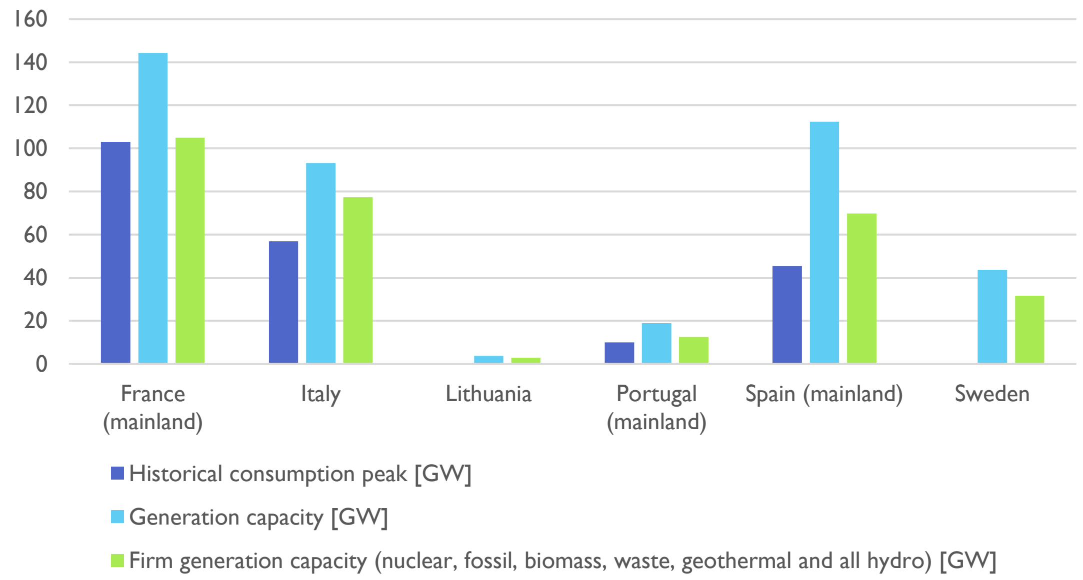

Figure 3.3: Comparison between the maximum consumption peak and the generation capacity in 2022 of the target countries.

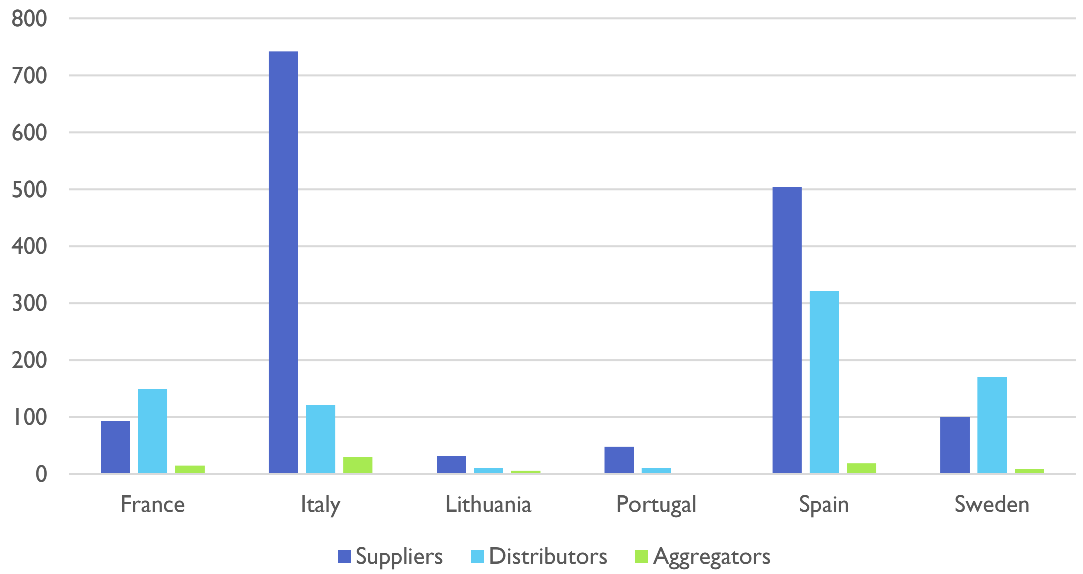

Figure 3.4: Comparison between the number of aggregators, suppliers and distributors for each of the target countries in 2023. The data has been both obtained from the surveys and from [163], [165], [166], [167], [168], [184].

Demand response mechanism

In France, the Government has implemented a system that allows for 2h rotative power outages, which are [185]: organized (planned and implemented as a last resort when all available options have been activated and electricity savings are insufficient), localized (targeted based on a geographical area of around 2 000 customers supplied by the same power line) and temporary (they last for 2 hours for the affected consumers and are limited to what is strictly necessary to minimize inconvenience) [185]. All residents in mainland France, regardless of their electricity contract, can be affected by these organized power outages, except for a few large electricity consumers directly connected to the transmission network and priority sites defined as sensitive locations [185].

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There is also a service for interruptible loads [186], [187]. Nonetheless, French consumers do not have the choice to take dynamic price tariffs, as the regulated tariff is not dynamic and no electricity supplier offers them in the country [188].

Last, Ecowatt is a citizen program implemented (i.e., a "behavioural demand response" as in the U.S., similar to CAISO power alert in California) by the French TSO, RTE, in partnership with the French agency Ademe[59] [189]. The service provides real-time information on the level of French consumption, aiming to encourage individuals, businesses, and communities to limit their consumption, especially during targeted periods when the grid is under stress [189]. According to the TSO, this is the only solution to avoid power curtailment [189]. Already available for several years in certain regions of France through the MonEcoWatt website (Brittany, Provence-Alpes-Côte d'Azur), this service was extended nationwide through a mobile application in 2022 [189].

In Italy, there are and have been interruptible loads for many years [190], [191]. The service, secured with three-year contracts, is an integral part of the national grid defence system and is one of the tools that the TSO has at its disposal for the safe operation of the power system, particularly to mitigate the risk of power outages in various operating conditions (e.g. for frequency stability) [191]. The country also has dynamic tariffs, and every consumer has the right to have a dynamic tariff [69].

Portugal had an interruptible loads system [192], which was phased out in December 2021, as it was not being used, 48 users were in that scheme in 2021 [193]. In 2021, the NRA approved a mechanism thought to substitute the interruptible service [194].

Based on the survey, Lithuania has dynamic, time-based and flat tariffs for households.

In Spain, the framework for interruptible loads has been functioning for many years both in the peninsula and in the Balearic and Canary Islands. Nevertheless, it has been quite controversial and the last auction in the Iberian Peninsula took place in the first half of 2020 [195]. The government proposed the creation of a new mechanism called the Strategic Reserve of Rapid Response[60] as a replacement for the interruptible industrial loads. Currently, that mechanism has not been approved.

Furthermore, the Spanish default tariff for household consumers until December 2023, was based on the price of electricity in the spot price [196]. Nevertheless, as a result of the energy crisis generated by the war in Ukraine, the Spanish Government has changed the algorithm to calculate the price, which will, since January 2024, be more stable and based on long-term markets [197], [198].

Other than those, in Spain, since 2014, the regulation includes the possibility for distributors of using a system known as *General Feeding Line Protection System*[61][118], [199]. This is a system designed to protect the main power line against overloads, preventing power supply failure for the entire building caused by the operation of the fuses in the main protection box. It achieves this by momentarily reducing the power intended for electric vehicle charging. This system can either disconnect loads or regulate the charging intensity. The disconnection and reconnection order can be applied to a contactor or an equivalent system. There is also a strategic reserve mechanism in Sweden that is supposed to reserve a 25% of the capacity for demand response resources, but in which no demand response resource was selected [193].

In Sweden, there are dynamic electricity tariffs [200]. Prior to entering into a contract involving dynamic electricity prices, the electricity supplier is obligated to provide the electricity user with comprehensive information regarding the terms, costs, and risks associated with such an agreement. Specifically, the electricity supplier must obtain the electricity

[59] Agency for the Environment and Energy Management.

[60] Reserva Estratégica de Respuesta Rápida.

[61] Sistema de protección de la línea general de alimentación (SPL).

user's explicit consent to the terms and conditions of a dynamic electricity price. It is important to note that an existing electricity contract cannot be converted into a dynamic electricity price contract unless the electricity user has been provided with the aforementioned information and has given their consent. Additionally, electricity suppliers serving over 200 000 electricity users and equipped with suitable metering infrastructure capable of measuring electricity consumption at regular intervals, at least equivalent to the frequency of market counting, are permitted to offer dynamic electricity price contracts to eligible electricity users. This ensures that users who possess the necessary metering equipment and infrastructure can avail themselves of the benefits associated with dynamic pricing options.

A summary of the current regulatory situation regarding demand response includes shown in *Table 3.33*.

Table 3.33: Current situation of demand response in the target countries.

	France	**Italy**	**Portugal**	**Spain**	**Sweden**
Dynamic price tariffs	No	Yes	No	Yes	Yes
Interruptible service	Yes	Yes	No	No [62]	No

3.2.2.3 Regulation of the aggregators

Independent aggregators may face regulatory hurdles in some regions, as regulations governing electricity markets and distribution can be complex and may not always be supportive of aggregation. In some cases, regulators may be slow to adopt rules that allow for independent aggregators to operate, or they may impose onerous requirements that make it difficult for aggregators to function effectively.

France has a long history with the residential DR programs, for long time, suppliers could value load curtailment within its own portfolio and, in fact, one of its main aggregators has been authorized by the TSO since 2008 [201]. Nonetheless, in 2013, the Brottes Law, created the mechanism NEBEF (*Notification d'Échange des Blocs d'Effacement* [63]) which allowed from that moment on load curtailment operators to interact in the wholesale electricity markets [202], [203]. As the mechanism did not exists in other countries, the first year (from end 2013 to end 2014) was devoted to testing and the load curtailment operators were encouraged to propose improvements, and the first rules, NEBEF 1.0, were published in December 18th, 2013 [203]. The current regulation for load curtailment goes back to 2015 [204], [205], and the last framework on aggregations was stablished, mainly, in 2015 and 2016. That said, Directive 2019/944 has also been mainly transposed.

The current framework on load curtailment, creates the load curtailment operator, that can be an electricity supplier, but that must provide a separate and independent load curtailment service, distinct from the supply offer, enabling the efficient utilization of load curtailment [204], [205].

The current regulation indicates that the TSO defines the rules for load curtailment in energy markets and the adjustment mechanism, following consultations with stakeholders in the electricity markets and DSOs [204], [205]. These rules, along with the consultation results, are subject to approval by the NRA [204], [205]. The rules, which must be published by the TSO on the website, may be revised in the same manner, either at the initiative of the TSO, or upon request by the Government or the NRA [204], [205].

The Italian NRA, ARERA, has established the legal basis for the participation of demand side resources to ancillary services market (MSD) [206]. Following this decision, the Italian TSO, Terna, has issued rules concerning the rules for

[62] It does not exist in the Iberian Peninsula, but it does in the islands.

[63] Notification of the Load Curtailment Blocs in French.

the participation of DERs in MSD. Nevertheless, it seems that there is an absence of secondary regulation in the country [190].

In Lithuania, the term of aggregation and independent aggregator has been introduced in 2021 and there is also a separate document which specifies the calculation of independent's aggregators baseline (for balancing market).

In Portugal, aggregators were introduced in 2022, when Decree-Law 15/2022 established the activity of aggregation defined as the combination of demand flexibility, storing of electricity, generated electricity and demand from multiple clients to buy and sell in electricity markets or by bilateral contracts [71]. This decree does not specify in which markets aggregators can operate, simply indicating that they can buy and sell products electricity markets or by bilateral contracts [71]. This lack of specific details on this issue can become a barrier to the development of this activity.

In Portugal, the NRA has recently made a public consultation on multiple aspects of the regulation of aggregators, such as [207]: operationalize emerging realities such as aggregation activities (including last resort aggregation) to develop the energy acquisition market for small producers and involve smaller customers in flexibility services (demand response). Allow the logistic operator responsible for changing suppliers to also handle the change of aggregators; operationalize storage activities, including autonomous storage, to enhance their contribution to the resilience and efficiency of the electricity system through flexibility; mandate large suppliers to offer fixed, indexed, and dynamic price options to consumers, ensuring diversity of offerings and choices; and establish flexible management of distribution networks.

In Spain, the figure of the independent aggregator has been partially transposed in 2020, as only the definition and the right for consumers and storage owners to get paid and participate in any market through the figure of independent aggregator [72]. Furthermore, Law 7/2021 mandates that within twelve months of its enactment, the Government and the Spanish national regulatory authority are required to submit a proposal to reform the energy sector's regulatory framework to encourage the active involvement of energy consumers in energy markets, including the facilitation of demand response through independent aggregation [208]. However, it is worth noting that this milestone has not been met thus far.

Other than that, the Annual Regulatory Plan of the Government has indicated for the last years that it is going to transpose Directive 2019/944 integrally [209]. Based on this, the Ministry for Ecologic Transition has performed the public previous consultation process between February 6th and February 27th, 2023, asking the opinion about aspects such as [210]: ensuring consumer rights and protection, identifying areas for improvement in electricity supply regulations, addressing additional regulatory aspects related to the transposition of Directive 2019/944, exploring regulatory development in the retail sector, determining the approach to the development and deployment of independent aggregators while adhering to regulatory principles, and considering the appropriate model for promoting the role of independent aggregators while minimizing potential issues for other sector agents.

Sweden has regulated the activity of aggregation and aggregators have been active in the country since 2020 [200]. *The role was introduced by Ei*[64] *during 2020 through a report on the Clean Energy within EU* (Ei 2020:20, 5:14). Based on the survey, in 2021, the Ei published a proposal (Ei R2021:03) to include a new chapter in the Swedish Energy Act that would establish the independent aggregator as a recognized legal entity. Subsequently, on February 9th, 2023, a legislative proposal was released, with the expectation that it will become effective in June 2023.

In Sweden, other operators in the electricity market cannot prevent an aggregation service provider from accessing the market. Regardless of their contract with an electricity supplier, electricity users should have the freedom to purchase and sell electricity services beyond just the supply of electricity, without needing the supplier's consent. Before providing aggregation services at an electricity user's location or taking over such services from another provider, the

[64] *Energy Inspectorate*, the Swedish National Regulatory Authority

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aggregation service provider must notify the network operator with whom the electricity user has a contract. An electricity supplier cannot impose excessive charges or unreasonable requirements on an electricity user based on their contract for aggregation services.

An aggregator must provide information about contractual terms to electricity users before entering into an aggregation service contract, in a non-discriminatory manner concerning costs, work, and time. Upon request, the provider should disclose the flexibility of an electricity user's queries, and ensure that users can switch aggregation service providers within three weeks of the request. The information related to query flexibility should be provided to the electricity user without any cost. Switching to a new aggregation service provider should be free of charge for consumers and small enterprises.

Table 3.34 provides a summary of the current situation on the primary regulation.

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Table 3.34: Current situation of independent aggregators in the European Union.

	Directive 2019/944 transposed regarding aggregators	Main regulation
France	Yes	Decree n. 2015-1832 Decree n. 2016-1132 Decree n. 2017-437
Italy	Yes	Legislative Decree, November 8th 2021, n. 210 Deliberation August 3rd 2021 352/2021/R/eel Deliberation May 5th 2017 300/2017/R/eel
Portugal	Yes	Decree-Law 15/2022
Spain	Only the definition	Royal Decree 23/2020
Sweden	No [65]	-

3.2.2.4 Framework for the distributed energy resources

This section compares the target countries based on the deployment of smart meters, provides information on how the measures are taken, which are the baselining methodologies used and whether submetering is allowed and used in the country.

Smart meters and measuring

In France, the rollout of smart-meters does not reach the total amount of consumers, but has been steadily increasing the amount of consumers and, at the end of 2021, 90% of the residential consumers had already a smart meter [159]. Furthermore, the French smart meters are among the most advanced, as they include capabilities like remote control of consumption and critical peak pricing [159]. In the European Union, only Austria, Germany, France, Norway and Sweden provide the former, and only Denmark, France, Latvia, Norway and Slovenia provide the latter [159]. A new functionality will be tested soon: remote temporary capacity limitation for residential customers during extreme peak events [211].

In Italy, smart meters are mandatory for all low voltage grid users (either consumers, generators or storage sites) since 2007 [212] and, currently, the rollout of the smart-meters reaches 98,6% of household consumers [159]. Based on the answers of the survey, the granularity is hourly for consumers and for generating resources not participating in global markets[66], and in the UVAM pilot project the granularity is 4 s for the aggregate while for unbalance calculation the relevant period is 15 minutes corresponding to global services smart meters.

The deployment of smart meters in Portugal has been slowly increasing. The country had quite recently overpassed 50% rollout in residential consumers. Nonetheless, the resolution of the smart-meters ranks among the highest, with 15 minutes resolution already in 2018 [213].

In Lithuania, mass smart meter rollout started in 2022. In 2019, only around 2,8% of the consumers had a smart-meter but [214], currently, based on the survey, more than 450k smart meters are installed (~30%). The target is to have a

[65] Not by the time of writing the report. The legal proposal has been approved and turned into force the 1st of june. The Swedish Energy Act is updated according to SFS 2023:238.
[66] "MSD" (Mercato Servizi di Dispacciamento) Ancillary services market

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70% of meters changed to smart meters by the end of 2025. The smart meters have hourly resolution, but 15-minutes is also possible. The data from CEER says that the country has 87% deployment in households [159].

From the survey, in the Netherlands, retail consumers get a smart meter from the DSO with a 15-minutes resolution. Large consumers need a metering company to place, read and maintain the meter, which also has a 15-minute resolution.

In Spain, more than 99% of consumers with less than 15 kW had already a smart meter in 2019 [214], [215]. Based on the survey, road map to 15 minutes resolution is ongoing.

In Sweden, the regulation specifies that, if an electricity consumer wishes to have their electricity consumption measured in a manner different from the regulations specified in the regulation, the network operator can charge them for the additional cost of the alternative measurement method and reporting the results [131]. If the alternative measurement requires a different metering device than the one prescribed in the regulations, the consumer will be responsible for the cost of the meter and any additional equipment needed for its installation at their point of electricity usage.

Nevertheless, there should be no additional charges imposed on an electricity user neither when they enter into an electricity supply contract that specifies hourly measurement of transferred electricity nor when they request the network operator to provide information regarding their hourly electricity consumption. Furthermore, a network operator is authorized to charge an electricity producer for the cost of a meter, its associated collection equipment, and installation at the entry point of the electricity producer.

Table 3.35 summarizes the situation of smart metering, and Figure 3.5 the evolution of the smart meter deployment in France, Italy, Portugal, Spain, and Sweden.

Table 3.35: Main indicators regarding smart meters in each of the countries.

	France	**Italy**	**Portugal**	**Lithuania**	**Spain**	**Sweden**
Household consumers with smart meters [159]	90,0 %	98,5 %	52,0 %	89 %	99,6 %	100 %
Time resolution [min.] [213]	30 (10 [67])	15	15	60 (15 [68])	60 (15 [69])	60 (15 [70])
Time-of-use with intra-day / weekdays / weekend energy price differentiation [159]	Yes	Yes	Yes	Yes	Yes	No
Real-time / hourly energy pricing [159]	Yes	No	No	No	Yes	Yes
Remote control of consumption [159]	Yes	No	No	No	No	Yes

[67] By default, the consumer takes a measure every 30 minutes, but the frequency may be increased to 10 minutes **Invalid source specified**.

[68] 15 minutes resolution is possible, but 1 h is currently used, based on the survey.

[69] Based on the survey, 15-minutes resolution is being deployed.

[70] Smart metering systems are currently being implemented in Sweden, with E.ON's grid having completed 50% of the deployment. It is expected that Swedish customers will have the new smart meters installed by 2025. Additionally, starting from November 1, 2023, there will be a legal requirement for meters to provide readings at a 15-minute resolution, as specified in SFS 2018:1426.

	France	Italy	Portugal	Lithuania	Spain	Sweden
Critical peak pricing [159]	Yes	No	No	No	No	No

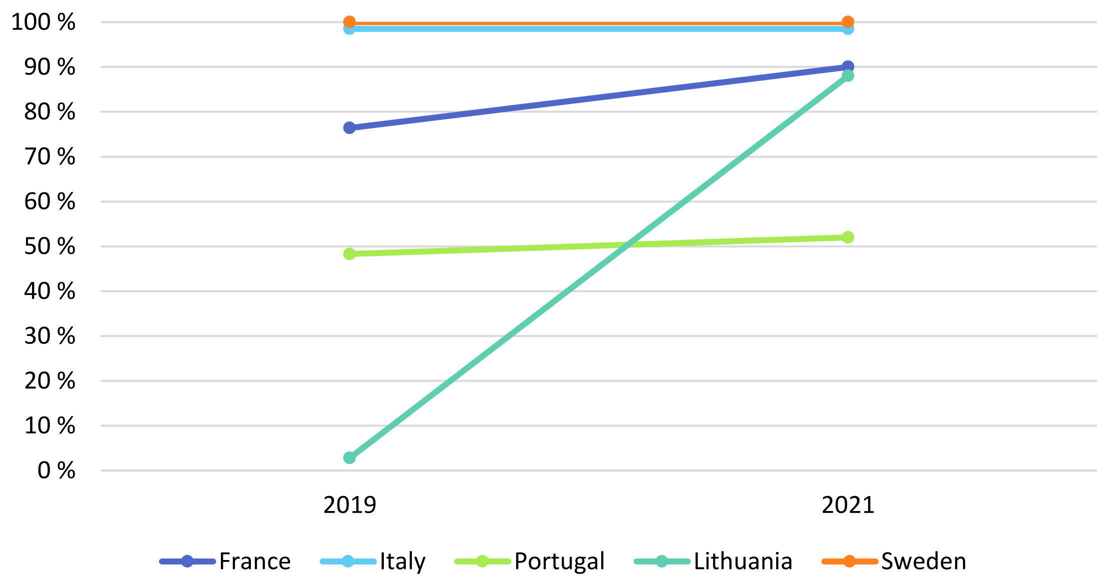

Figure 3.5: Evolution of smart meter deployment in the target countries for household consumers [106], [159], [214]. *Data from ESO differs from the one in the ACER and CEER report, but the latter has been kept for coherence.*

Baselining

The French framework defines the consumers, the demand-response unit, composed of multiple consumers, and the demand-response operator, composed of multiple demand-response units. That said, the framework defines two kinds of consumers and groups of consumers bases on how the measures are taken [216]:

- **Profiled consumer** [71]: Consumers connected directly or indirectly to the distribution network, whose consumption is estimated based on a profile. The rules of the electrical power system define a set of residential and professional profiles since, at least, 2003.
- **Remotely-read consumer** [72]: Consumers which are not profiled.

Table 3.36: Peak hours in the French regulation based on whether the consumer is a profiled or remotely read.

	Profiled	Remotely read
Off-peak hours	Remaining hours	Remaining hours
Peak hours	Between 7h and 23h	Between 8h and 20h and between Monday and Friday

[71] « Profilé » in French.
[72] « Télérelèvé » in French.

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Based on this, the framework also defines two kinds of demand-response units [216]:

- **Profiled demand-response unit**: Composed exclusively of consumers that have a consumption below the limit defined to be a profiled consumer.
- **Remotely-read unit**: Remaining ones.

And, based on that framework defines four kinds of baselining, some of them applied exclusively for some kinds of demand-response units and consumers [216]:

- **Double-corrected reference rectangle** [73]: On each Half-Hourly Interval of the Demand Response Range considered, the value of the Demand Response Entity Reference Curve is equal to the minimum value between the initial reference power and the final reference power. The initial reference power is the average power per Half-Hourly Interval of the Demand Curve of the Demand Response Entity, over a duration equal to the Demand Response Range considered to end at the Start Time of 'Erasure. The final reference power is the average power per Half-Hourly Interval of the Demand Curve of the Demand Response Entity, over a duration equal to the Demand Response Range considered to start at the Time of End of Demand Response.
- **Site-to-site algebraic rectangle**: It is only applicable to profiled units with more than 3.000 consumers and it is calculated as the sum of the individual reference baselines for each of the sites.
- **Consumption historic**: The median or the mean average of either the last ten days of the last four weeks is used to estimate the baseline. It may only be applied for consumption points with smart meters.
- **Consumption forecast**: A forecast for the whole week is given Friday of the week before is used as baseline. As the last, may only be applied for consumption points with smart meters.

The French DSO Enedis has proposed multiple other methodologies [217].

To check if the service has been indeed provided, the French framework uses some measures. As an example, in the two last baselining methodologies (the ones that are applied for consumption points with smart meters), Equations (1) (absolute error) and (2) (centration error) are used to check the provision of the service.

$$\varepsilon = \frac{1}{N}\sum_{i=1}^{N}\frac{|referenceconsumption_i - realconsuption_i|}{maximum\ reduction\ capacity} \quad (1)$$

$$\varepsilon' = \frac{1}{N}\sum_{i=1}^{N}\left|\frac{reference\ consumption_i - real\ consuption_i}{maximum\ reduction\ capacity}\right| \quad (2)$$

According to the survey conducted, in Italy, the baseline is currently being considered by the law in connection with the UVAM pilot project. The responsibility for communicating the baseline lies with the BSP [218]. This communication should be made for each quarterly period included in each sub-phase of programming, following the defined modalities and format by the TSO [218].

In Lithuania, a methodology to calculate of independent's aggregators baseline (for balancing market) has already been defined.

Neither in Portugal nor in Spain baselining is not currently considered in the legislation.

[73] « Rectangle a double réference corrigée » in French.

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In Sweden, based on the survey, baselining methodologies have not been defined in law. Nevertheless, existing aggregators are using different baselines methodologies depending on the assets.

Last, even if not included in the list of countries analysed, the United Kingdom uses a "High X of Y" methodology. The process to calculate the baseline on a given settlement day, using half-hourly metered data [219]:

- **Step 1**: Historical settlement days within a sixty-day window (from D-60 to D-1) are identified to calculate the operational baseline. The selection starts by identifying "Eligible Days" for each relevant Unit Meter Point, which are settlement days within the sixty-day window that matches the same time type as the target day (either working day or non-working day), have available half-hourly metered data for the unit meter point, are not event days[74], and are not "clock change" days [75].
- **Step 2**: The Unadjusted Baseline Value is calculated for each Settlement Period of the target day (Day D). Firstly, a subset of historical Settlement Days identified in Step 1 is chosen based on the type of day (Working Day or Non-Working Day). For a Working Day, all six to ten Eligible Days from Step 1 are used, while for a Non-Working Day, two of the four Eligible Days are selected (the middle two based on the total Unit Meter Point Metered Volume). Then, for each Settlement Period in Day D, the Unadjusted Baseline Value is determined as the average of the Half-Hourly (HH) Metered Volume for the corresponding Settlement Period across the chosen historical days. When Day D coincides with a clock change day, special considerations are made:
  a) In the case of a "long day" with fifty Settlement Periods, Settlement Periods 1-2 on Day D correspond to the same periods on the historical day, Settlement Periods 3-4 on Day D correspond to periods 1-2 on the historical day, and Settlement Periods 5 to 50 on Day D correspond to periods 3-48 on the historical day.
  b) For a "short day" with forty-six Settlement Periods, Settlement Periods 1-2 on Day D match periods 1-2 on the historical day, and Settlement Periods 3-46 on Day D correspond to periods 5-48 on the historical day. These mapping rules align with the ones used for Energy Contract Volume Notifications in Section P of the BSC (Balancing and Settlement Code).
- **Step 3**: A In Day Adjustment is calculated specifically for residential units. This adjustment takes into consideration fluctuations in factors such as weather and temperature. It involves comparing the actual metered data during the three-hour period preceding one hour before the relevant Settlement Period with the calculated values. An additional adjustment is then made to ensure that the baseline profile aligns with the actual data.

Table 3.37 summarizes the situation baselining in the target countries.

Table 3.37: Summary of the situation of baselining in each of the countries.

	France	**Italy**	**Lithuania**	**Portugal**	**Spain**	**Sweden**
Baselining considered in regulation	Yes	Yes (testing)	Yes	No	No	No

[74] Refers to a Settlement Day with a Settlement Period where the TSO issued a demand flexibility acceptance, the associated unit meter point has an owner or occupier who confirmed participation in the service delivery, and it is not a non-Participating day.
[75] Such as the start and end of British Summer Time.

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Measurement and validation

In France, for energy supply, the system operators are responsible of ensuring colleting and validating the measurements. Particularly for load curtailment, the TSO validates the methods for assessing the volume of load curtailment and the rebound effect, based on objective, transparent, and non-discriminatory criteria [204], [205]. The data must be transmitted by the DSO to the TSO. Third parties proposing such methods to the operator must provide all necessary data for the evaluation of these methods. Furthermore, if the metering data available to the DSO or the TSO do not possess the required characteristics for the precise evaluation of load curtailment or rebound effects, statistical data-based methods may be employed as long as they yield reliable results.

In Italy, according to the survey conducted, the DSO is responsible for collecting and validating measurements for the distribution grid, while the TSO performs this task for the transmission grid. The TSO validates the service delivery based on measurements obtained from the certified meter provided by the DSO. In Italy, when there is no smart meter, BSPs may communicate measurements that are matched with uncertified DSO measurements.

Particularly, in the context of UVAM[76], the process of data verification and validation involves the TSO ensuring that each point included in the UVAM meets the specified requirements [218]. Once the verification is successful, the TSO communicates the associated points to the relevant system operators [218]. The system operators have the option to validate a point without any technical limitations, specify operational technical limits for dispatching services within the MSD (Dispatching Services Market), or reject the validation with appropriate justification [218]. The TSO may accept the enabling request and proceed with technical tests in collaboration with the UVAM or reject the request, providing reasons, or propose modifications [218]. The TSO reserves the right to conduct inspections and verifications at the solicitor facilities, and if any false statements are discovered, the TSO may revoke the UVAM enabling for the MSD [218].

In Lithuania, both the measuring and the storage of the data is managed by the DSO. If there are no smart meters (the deployment of smart meters is low), customers have to provide their consumption to the supplier, which checks it from time to time. Nevertheless, there does not seem to be a method to use aggregation is smart meters are not available.

In the Netherlands, as specified in the survey, the DSO is in charge of measuring the consumption of small consumers. For large customers an independent metering company is in charge or this task [220].

In Portugal, the DSO is the owner and is in charge of installing, gathering, and managing the operation of the smart meters. Moreover, the management of information is also handled by the DSO. Each consumer location is assigned a unique connection code, known as the Customer Point Identifier (CPE), which serves as its identification. This CPE code is linked to the consumer's supply contract with a retailer, and the relevant meter readings are subsequently transmitted to the retailers for billing purposes.

Furthermore, consumers have the option to personally read their energy meters and share the readings with their contracted retailer. Retailers are obligated to provide consumers with automated phone systems or online platforms for submitting their measurements. Additionally, as per the Quality-of-Service Code, the DSO is required to conduct physical measurements at least once every three months. In months when no physical measurement is available, billing will be based on estimated values.

[76] "Unità Virtuali Abilitate Miste" (UVAM) refers to Virtual Aggregated Mixed Units in the context of the electricity market. UVAMs are characterized by the presence of production units (both relevant and non-relevant), storage systems, and consumption units [218]. They can also be included in dispatching contracts of different users. The UVAM pilot project also encompasses storage systems dedicated to electric mobility, as they are comparable to other storage systems in terms of connection points to the grid for charging and discharging. Therefore, the UVAM pilot project acts as an enabler for the "vehicle-to-grid" technology within the Dispatching Services Market (MSD). They have been created for the purposes of testing in the "*Regolamento Recante le Modalità per la Creazione, Qualificazione e Gestiona di Unità Virtuali Abilitate Miste (UVAM) al Mercadto dei Servizi di Dispacciamento*".

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In Spain, DSO and TSO, within regulatory framework, are in charge of collecting and storing the measuring data. In Sweden, DSO gathers and stores the measures as well as perform the validation. If ever there is no smart meter, the settlement data is estimated.

Submetering

In France, starting from June 1st, 2021, RTE, the TSO, initiated an experiment on submetering, which involves measuring reductions in electricity consumption based on measurements taken at a smaller scale than the consumption site [216]. This experimental phase will last until December 31, 2023, and its extension will depend on the lessons learned from the experiment [216]. The objective of the experiment is twofold [216]:

- Identify new sources of reductions.
- Improve the accuracy of measuring these reductions while avoiding any risk to the actual reductions achieved at the site level.

To minimize potential risks, the experiment is conducted within a framework that includes the following conditions [216]:

- Each aggregator is allowed a maximum of twenty (20) remotely monitored consumption sites and five thousand (5 000) profiled consumption sites.
- The maximum power that can be reduced by each aggregator is 100 MW across all segments.
- RTE sets a global power limit for the experiment to maintain the stability of the electrical system. This limit is made public on RTE's website and may be increased based on positive outcomes from the initial phase of the experiment.
- Each participating consumption site is required to conduct a minimum of five (5) reduction programs, each lasting at least thirty (30) minutes, within the first two years of participation. These programs must cover at least 50% of the declared reducible power of the consumption site, following the qualification procedures.

The experiment is open to sites connected to both the distribution and the transport grid [216]. During the experiment, eligible sites have access to the "double-corrected reference rectangle" method and the "site-to-site algebraic rectangle" method for measuring reductions, but not to the "consumption history" method [216]. The "consumption forecast" method is also available, but only for eligible for sites connected to the distribution grid [216].

Neither Italy, nor Portugal, nor Spain seems to have regulated the submetering of energy.

In Sweden, based on the survey, submetering is utilized for validating the delivery of flexibility in cases where alternative solutions are not available in flexibility markets. However, there is currently no legal implementation for this practice. Energy optimizing and flexibility tracking devices are connected to existing meters in households.

Table 3.37 summarizes the situation baselining in the target countries.

Table 3.38: Summary of the situation of submetering in each of the countries.

	France	Italy	Portugal	Spain	Sweden
Submetering considered in regulation	Yes (testing)	No	No	No	No

Rebound effect

France seems to be the unique country targeted in the project that has considered rebound effect on his regulation. In fact, Decree 2016-1132 indicates that a specific consumer site can lead to changes in its consumption patterns before and after the erasure period [205]. These effects are considered if they are proven and significant, during the certification, energy transfers between the responsible balance areas, and the payment from the erasure operator to the supplier of the erased sites. In cases where these effects cannot be precisely evaluated and accounted for within the balance areas for each erasure without requiring disproportionate means, the rules may allow for a normative consideration of these effects based on conducted studies.

Contract for aggregation

In France, an integrated load curtailment service is obtained through a contractual agreement between an electricity end consumer and their electricity supplier [204], [205]. This agreement includes flexible periods that are communicated to the consumer in advance. During these periods, the variable part of the supply price is significantly higher than the rest of the year, and separate tracking of consumed electricity quantities is conducted. The load curtailment operator must obtain prior written or electronic consent from the respective end consumers before implementing load curtailment.

In Italy, according to Legislative Decree n. 210/2021, and following what has been indicated in Directive 2019/944, customers are free to purchase and sell all services related to the electricity market other than supply and to enter into aggregation contracts with electricity companies of their choice, without the need for consent from their electricity supplier [69]. Customers have the right to receive comprehensive information from market participants involved in an aggregation regarding the terms and conditions of offered contracts, as well as to receive free access to demand management data and data on supplied and sold electricity, at least once per billing period. These rights apply to all customers, including final customers, without discrimination in terms of costs, charges, or timing, and customers cannot face any burdens or discriminatory actions from their suppliers for participating in an aggregation contract. Customers also have the right to participate in aggregations for the collective management of their electricity demand, regardless of their supply contract and without the consent of their respective suppliers. The aggregator informs the participating final customers of the terms and conditions for managing their electricity demand. Transmission and distribution system operators ensure equal treatment between participants in aggregations and producers in terms of demand management when purchasing ancillary services, based on their respective technical capacities.

Neither Spain nor Sweden seem to have regulated this aspect yet.

3.2.2.5 Data exchange and confidentiality

In France, the necessary information is given to the TSO, who centrally manages the data that is needed for aggregation.

In the Netherlands, the metering data is centrally stored in a register, as part of EDSN IT-platform facilitator to enable interactions and data exchange between the various roles in the energy sector [221].

In Italy, the primary regulation specifies that the roles and responsibilities of electricity companies and customers must be defined based on non-discriminatory and transparent rules, and data exchange between market participants involved in an aggregation and electricity companies should occur through transparent and non-discriminatory norms and procedures that provide equal access while protecting commercially sensitive information and customer personal data [69].

In Spain, the distributors[77] have created and are promoting a platform called Datadis [222]. This platform allows access to the data of multiple supplies from a single location, providing convenience and efficiency for any user that needs the data from a centralized platform. This platform might serve as a valuable tool in the ongoing efforts to enhance the accessibility and utilization of electricity data for improved decision-making and optimization within the energy sector.

[77] The five biggest five distributors (e-Distribucion, E-Redes, i-DE, UFD and Viesgo) and the two associations (Cide and ASEME) including the smaller distributors are promoting the platform.

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3.2.2.6 Market access and compensations

This section covers different aspects related to the participation of aggregators and demand response in markets.

Market access

In France, based on the regulation, the load curtailment operator may access markets for energy and balancing [204], [205].

Current legislation in Italy specifies that the NRA is responsible for defining technical rules, including those related to aggregated loads, and detailed rules for participation in the internal electricity market by entities involved in aggregations for demand management, ensuring the right of market participants to enter the internal electricity market without requiring consent from other participants [69]. Moreover, the UVAM units are allowed to provide ancillary services markets [218].

In Lithuania, currently, based on the survey, it is the TSO who sends the order for aggregators participating in balancing market. If DSO would be the one procuring flexibility (even though at the moment DSO does not procure it) they would be the one sending signal. That said, there is no independent market operator for the balancing market.

In Portugal, according to the primary legislation, an aggregator has various rights, including the ability to trade electricity through organized markets or bilateral contracts, aggregate and represent non-remunerated electricity producers, access networks and interconnections for electricity delivery to customers, and freely contract the purchase of electricity with the producers they aggregate [71]. Nevertheless, there is a lack of secondary regulation.

In Spain, this aspect has not been regulated yet.

In Sweden, the flexibility services in distribution networks are regulated as follows:

1. A distribution network operator is required to develop specifications for flexibility services and standardized market products for such services after consulting with transmission system operators and other relevant market participants.
2. The operator must submit these specifications and market products to the Energy Inspectorate for approval.
3. Once approved by the Energy Inspectorate, the operator is obligated to publish a list of the market products.

The Energy Inspectorate is responsible for approving the specifications and market products to ensure the effective and non-discriminatory participation of relevant market participants. Additionally, the Energy Markets Inspectorate has the authority to issue regulations on the publication of the market product list.

Furthermore, the Government or the designated authority may establish regulations concerning the obligations of distribution network operators. These regulations may include requirements for developing specifications for flexibility services, obtaining approval from the network authority for these specifications and market products, and publishing a list of market products. The regulations may also outline the criteria that specifications and market products need to meet.

Compensations for the transfer of energy

In Europe, most, but not all countries have opted for a central settlement method [223]. Nevertheless, it remains unclear which is the best model, as for example, a corrected model, if applied to load curtailment provides the following advantages: has low transaction costs and equals the compensation price to the retail price. The uncorrected model, e.g., is mostly used for the provision of symmetrical, capacity payments.

In France, the primary regulation defines a methodology for compensations between the aggregator and the supplier. That said, when load curtailment is valued in energy markets or balancing markets, the payment amount owed by the end consumer to the supplier of each affected site is determined as follows [204], [205]:

1. The supplier invoices the end consumer, based on their contractual agreement, for the energy that would have been consumed if there was no load curtailment. The energy quantity is determined by the TSO during the certification process for load curtailment volumes.
2. Alternatively, the load curtailment operator may directly make the payment instead of the end consumer. The payment is determined using predefined scales based on specific consumer categories outlined in the rules. These scales consider the characteristics of the affected consumption sites. The methodology, reference costs, and frequency of scale revisions are defined within these rules. The scales reflect the energy portion of the supply price for the consumption sites subject to load curtailment. They may be further detailed based on consumer profiles and are publicly available on the website of the electricity transmission network operator.
3. The rules also allow for the establishment of payment arrangements through a contract between the load curtailment operator, the supplier, and, if applicable, the end consumer. The load curtailment operator and the supplier inform the transmission system operator about the conclusion of such a contract.

A specific account is opened by the TSO or a designated third party to track and centralize financial transactions between the load curtailment operators, the TSO, and the electricity suppliers. It also includes financial flows between the BRP and the TSO related to load curtailment activities valued in energy markets and, if applicable, the balancing mechanisms [204], [205]. The actor who opens the account is also responsible for the administrative, accounting, and financial management of this account in accordance with private accounting rules [204], [205]. They handle invoicing and collection of amounts owed by the erasure operators to the suppliers, identify any payment defaults, and, if necessary, implement guarantees provided by the erasure operators [204], [205].

The interest generated by the funds in the account is primarily used to pay the remuneration for managing the account by the operator of the public electricity transmission network or the designated third party, as well as the expenses incurred for this management [204], [205]. The total amount paid by the fund to each supplier, after deducting the amount covered by the TSO, cannot exceed the amount owed to the operator and actually paid by the load curtailment operators [204], [205].

Financial safeguards are implemented to ensure the financial capacity of the erasure operators to honor their obligations to all suppliers [204], [205]. After implementing the payment recovery procedure, if a discrepancy is found between the amount paid and the amount owed by a load curtailment operator to a supplier, the supplier may request TSO to disclose the identity of the defaulting load curtailment operator and the outstanding amount due to the supplier [204], [205].

Based on what has been said, the French Grid Code provides three different models for compensating the supplier [216]:

- **Contractual Model**: The terms of payment owed by the aggregator to the supplier following a curtailment of electricity consumption are defined by a contract between the aggregator and the supplier, and, if applicable, the given consumer.
- **Corrected Model**: The aggregator to the supplier following a curtailment of electricity consumption is ensured, on behalf of the aggregator, by the end consumer. The supplier invoices the end consumer, based on the contractual terms between them and using the supply component of the price of supply, for the energy that would have been consumed in the absence of curtailment.
- **Regulated Model**: The payment owed by the aggregator to the supplier following a curtailment of electricity consumption is determined based on flat rate schedules. We understand it corresponds to the central settlement model defined by USEF.

Table 3.39 summarizes the different aggregation models and the conditions to be applied.

Table 3.39: Models for the relationship between the aggregator and the supplier in the French framework [167].

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Conditions	Compensation model		
	Corrected	Regulated	Contractual
More than 36 kVA and with smart meter	Compulsory	Not allowed	Not allowed
Otherwise	Not allowed	Default	Allowed if agreed between the aggregator and the supplier

Other than that, the French framework also defines a formula to calculate the price for the energy compensated to the aggregator. The formula differs depending on whether the consumer is a profiled one or it is has a smart meter, and whether the consumer has a flat tariff or a time of use tariff [167]. When the consumer is a profiled one, the formula uses the ARENH price, the capacity price, the electricity futures price and, only if the energy offer is a time of use one, the futures for the peak hours and for baseload energy. Otherwise, the formula also considers multiple time variables, as the hour of the day, the season.

Neither in Italy, nor Spain nor in Portugal have defined the framework for the compensations for the transfer of energy.

Last, in Sweden, based on the survey, compensation mechanism is suggested in the legal proposal, but the methodology has not been determined yet.

The summary of the models found are shown in Table 3.40.

Table 3.40: Summary of the models for the relationship between the aggregator and the supplier.

Country	Contractual			Non-contractual		
	Integrated	Broker	Contractual	Uncorrected	Corrected	Central settlement
France	-	-	< 36 kV	-	≥ 36 kV w/ smart meter	< 36 kV
Italy	-	-	-	-	-	-
Portugal	-	-	-	-	-	-
Spain	-	-	-	-	-	-
Sweden	-	-	-	-	-	-

Prequalification

In France, the technical approval process aims to verify the load curtailment operator's capability to implement load curtailment effectively, without predefining the specific technical methods used for load curtailment [204], [205]. Approval is granted based on transparent, objective, and non-discriminatory criteria. The load curtailment operator has the option to aggregate the load curtailment capacities of multiple consumption sites, allowing for collective optimization and utilization of the achieved load curtailment. Depending on the kind of baseline and metering device, the prequalification of the resources, units and the aggregator is slightly different.

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According to the survey findings, in Italy, there is a pre-qualification process consisting of two phases for both frequency control and constraint management of DERs. In the first phase, the TSO verifies the DERs' technical data for compliance with its rules. In the second phase, the DERs are required to successfully undergo a technical test as prescribed by the TSO.

In Lithuania, from the survey, in the frequency control markets, the prequalification process is applied for aggregator not for the specific DERs. In the constrain management market, there is a qualification for each set of DERs which would provide services in specific location.

In the Netherlands, the basic congestion management service providers recognition procedure consists of two parts [169]: approving a party as a congestion management service providers and pre-qualifying connections. Congestion management service providers are approved upon completing the National Assessment successfully. To apply for congestion management service providers acknowledgement, the signed Application Form and supporting documents (Chamber of Commerce extract, pro-forma invoice, National Assessment CSP form) must be submitted to the TSO. It's important to note that prequalification of connections is separate from congestion management service providers acknowledgement, and it is possible to apply for congestion management service providers acknowledgement without connections.

Neither Spain nor Portugal seem to have defined these aspects.

In Sweden, there is a well-defined methodology for the wholesale energy markets, balancing markets, and TSO constraint management markets, as stated in the survey. However, there is currently no specific process in place for DSO constraint markets.

3.2.2.7 Competition

As shown in Section 3.2.1.6, the question on whether there should be a competitive or a monopolistic model on aggregation is still to be answered.

That said, as shown in Table 3.32, most of the countries analysed (Italy, Lithuania, France and Sweden) have multiple aggregators. Indeed, in France, where the aggregation model has been well developed, there is a competitive model.

Furthermore, no limitation on the number of aggregators has been found in any of the countries analysed. Neither in Spain or in Portugal, the regulation does not limit the number of aggregators. In Sweden, even if the independent aggregator role that has still not been implemented (by the time of the writing of this report), there are already more than one aggregator.

The results of this section are summarized in Table 3.41.

Table 3.41: Comparison on the monopoly on aggregation among the different countries analysed.

	France	**Italy**	**Portugal**	**Spain**	**Sweden**
Monopoly on aggregation	No	No	No	No	No [78]

3.2.2.8 New actors and roles

[78] The regulation has not been approved, but there is already more than one aggregator.

This subsection compares the situation of some new roles and/or figures that have been created and which are related to the aggregator and the aggregation.

Last resort aggregation

The activity of last resort aggregation is a mechanism to ensure the existence of aggregators when market-based aggregators are not available or are unable to operate [71].

In Portugal, the last resort aggregator steps in to purchase electricity from renewable energy producers (except for hydroelectric power plants with more than 10 MVA), from producers benefiting from guaranteed remuneration or other subsidized support schemes, and self-consumers who inject excess energy into the electric grid when there is no other aggregator exists. That said, if there is no market-based aggregator or if the market aggregator is unable to operate, the last resort aggregator applies reference tariffs set by the national regulatory authority, ERSE. Renewable energy producers and self-consumers are required to contract with a registered aggregator within four months, according to the regulations defined by the Regulatory Authority. This is to ensure that there is a market-based aggregator available to purchase the electricity, and to avoid relying on the last resort aggregator.

The license for the last resort aggregator is awarded through a competitive procedure. The opening of the procedure and approval of the necessary documents are carried out by a government member responsible for the energy sector. The duration of the license is established in the procedure documents, with a maximum limit of 20 years from the date of issuance.

The exercise of the activity of the aggregator of last resort is entitled a remuneration in accordance with the Tariff Regulation that ensures the economic and financial balance of the licensed activity under conditions of efficient management. And the duties include placing the electricity acquired in organized markets, through bilateral contracts or through regulated mechanisms, in both cases previously approved by the regulator.

Neither France, nor Italy, not Lithuania, nor Sweden, nor Spain seem to have regulated the figure of last resort aggregator.

Table 3.42 summarizes the existence of the last resort aggregator in the analysed countries.

Table 3.42: Existence of last resort aggregators.

	Regulated	**Maximum time to be in the last resort aggregator**
France	No	-
Italy	No	-
Portugal	Yes	4 months
Lithuania	No	-
Spain	No	-
Sweden	No	-

Logistic operator for aggregator changes

In Portugal, the logistics operator for changing electricity supplier and aggregator facilitates the process of switching electricity suppliers and aggregators for consumers and electricity producers [71]. The activity is regulated by principles such as rational resource use, market rules, competition, public service obligations, consumer and personal data protection. LOCSA operates nationwide and independently from other stakeholders in the National Electricity System (NES). The services provided for switching suppliers or aggregators are free of charge. Personal data processing complies with data protection laws and requires the consent of the individuals involved.

Neither Italy, nor Spain, nor Sweden seem to have such organization for aggregation.

3.2.2.9 Enabling framework

This subsection of the chapter compares the promotion of aggregators and demand response in each of the countries.

National Energy and Climate Plan

The French NECP presents two measures intended to promote the creation of smart-grids and the promotion of load curtailment [106]. The first of those measures, measure 4.5.1.1., encompasses various technical solutions leveraging information and communication technologies to adapt and support the ongoing transformations in the electricity system. The document considers that smart grids provide benefits to all stakeholders in the electricity system, as they empower consumers to participate in system optimization through self-consumption, load curtailment, and intelligent charging. Furthermore, they enable network operators to optimize their operations, improve grid resilience, reduce network losses, and optimize production. Smart grids also facilitate the integration of renewable energies and the valorisation of storage for flexibility. Studies have shown the socioeconomic benefits of smart grid solutions, with estimated net benefits of around €400 million per year for society. However, the economic viability of smart grid technologies depends on the regulatory framework's ability to accurately reflect the services provided to the electricity system. The technical challenges in implementing smart grids include frequency and voltage regulation, energy storage, intelligent charging of electric vehicles, and the development of software and telecommunications solutions. The involvement of various actors, such as electricity suppliers, balance responsible parties, equipment manufacturers, and software providers, is crucial for optimal development. The development of smart grids in France has been supported through public initiatives, investments, and collaborative research efforts. The deployment of smart meters, known as Linky meters, has played a significant role in modernizing the grid by providing precise consumption data, bi-directional communication capabilities, enhanced observability, and the potential for demand-side management. The availability of data from smart grids raises governance and data management challenges that require transparent and secure mechanisms. Overall, the deployment of smart grids and the adoption of smart metering contribute to the energy transition and optimize the electricity network and generation resources.

Then, measure 4.5.1.2. intends to promote the development of electricity demand flexibility through load curtailment and demand aggregation. It highlights how evolving electricity usage, driven by new electrical equipment and carbon neutrality goals, impacts consumption patterns. Load curtailment is identified as a useful tool to balance the electricity system by temporarily reducing consumption. It can replace peak production means and limit network reinforcement need. Load curtailment can be achieved through consumer incentives or by load curtailment operators. The valuation framework for load curtailment involves participation in adjustment mechanisms, system reserves, energy markets, and capacity mechanisms. The document also outlines the current load curtailment capacity and the potential for industry development. Studies have evaluated the prospects for load curtailment, with estimates ranging from 3 to 5 gigawatts of capacity. The French market has undergone reforms to open up market mechanisms for load curtailment, and further adjustments are being considered. Achieving the target of 6,5 gigawatts of load curtailment capacity by 2028 depends on cost evolution and the system's capacity needs. The summary emphasizes the importance of load curtailment in achieving a flexible and balanced electricity system and the ongoing efforts to support its development.

The Italian NECP discusses national objectives for increasing the flexibility of the national energy system. The objectives focus on developing domestic energy sources, demand management, and energy storage [109]. The regulatory authority, ARERA, has already defined criteria to enable the participation of demand dispatch services, non-registered production units (including distributed generation), and storage systems in the market. Pilot projects have also been launched to allow aggregators to participate in the market by combining consumption units, non-relevant production units, and relevant production units not yet registered for service markets.

The text considers that the development of renewable energy sources and storage systems should be coordinated with the expansion and modernization of the transmission and distribution network. This includes enhancing grid infrastructure, implementing smart grids, and installing devices to optimize energy flows.

In terms of demand response, the objectives include increasing the proactivity and flexibility of electricity demand, promoting the participation of consumers, and leveraging technologies such as smart meters. The goal is to encourage a convergence of demand and supply peaks. The text emphasizes the importance of aggregators in enabling the participation of various resources in energy markets and removing barriers to their involvement. The regulatory framework will be revised to ensure non-discriminatory participation and a level playing field for different resource types.

The objectives also address the adequacy of the electricity system and the need for flexibility in renewable energy production. Adequacy analyses will be conducted to determine the required capacity and evaluate potential investments in generation, storage, and demand response. These analyses will consider the growth of renewable energy sources and the phase-out of coal-fired capacity by 2025.

In terms of technological advancements, the objectives include developing advanced models for system architecture and management, integrating renewable generation, self-consumption, storage, energy communities, and aggregators. Advanced information technologies, the Internet of Things (IoT), and peer-to-peer systems will be employed to enhance the security and resilience of the grid.

The objectives also highlight the importance of advancing electric vehicle integration, implementing innovative control and management methods, and continuing the modernization of the electricity distribution network. This involves upgrading hardware and software components to enable bi-directional flows and facilitate demand response initiatives.

The Lithuanian NECP highlights the absence of energy savings from demand response programs by energy aggregators in Lithuania [224]. Nonetheless, it aims to enhance market integration by improving system flexibility. This includes initiatives such as fostering aggregation and demand response, facilitating energy storage and distributed generation, optimizing dispatching and curtailment mechanisms, and establishing real-time price signals. To explore potential opportunities of demand response and aggregation, meetings and workshops were conducted with potential customers and consumer groups capable of aggregation. These interactions focused on assessing their technical requirements and characteristics, with the intention of determining the potential capacities of demand response services and conducting cost-benefit analyses for the most promising providers.

The draft of the 2023 Portuguese NECP establishes the national objectives regarding the non-discriminatory participation of renewable energy, demand response, and storage, including aggregation, in all energy markets [225]. The recent Decree-Law 15/2022 introduces a more decentralized system, encouraging active consumer involvement in production, storage for self-consumption, and potential surplus sales for flexibility services and production aggregation. The establishment of independent aggregators plays a crucial role in removing barriers for electricity market participation, particularly for small consumers. The regulatory framework for demand management needs to define technical requirements, facilitate fair data exchange, and establish dispute resolution mechanisms.

To manage the national electric system effectively, flexibility through aggregation is emphasized. Consumers and small producers are encouraged to participate in providing aggregation services to ensure system stability. A roadmap is being developed to analyse various trajectories for aggregation development, considering local and system flexibility needs aligned with renewable energy and decarbonization goals.

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The regulatory framework for market aggregation is being implemented, aiming to address market gaps in aggregation services. The aggregator's role includes the acquisition and market placement of energy produced by special regulated producers. Additionally, regulatory and market frameworks for system services are being revised at the European level, aiming to harmonize national markets into single European platforms.

The draft of Spain's 2023 National Energy and Climate Plan (NECP) includes four measures concerning aggregation [226]. These measures aim to enhance the regulatory framework for demand management, establish the role of independent aggregators, update operation procedures, and promote new business models.

Firstly, the development of the regulatory framework for demand management is crucial. Technical requirements need to be defined for market participants offering renewable energy, energy storage, and demand response services. The introduction of independent aggregators is essential to enable small consumers to participate in the electricity market without the need for consent from other participants. Clear functions and responsibilities should be assigned to electricity companies and customers, ensuring fair and non-discriminatory data exchange while protecting sensitive information. Dispute resolution mechanisms should also be established between aggregation service providers and other market participants, including addressing responsibilities for deviations.

Secondly, the independent aggregator role, which was introduced through Royal Decree-Law 23/2020, needs to be further developed. A public consultation took place in February 2023 to finalize the regulations governing this role. Independent aggregators will play a key role in maximizing the utilization of distributed energy resources and leveraging sector integration to effectively respond to variations in demand driven by renewable energy.

Thirdly, operation procedures must be updated to accommodate the inclusion of new actors in the energy system. This ensures that the necessary mechanisms and protocols are in place to facilitate the participation of independent aggregators and other relevant market participants.

Lastly, there is a focus on promoting new business models. Energy aggregators and energy efficiency contracts are among the models to be encouraged. Regulatory measures will be implemented to develop new contract models and provide support to these companies through various assistance programs. Information and communication efforts will be made to raise awareness of these models. Emphasis will be placed on energy projects with high energy-saving potential, enabling investment recovery through reduced energy costs or improved long-term energy provision. Examples of such projects include self-consumption and energy communities, which foster the emergence of energy prosumers and aggregators while promoting business models centred around renewable energy generation and demand reduction.

The Swedish NECP, regarding the internal energy market, focuses on increasing system flexibility, market integration, and promoting competitively determined electricity prices [110]. There is a continuous effort to develop measures and participate in Nordic cooperation to achieve these objectives. The Nordic Electricity Market Forum facilitates dialogue among stakeholders and highlights key areas for development, including flexibility, accurate price signals, sector integration, network development, and resource adequacy. Milestones of the Action Plan include the implementation of the Nordic Balancing model, Single Price Model, 15-minute settlement period, and the launch of Nordic Capacity Markets. Sweden does not have specific national objectives related to non-discriminatory participation of renewable energy, demand response, and storage. However, provisions in the Electricity Act aim to prevent technical requirements that hinder changes in electricity consumption and encourage efficient use of the electricity network. Sweden also aims to ensure electricity system adequacy, and the reliability standard has been set at one hour per year, with the Energy Market Inspectorate mandated to propose new standards if necessary. Measures are being implemented to increase the flexibility of the energy system, including smart grids, aggregation, demand response, storage, and mechanisms for dispatching and curtailment [110]. The Energy Market Inspectorate is promoting a more flexible electricity system and analysing the need for further action. Sweden cooperates with Nordic countries on demand response issues and follows developments to enable demand response through regulatory frameworks. Measures are also taken to enable and develop demand response, including the possibility for network operators to test tariffs that stimulate more efficient use of the network through demand response. Regulations have been issued for the design of network tariffs and to inform electricity users about charges and opportunities to influence costs.

Table 3.43 summarizes the inclusion of the figure of aggregator in the National Energy and Climate Plan of each of the targe countries.

Table 3.43: Consideration of the aggregators in the NECP.

	France	**Italy**	**Portugal**	**Spain**	**Sweden**
Regulation and/or promotion of aggregators	Yes	Yes	Yes	Yes	Yes
Regulation and/or promotion of demand response or flexibility	Yes	Yes	Yes	Yes	Yes

State aids

In Spain, the government has approved the “aids for new business models in the ecologic transition” program [87]. It encompasses several areas aimed at fostering innovation and advancing the energy system’s flexibility and digitalization. The first area focuses on innovative products and services that contribute to system flexibility, such as demand management and the introduction of aggregators offering innovative renewable energy management services. The second area emphasizes the transformation, innovation, and digitization of the energy system, including digitalization for the energy transition, data access services, and cybersecurity. The third area concentrates on strengthening the value chain of energy storage, promoting sustainable materials and innovative processes, and exploring standardization and recycling solutions. The fourth area focuses on regulatory innovation activities, encouraging projects that enhance energy efficiency, reduce carbon emissions, and promote transparency and consumer protection in the energy sector. Table 3.44 summarizes the characteristics of the different programs.

Table 3.44: Maximum intensity.

Program	**Maximum intensity**		
	Small enterprise	**Medium enterprise**	**Big enterprise**
Innovation in the energy transition	45 %	35 %	25 %
Innovation in the energy transition (for actions of this type that also involve effective collaboration or the widespread dissemination of results)	60 %	50 %	40 %
Decarbonization of the energy sector and improvement of the integration of renewable energies.	60 %	50 %	40 %

None of the other countries seem to have such program.

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3.2.2.10 Barriers

Despite the many potential benefits of aggregators, there are several barriers that can hinder their adoption and operation. These barriers can be categorized into four main types: legal, technical, economic, and administrative. This section classifies and summarizes the barriers found for each of these kinds.

Legal, regulatory and administrative

Legal barriers refer to regulatory and legal frameworks that may limit the development and operation of electricity demand aggregators. These may include restrictions on market access, requirements for certification or licensing, and legal uncertainties around data privacy and sharing.

In France, the regulation on aggregation has been developed for many years. That said, no other barriers have been indicated. In Italy, no regulations have been indicated in the survey either.

In Portugal, aggregators were transposed by Decree Law 15/2022 [71]. Nevertheless, the decree does not go into further detail, so the problem is a lack of regulation for aggregators. Lithuania has the same problem of lacking specific regulation, for example, in the aggregation scheme.

In Spain, the problem also remains the lack of specific regulation for aggregators, which is even less specific than in Portugal. In fact, only the definition has been transposed to the national legislation [72]. In the same line, in Sweden, based on the survey, the regulation on aggregation still has to be transposed.

Last, in Sweden, aggregators are required to obtain prior approval from the final consumer’s supplier and the BRP in order to enter the market. Furthermore, the aggregator is limited to bid using exclusively resources within the same BRP. Furthermore, the prequalification processes have not been developed to accommodate independent aggregators, leading to challenges and uncertainties in the administrative procedures. However, this is changing with the implementation of the legal proposal.

Table 3.45 summarized the legal barriers found in the different target countries.

Table 3.45: Legal, regulatory and administrative barriers for aggregators found.

	Lack of regulation
France	No
Italy	No
Portugal	Yes
Lithuania	No
Spain	Yes
Sweden	Yes

Technical

Technical barriers are related to the physical and technical infrastructure needed to support the operation of demand aggregators, including communication networks, metering systems, and interoperability standards. Technical barriers can also arise from the complexity of integrating distributed energy resources (DERs) and managing their variability and uncertainty.

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No technical barriers have been indicated neither for France, nor for Lithuania, nor for Portugal.

In Italy, there are technical limitations due to the grid technical requirements of the system operators, this is, both the DSO and the TSO.

Based on the survey, in Spain, the problem refers to the fact that is a merchant business, particularly in the capability to access market signals though transparency.

In Sweden, a network operator is prohibited from imposing technical requirements or conditions that hinder the provision of demand response services [131]. However, they are allowed to impose conditions that are essential for the safe, reliable, and efficient operation of the power grid. The government or the authorized governing body establishes the regulations regarding the technical requirements that network operators may impose specifically for demand response services. Furthermore, the Energy Market Inspectorate must annually compile and make publicly available the technical requirements and other conditions for the provision of demand response [227]. Based on the survey, currently, there is a need to establish an API and a correct protocol to send meter data to market operator. Furthermore, there is a need for specific communication systems. Also, submetering is needed in many cases.

Table 3.46 summarizes the technical barriers found for aggregators in the different target countries.

Table 3.46: Technical barriers for aggregators.

	Summary of the technical barriers
France	*(None specified)*
Italy	Grid requirements
Portugal	*(None specified)*
Lithuania	*(None specified)*
Spain	Access market signals
Sweden	Need for an API and protocol to send meter data to market operator. Specific communication systems. Submetering needed in many cases.

Economic

Economic barriers refer to the financial challenges that electricity demand aggregators may face, including high upfront costs for technology deployment and ongoing operating costs. In addition, revenue streams for demand response and energy trading may be uncertain, and business models may need to be adapted to incorporate new services and value streams.

No economic barriers have been indicated for neither for France nor for Spain.

Based on the survey conducted in Italy, the most significant economic barriers identified are profitability and high marginal costs for the engagement of DERs in a pool of sufficient size and capability. These factors pose significant challenges to the economic viability of DER participation.

In Portugal, the regulation does not specify in which markets aggregators may operate, as the Decree simply states that they can buy and sell energy through markets of bilateral contracts [71]. This lack of specific details might become a barrier to the development of this activity.

In Lithuania, the question regarding the double payment for increased electricity consumption (when aggregators increase consumption, they have to pay to balancing market and to electricity supplier as well) has been noted to be a barrier. This is because the law does not allow to deduct this consumption from supplier's invoice.

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Companies in the Netherlands, primarily driven by unfamiliarity with flexibility, the intricate nature of the process, and a desire to safeguard their core business, continue to demonstrate a preference for offering minimal flexibility despite being connected to the grid.

In Sweden, based on the survey, once the proposed legislation takes effect in June 2023, independent aggregators will also act as BSP and BRP. This will be accompanied by the establishment of a financial compensation mechanism between the aggregator and the aggregator's BRP, although the specific details of this mechanism are still being developed. However, there are certain barriers that hinder the economic feasibility of aggregation, such as minimum bid size.

Table 3.47 summarizes the economic barriers found in the different target countries.

Table 3.47: Economic barriers for aggregators.

Country	Summary of the economic barriers
France	*(None specified)*
Italy	Profitability and high marginal costs for DERs
Portugal	No indication on the markets in which aggregators may operate
Lithuania	Double payment for increased electricity consumption
Netherlands	Little flexibility offered caused by unfamiliarity with flexibility, the intricate nature of the process, and a desire to safeguard their core business
Spain	*(None specified)*
Sweden	Minimum bid size

3.2.3 Issues and proposals on aggregation

The final section on the aggregators' role presents nine recommendations deemed essential for establishing an aggregation framework. These suggestions encompass various aspects, including baseline setting, imbalance management, the rebound effect, the aggregator's bargaining power, potential conflicts of interest with suppliers, the necessity for an independent market operator, and considerations regarding market-traded products.

Is it really necessary to have a specific baseline methodology?

The provision of the right baseline has been a problem for many years, as there is no perfect solution for it. The electricity consumption of each consumer at the moment t may be considered as a random variable, and its distribution depends on many aspects.

Suppliers have been trying to improve their demand forecast for many years to reduce the imbalance penalties they have to pay for the forecast errors they have. If the supplier has done its homework, it should have a state-of-the-art forecast algorithm to guess the real consumption. That said, regulation will never be up to date to the algorithms used by aggregators and suppliers and might halt innovation in improvements in the forecasts by incentivizing the adoption of a given algorithm.

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That said, the best strategy might be to adopt the forecast provided by both the supplier and the aggregator. To do so, if the regulation is well-designed, suppliers and aggregators have to pay a high fee for their imbalances. Therefore, they already have an incentive to buy an amount of energy equal to their best guess in the day-ahead or in the intraday markets (based on the updated forecast or on their strategy to buy cheaper electricity), to pay the minimum imbalance penalties.

As a consequence of this, we may use as a baseline the energy that has been bought or sold by both the aggregator (or declared before a certain hour, if the operator) and the supplier in the markets as their baseline.

How to distribute the imbalance between the aggregator and the supplier

Mathematically, there are three axes that we might use to characterize the energy consumption of a consumer in the vectorial space defined in (4): the time or instant and the metering point. From that, we might define the set R as in (7).

$$W = \mathbb{R}^{Card(D)\cdot Card(T)}, \textit{ where each dimension represents the measured consumption at a given meter D and a given market moment T} \quad (3)$$

$$W \text{ is a vectorial space} \quad (4)$$

$$w_a, w_s \in W \quad (5)$$

Given that, if we want to differentiate the energy consumption that belongs to each of the actors (the aggregator and the supplier), we must have two colinear vector, so (7) must be true.

$$w_a \cdot w_s = 0 \quad (6)$$

Therefore, to accomplish that, we must be in one of the following situations:

- **Different meters**: This might be achieved by either using split metering or using submetering. In this situation, the consumption must be managed/associated completely to one of the actors.
- **Different time intervals**: This might be achieved by assuming that, when one of the actors is providing services, the other does not.

The independent aggregator provides flexibility, which is, essentially, an increase or decrease in the expected consumption. Therefore, if the supplier and the aggregator are providing energy or using flexibility to/from the appliances connected to the same metering point and at the same instant, there is no possible way to differentiate them.

As a consequence, given that not perfect solution is available, but it is necessary to define a methodology to split the imbalance responsibility of each of the actors, we might use their guess as the baseline and make them pay the imbalance proportionally to the amount of sourced energy. In other words, we may define the total imbalance in a given area, $i_{a,s}$, as in (7):

$$\forall t \in T, \forall a \in A, \forall s \in S, i_{t,a,s} = \sum_{c \in C_a \cup C_s} e_{t,c} - (e_{t,c,a} + \hat{e}_{t,c,s}) \quad (7)$$

Then, to share the imbalance responsibility between the two actors, we may use (8) for the supplier and (9) for the aggregator, which distribute the imbalances proportionally among the two actors for the whole shared portfolio.

$$i_{t,s} = \sum_{c \in C_s \cup_{a \in A}(C_a)} \left(e_{t,c} - \hat{e}_{t,c,s}\right) + \sum_{a \in A} i_{t,a,s} \frac{\sum_{c \in C_a \cup C_s} |\hat{e}_{t,c,s}|}{\sum_{c \in C_a \cup C_s} \left(|\hat{e}_{t,c,s}| + |\hat{e}_{t,c,a}|\right)} \quad (8)$$

$$i_{t,a} = \sum_{s \in S} i_{t,a,s} \cdot \frac{\sum_{c \in C_a \cup C_s} |\hat{e}_{t,c,a}|}{\sum_{c \in C_a \cup C_s} \left(|\hat{e}_{t,c,s}| + |\hat{e}_{t,c,a}|\right)} \quad (9)$$

To apply these formulas it is, nonetheless, necessary to know the electricity forecast in the set of shared consumers both for the aggregator and the supplier. In other words, the supplier also has to disaggregate the forecast for each zone it has in common with one aggregator.

Last, it is interesting to say that in this situation, three effects might appear:

- An aggregator might prioritize the suppliers that are making the best forecast.
- A supplier may also prefer the aggregators that are providing the best forecast.

Last, there is a drawback in this model, and it is the fact that even if the supplier might not know the name of the aggregator that is providing the services, it is going to know which is the set of customers that it is with each one of them.

Rebound effect

It is clear that the aggregator should also compensate the supplier for the rebound effect it generates. Nevertheless, as not all the appliances behave on the same way, it is not clear neither how to differentiate the rebound effect nor how the rebound effect changes over time. In other words, is it possible to the differentiate the rebound effect generated by an appliance five days after its activation? Is the rebound effect an equivalent to the transfer of energy for that appliance or has it been reduced by the delay?

If we have no direct control over the appliances, we might infer that, if the imbalance in a certain consumer of portfolio is an outlier (outside the boundaries defined by a specified number of standard deviations away from the mean), it might have been caused by either an outlier or a big forecast error of either the supplier of the aggregator. But, which one is more common?

If the appliances may be controlled and/or measured, the payment of the rebound effect gets simpler.

Bargaining power in congestion management in the short-term

One of the problems that the regulation would need to solve is the market power balance between the aggregators and the system operators. There might be some situations in which one of the actors has a high market power and the resulting market might not be competitive.

As an example of this, let’s analyse a short-term situation, in which a system operator does not have the choice to change the grid to solve the congestion [228]. The principle of common knowledge states that any player is aware that the other players are also going to be rational. Moreover, distribution system operators have to follow a given set of rules, so have no possibility to do what they want.

Assuming perfect information, the aggregator knows that it is the only able to provide flexibility services in a given zone when requested by a DSO. This assumption might be real given that even if a given aggregator does not know whether

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there is a competing aggregator in that zone, it might apply revealed preference theory to verify whether there is a competing one.

Let's define a vector that includes the earnings z_{agg} of the aggregator and z_{so} the system operator as in (10).

$$(z_{agg}, z_{so}) \in \mathbb{R}^2 \qquad (10)$$

Furthermore, let's define γ as the cost of the energy non supplied to the consumers that are impacted by the grid congestion. Last, to solve that congestion, let's imagine that there is a single aggregator available to solve that congestion. Given this framework, we have a sequential game in which the aggregator bids a certain amount of money and then the system operator chooses whether to buy or not to buy flexibility, whose results are shown in Table 3.48.

Table 3.48: Analysis of the market power between the system operator and the aggregator when a congestion needs to be solved in the short-term.

		System operators	
		Buy flexibility	**Not buy flexibility**
Aggregator	**$z_{agg} \in (\gamma ; \infty)$**	$(z_{agg} ; -z_{agg})$	$(0 , -\gamma)$
	$z_{agg} = \gamma$	$(z_{agg} ; -z_{agg}) = (\gamma , -\gamma)$	$(0 , -\gamma)$
	$z_{agg} \in (-\infty ; \gamma)$	$(z_{agg} ; -z_{agg})$	$(0 , -\gamma)$

If that game is played and the system operator acts rationally, the choice of the system operator given the bids of the aggregator are in the cells with a grey background. This is, if the aggregators' price is bigger than the cost of the energy not supplied, the system operator is going to disconnect the consumers. If lower, is going to buy flexibility. If equal, is going to have a choice between both options.

As a consequence of this result, if the aggregator wants to maximize its results, it wants the system operator to buy the flexibility. The only option in which it will buy the flexibility is when (11) is verified.

$$Z_{agg} \in (-\infty ; \gamma) \qquad (11)$$

And, in that range, the aggregator wants the price to be as close to γ as possible.

Of course, γ might be extremely high compared to the real price of flexibility, and the system operator might not have the choice. Therefore, we consider that such situations should be avoided and we should try to set a certain bound to the prices if such a situation exists.

Bargaining power in congestion management in the long-term

In the long term, the system operator has the option to solve the congestion by changing the structure of the grid, this is, by constructing new infrastructures that allow the DSO to not have it.

We define the following Net Present Values (NPVs):

- **NPV of disconnection** (NPV_{dis}): Current forecasted value of the cost of the disconnection charges, defining γ as the price of disconnecting the given grid zone, n the number of expected disconnections and h the discount factor.

$$NPV_{dis} = -\sum_{y\ years} \frac{\gamma \cdot n}{1 + h_y} \tag{12}$$

- **NPV of flexibility** (NPV_{flex}): Current value of the flexibility needed to solve that disconnection charge defining γ as the price of disconnecting the given grid zone, n the number of expected disconnections and h the discount factor.

$$NPV_{flex} = -\sum_{y\ years} \frac{\alpha \cdot n}{1 + h_y} \tag{13}$$

- **NPV of the new grid** (NPV_{inv}): Current value of the investment that the system operator has to execute to solve the congestion and do not use flexibility nor need to disconnect the users from the grid, this is, the overnight investment ($R_{overnight}$) and maintenance in the year y ($R_{maintenance,\ y}$) with the given discount factor (h) for a given year (h_y). We also have to consider the disconnection charges or the flexibility during the construction.

$$NPV_{inv+dis} = -R_{overnight} - \sum_{y\ operation\ years} \frac{R_{maintenance,\ y}}{1+h_y} - \sum_{y\ construction\ years} \frac{\gamma \cdot n}{1+h_y} \tag{14}$$

$$NPV_{inv+fle} = -R_{overnight} - \sum_{y\ operation\ years} \frac{R_{maintenance,\ y}}{1+h_y} - \sum_{y\ construction\ years} \frac{\alpha \cdot n}{1+h_y} \tag{15}$$

Given this, and using the same vector of earnings defined in (10), we may easily see that the offer of the aggregator has to be the lowest compared to the others, but the other prices may be quite high. Therefore, to avoid these situations, it might be necessary to stablish rules on how to price flexibility when there is only a single provider.

Conflicts of interest between the aggregator and the supplier

As presented by Barbero et al., if suppliers have enough flexibility, they may also provide services to system operators, which, as they are acting both as suppliers and aggregators, might rise some conflicts of interest [229]. Also, as explained by Schittekatte et al., traditional suppliers are reluctant to offer demand response schemes, as this business directly interferes with theirs [230].

An independent aggregator which earns a percentage on the amount of money that is saving to the customer, will indeed try to optimize the consumption. Nevertheless, an aggregator integrated in the supplier might not have this incentive, depending on its profit.

Nonetheless, we may also think on other pricing schemes where the supplier earns more when the consumer consumes energy on the moments where the price is lower. One example of this is shown in Table 3.49, where the customer pays a fixed amount for each energy unit, but the supplier does not buy the energy at a fixed price. In this situation, if the supplier optimizes the consumption of its customers, it will earn more money, so there it has an incentive to provide optimization services.

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Table 3.49: Situation in which the supplier earns a fixed rate per each energy unit.

	Consumption not optimized for the consumer		**Consumption optimized for the consumer**	
	Expensive hour	**Cheap hour**	**Expensive hour**	**Cheap hour**
Energy	100	0	0	100
Unitary price of the energy	60 €/MWh	20 €/MWh	60 €/MWh	20 €/MWh
Suppliers selling price	100 €/MWh		100 €/MWh	
Supplier's income and consumer's cost	10 000 €		10 000 €	
Supplier's earnings	4 000 €		8 000 €	

The role of an independent market operator

The conditions to have perfect competition are: a large number of buyers and sellers, homogeneous products, free entry and exit, perfect knowledge, absence of collusion between the market participants, and every participant is a price taker (cannot influence the market prices).

Given those characteristics, a market operator offers more visibility on the prices of the market participants, so it offers a better knowledge of what happens to all market participants. Furthermore, a central market operator allows for a better coordination of both the bids and the offers, so the aggregators may offer their flexibility in all markets for all services. This simplifies the principle of value stacking.

Nonetheless, in many situations, the product offered is not homogeneous, as flexibility is dependent on the grid node where it is being offered. To this extent, the solution may be to include in market clearing or in the definition of the network operation needs information about the grid characteristics and not only about the bids, offers and market results.

Should we compensate the supplier?

Under certain conditions, if the aggregator is giving using the energy that the supplier has bought in the market, the aggregator is creating an "artificial" (not motivated by the normal consumer's behaviour) forecast error in the forecast of the supplier. We could, eventually, get to a point where the aggregator might reduce a 100% of the supplier's energy forecast and make the supplier pay for the whole imbalance.

As a consequence of all of this, it makes sense make the aggregator compensate the supplier for the transfer or energy it generates, but exclusively, when the imbalance responsibility has been transferred to the supplier. In case the consumer keeps the imbalance responsibility, and the consumption does not fit what agreed, it is the consumer who should pay for the wrong forecast.

Furthermore, not stablishing a default compensation might give too much bargaining power to the supplier, as the supplier might prefer having no aggregator that modifies the consumption of their consumers. As a consequence, we consider that, when the consumer has transferred the imbalance responsibility to the supplier, the aggregator should compensate the supplier. Otherwise, we should let the consumer and the aggregator define a fair price for their products.

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Focusing on the price, a regulated value should be defined in case the supplier and the aggregator do not reach an agreement. The valuation of the supplier's energy should be valued in such a way that does not provide any income to neither the supplier nor the aggregator. That said, among others, the following inventory valuation methods:

- **Last In, First Out** (LIFO): The most recently acquired items are used or sold first. Under LIFO, the cost or valuation assigned to these items is based on the price of the most recent acquisition. This implies that the cost of goods sold and the cost of ending inventory reflect the prices of the most recent purchases.
- **First In, First Out** (FIFO): The oldest items in the inventory are used or sold first. According to FIFO, the cost or valuation assigned to these items is based on the price of the earliest acquisition. This means that the cost of goods sold and the cost of ending inventory represent the prices of the oldest purchases.
- **Weighted Average Cost** (WAC): The value assigned to each item is calculated by taking the average cost of all the units in inventory. This is determined by dividing the total cost of goods available for sale by the total number of units available. The WAC method assumes that the cost of each unit is the same and is an average of the costs incurred for different purchases or production runs.

Given these options, as the supplier may not choose when the transfer of energy is done, we consider that, using the WAC of the energy, seems the fairest compensation to the supplier when getting the aggregation is getting energy from its portfolio. That said, we must define the prices of the transfer of energy (ToE) from aggregator to supplier (AtS) and the transfer of energy from supplier to aggregator (StA) for all the hours of the day, all suppliers and all aggregators as in (16) and (17).

$$\forall c \in C, \forall t \in T, \forall s \in S, \forall m \in M, \exists p_{m,t,c,s}^{ToE,\ StA} \in \mathbb{R}^{+} \tag{16}$$

$$\forall c \in C, \forall t \in T, \forall s \in S, \forall m \in M, \exists p_{m,t,c,s}^{ToE,\ AtS} \in \mathbb{R}^{+} \tag{17}$$

$$\forall c \in C, \forall t \in T, \forall s \in S, \forall m \in M, \forall a \in A,\ e_{m,t,c,s,a}^{ToE,\ StA} \cdot e_{m,t,c,a,s,a}^{ToE,\ AtS} = 0 \tag{18}$$

Then, when analysing the transfer of energy, we might have two situations, which are shown in (19) and (20).

$$e_{m,t,c,a,s}^{ToE,\ StA} = 0, \qquad e_{m,t,c,a,s}^{ToE,\ AtS} > 0 \tag{19}$$

$$e_{m,t,c,a,s}^{ToE,\ StA} > 0, \qquad e_{m,t,c,a,s}^{ToE,\ AtS} = 0 \tag{20}$$

If the situation where (19) is verified, in other words, we have a ToE StA, the price paid by the supplier to the aggregator should be the clearing price of the current market, as in.

$$p_{m,t,c,s}^{ToE,\ AtS} = p_m \tag{21}$$

Otherwise, we might have two situations: the energy stock of the supplier is enough to provide the ToE to the supplier, or it is not. These situations are shown in (22) and (23).

$$e_{m,t,c,a,s}^{ToE,\ StA} \leq \sum_{i \in M \ already\ cleared} \left(e_{i,t,c,s} - \sum_{a \in A} \left(e_{i,t,c,a,s}^{ToE,\ StA} - e_{i,t,c,a,s}^{ToE,\ AtS}\right)\right) \tag{22}$$

$$e_{m,t,c,a,s}^{ToE,\ StA} > \sum_{i \in M \ already\ cleared} \left(e_{i,t,c,s} - \sum_{a \in A} \left(e_{i,t,c,a,s}^{ToE,\ StA} - e_{i,t,c,a,s}^{ToE,\ AtS}\right)\right) \tag{23}$$

If (22) is verified, we should apply exclusively the price defined in (24), which corresponds to the WAC of the supplier's energy stock.

$$p_{m,t,c,s}^{ToE,\ StA} = \sum_{m \in M \ already\ cleared} \frac{p_{m,t,c,s} \cdot e_{m,t,c,s}}{e_{m,t,c,s}} \tag{24}$$

Otherwise, for the remaining energy, in other words for λ as defined in (25), we should apply the price in (26).

$$\lambda = e_{m,t,c,a,s}^{ToE,\ StA} - \sum_{m \in M \ already\ cleared} e_{m,t,c,s} \tag{25}$$

$$p_{m,t,c,s}^{ToE,\ AtS} = p_m \tag{26}$$

And, we also consider that the transfer of energy should be compensated each time that a market is cleared as, otherwise, this might generate incentives for the aggregator to "play" with supplier's energy. A situation in which the aggregator might generate losses to the supplier may be seen when comparing the situation shown in Table 3.50 with the one shown in Table 3.51.

Table 3.50: Example of the compensation for the transfer of energy is made at the end, for a given hour in which, when all markets have been cleared. We assume that there is a single aggregator. Both for economic and energetic streams, negative symbol is used if the stream reduces the monetary capital or the energy rights stock of the given actor.

	Markets			**Final situation**	
	Interactions	**Day-Ahead**	**Intraday Market**	**Energy**	**Financial**
Market	Clearing price [€/MWh]	+ 20 €/MWh	+ 40 €/MWh		
Supplier	Energy bought in market [MWh]	100 MWh	100 MWh	200 MWh	-6 000 €
	Market payment [€]	-2 000 €	-4 000 €		
	Compensation [€]	0 €	0 €	0 MWh	0 €
	Energy stock [MWh]	120 MWh	200 MWh	200 MWh	5 600 €
	Energy stock value [€]	2 400 €	5 600 €		
Aggregator	Energy bought in market [MWh]	20 MWh	- 20 MWh	0 MWh	400 €
	Market payment [€]	- 400 €	800 €		
	Transfer of energy [MWh]	- 20 MWh	20 MWh	0 MWh	0 €
	Compensation [€]	0 €	0 €		

Table 3.51: Example when the compensation for the transfer of energy for a given hour is made at the clearing of each one of the markets. We assume that there is a single aggregator. Both for economic and energetic streams, negative symbol is used if the stream reduces the monetary capital or the energy rights stock of the given actor.

Actor	Markets			Final situation	
	Interactions	Day-Ahead	Intraday Market	Energy	Financial
Market	Clearing price [€/MWh]	+ 20 €/MWh	+ 40 €/MWh		
Supplier	Energy bought in market [MWh]	100 MWh	100 MWh	200 MWh	-6 000 €
	Market payment [€]	-2 000 €	-4 000 €		
	Compensation [€]	- 400 €	582 €	0 MWh	182 €
	Energy stock [MWh]	120 MWh	200 MWh	200 MWh	5 600 €
	Energy stock value [€]	2 400 €	5 600 €		
Aggregator	Energy bought in market [MWh]	20 MWh	- 20 MWh	0 MWh	400 €
	Market payment [€]	- 400 €	800 €		
	Transfer of energy [MWh]	- 20 MWh	20 MWh	0 MWh	-182 €
	Compensation [€]	400 €	-582 €		

A model that benefits or favours one agent over another cannot be justified neither in terms of efficiency, nor for level-playing field.

Considerations for the market products

Residential aggregators have a big number of consumers, which do not usually provide enough flexibility independently. Furthermore, it is not sure whether the aggregators will have enough consumers at the beginning or even at certain moments to provide more than 1 MW in demand response aggregation.

As explained by Barbero et al., it is interesting to create markets which have the following characteristics [229], [231]: minimum bid size (between 0,1 and 1 MW, depending on the service), symmetrical products (FCR should be symmetrical while FCR and RR should not be symmetrical), notification time (between 15 s and 2 h, depending on the kind of service), duration of delivery (residential consumers may only activate flexibility during 1 or 2 hours) and tender period (daily).

Another interesting characteristic, which already exists in France, is the possibility to provide flexibility in a 30-minutes windows using different sets of consumers for 10-minutes intervals.

3.2.4 Interim conclusions

Unlocking the potential of aggregation of distributed energy resources holds great promise for sustainability, efficiency, and grid resilience. However, realizing this potential requires clear roles, responsibilities, and an understanding of the

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challenges involved. This document aimed to provide a comprehensive framework that defined the roles, guidelines, and responsibilities to maximize the benefits of aggregated energy resources while addressing current challenges.

The document started by analysing the existing literature on regulation and issues on aggregation to establish a foundation of key concepts and principles. It then examines the European framework and regulatory landscape. Then, by analysing the national legal frameworks of target countries, the document highlights similarities, differences, and lessons that can be learned from their experiences.

Based on the analysis conducted, the document proposes regulatory recommendations for aggregators in the European context. These recommendations aim to foster an enabling and supportive regulatory environment. Those aspects may be summarized in:

- If the regulation is well though and both the supplier and the aggregator are penalized for their imbalances, we might use the energy bought and sold by those actors as their baseline.
- If the aggregator does not supply energy to the assets that it uses to provide flexibility in the wholesale markets, using exclusively metering devices, it is impossible to divide the imbalance responsibility between the given supplier and the aggregator. Therefore, a possible option is to divide such imbalance proportionally to the energy traded with that asset.
- Not many countries have thought about the rebound effect and, in many situations, it might be difficult to prove that a certain imbalance is in fact caused by a rebound effect. That said, it is necessary to analyse this problem closely.
- When solving congestions, aggregators might have a relevant bargaining power and might offer their flexibility expensively. As a consequence of this, it might be necessary to consider this situation in the regulation.
- As there might be conflicts of interest between the aggregation and the supply, as the European regulation already indicates, it is interesting to create the figure of independent aggregator.
- For transparency and for increasing the competition, it is interesting to have an independent market operator.
- The aggregator should compensate the supplier for the transfer of energy. Such transfer of energy should be done (or accounted) at each market clearing.

Considering these aspects, the current document tries to provide relevant regulatory recommendations that we consider should be taken into account when regulating aggregators.

3.3 Enablers to foster flexibility deployment: Baselining and submetering

3.3.1 Baselining methodology to validate the system service provision

The evolving landscape of flexibility markets is marked by a diverse range of product characteristics, various flexibility purchasers, and a wide array of potential Service Providers (SPs), including those linked to distribution networks. Generally, SPs that lack a pre-established schedule from prior markets, such as wholesale energy markets, require a reference point for service verification, commonly referred to as the baseline [232]. This section delves into the suitability of different baseline methodologies, considering the distinct characteristics of resources, markets, and products. It introduces an innovative framework for baseline decision-making. The analysis aims to provide to the BeFlexible demonstrators with essential insights and a structured approach for selecting the most appropriate baseline method for the demonstration activities.

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The baseline establishes a mutually agreed-upon reference value between the buyer and seller, essential for verifying the delivery of the product, as represented in Figure 3.6. It is particularly necessary for validating the service provision of SPs who do not operate on an individual schedule [232].

Verification = Metered - **Baseline**

Energy Products
(e.g. Flexibility Activation)

Figure 3.6. Concept of the chain related to metering, baselining, and verification

3.3.1.1 Review of the baselining methodologies available in literature

Various baseline methods have emerged over time, both in academic research and practical applications [232], [233]. The majority of methods employed in global practices and European research initiatives are based on historical data [234]. This approach involves using metered data from times identical to the activation time (the period when flexibility is expected to be delivered) but from preceding days that have similar characteristics to the activation day. These characteristics might include simple criteria like the type of day, for instance, distinguishing between weekdays and weekends. Table 3.52 provides the overview of the definition of the main baselining methods available in literature. An alternative to baselining is represented by the capacity limitation service, defined as a set of parameters that define and regulate the total active power consumption limit allocated to a SP [235].

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Table 3.52. Main baselining methods available [232]

Baselining method	Definition
High X of Y	From an original pool of the last Z calendar days, the last Y working days are selected after applying the exclusion rules. The daily load of each of those Y days is calculated. The Y days are ranked according to their daily load from the highest to the lowest and, then, the highest X days are selected. The estimated load of the event day is the average of the load of the same hour of the days from those X days.
Rolling average	The Rolling average baseline uses historical meter data from many days, but it gives greater weight to the most recent days. The baseline relies on a greater number of data points, which could improve accuracy for a customer who has similar load patterns and levels throughout the year. For customers whose energy usage fluctuates between seasons, however, the rolling average may not be the best method.
Comparable day	The comparable day method allows an aggregator to find a day that is similar to the event day and use the load of that similar day as the baseline for the actual event day.
Regression methods	Use past data to derive a function capable of estimating an accurate baseline. Variables can be: calendar variables (day of the week, holiday indicators, season), weather variables (temperature), daylight variables (daylight saving time, times of sunrise and sunset), time series variables (e.g. average of consumption of the past weekdays)
Other machine learning techniques	Machine learning techniques are used to estimate the baseline for the activation day. A model is built from past data using a variety of techniques
Meter before, Meter after (MBMA)	Comparison between the metering instants before the product delivery and during product delivery
Zero baseline	The baseline is equal to zero. This method is mainly used for backup generators.
Control group	A group of non-SP customers sharingsimilarities with the SP being baselined is considered. Their average profile during the activation is used as a baseline.
Self-reported	The SP is requested to report a profile

The applicability of the different baselining methods depends on the characteristics of the resources that the SPs exploits. Table 3.53 provides an evaluation at the DER level of various baseline methods for each type of Distributed Energy Resource (DER), based on three key criteria: accuracy, simplicity, and integrity [232]. The self-reported baseline method is noted for its simplicity, as it does not require complex calculations, however it lacks integrity. However, the complexity of baseline calculation can vary depending on the specific DER/SP and product characteristics, sometimes necessitating more advanced algorithms from the SP. The size of the SP is another factor influencing the choice of baseline methodology. Industrial loads or utility-scale Distributed Generation (DG) and Energy Storage Systems (ESS) typically have more sophisticated energy management capabilities compared to residential loads. In such cases, the emphasis on simplicity may be less critical, with a greater focus on accuracy. For these larger SPs, flexibility procurers or regulatory bodies may also pay closer attention to the integrity aspect.

Table 3.53. Baseline methods assessment for different types of DER [232]

Baseline Technique	Accuracy				Simplicity				Integrity			
	Flex. Load	DG-C.*	DG-N.C.	ESS	Flex. Load	DG-C.	DG-N.C.	ESS	Flex. Load	DG-C.	DG-N.C.	ESS
XofY Baselines	Mid	Low	Low	Low	High	High	High	High	Mid	Low	High	Low
Rolling average	Mid	Low	Low	Low	High	High	High	High	Mid	Low	High	Low
Comparable day	Mid	Low	High	Low	High	High	High	High	Low	Low	Mid	Low
Regression methods	High	Low	Mid	Low	Low	Low	Low	Low	High	Low	High	Low
Other ML techniques	High	High	High	High	Low	Low	Low	Low	High	Mid	High	Mid
MBMA	Low	Mid	Mid	Mid	High	High	High	High	Low	Low	Mid	Low
Zero baseline	NA	Mid	NA	Mid	High	High	High	High	NA	Mid	NA	Mid
Control group	Mid	Low	Mid	Low	High	High	High	High	High	High	High	High
Self-reported	NA	NA	NA	NA	High	High	High	High	Low	Low	Low	Low

Legend: Flex. Load – Flexible Load; DG-C.- Distributed Generation – Controllable;
DG-N.C. – Distributed Generation – Non-Controllable; ESS: Energy Storage System;
NA: Not applicable.
* Except CHP

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3.3.1.2 Decision framework for baseline method selection

Based on the evaluation in Table 3.53, this section outlines the decision framework for selecting baselining methods defined in [232] and proposed to be adopted in the BeFlexibile project. This framework is tailored to the specific characteristics of the products and participants ad it is structured as a decision tree, as illustrated in Figure 3.7.

The initial step involves determining if the SP has an individual schedule (i.e., a pre-committed demand and generation plan for other markets like the day-ahead market). If so, no separate baseline is needed, as the SP's existing schedule would suffice.

The next factor to consider is whether the SP is aggregated. For SPs consisting of a single DER, the choice of baseline method varies based on the DER type and is further influenced by the product and unit characteristics. The chosen design should also align with market characteristics, such as the feasibility of Specific Demand Adjustments (SDAs). Certain baseline methods may be more appropriate depending on the product direction and market/activation timing. For SPs comprising multiple DERs, submetering could be employed for individual technology baselines. Alternatively, cluster baselines offer simplicity but may sacrifice accuracy. Comparable day, control group, or self-reported baselines are also options for multi-DER aggregations.

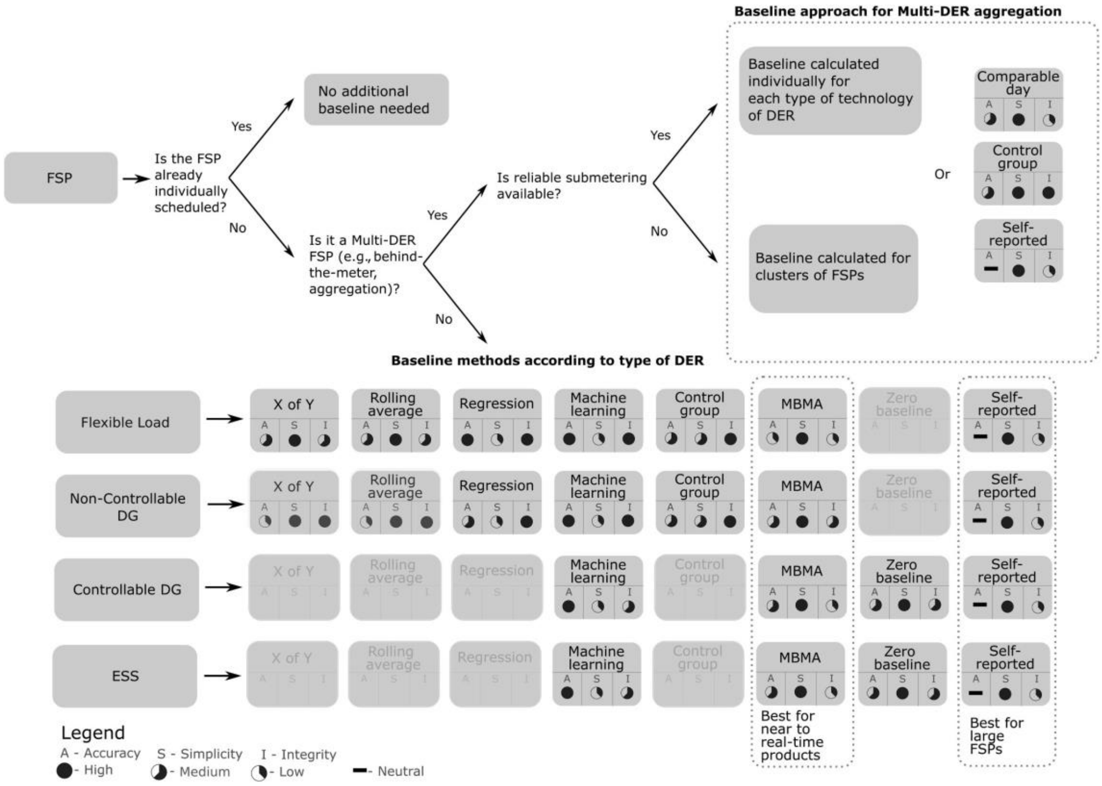

Figure 3.7. Baseline decision framework according to SP, DER, and multi-DER presence type [232]

3.3.1.3 Overview of BeFlexible demonstrators' preferences in adopting baselining methodologies

In this section, the results of the survey of the BeFlexible demonstrators' preferences in adopting baselining methodologies is provided. This activity is preparatory for the assessment on demo activity will be part of WP7. The BeFlexible demonstrators' preference on the adoption of the baselining methodologies was collected by means of a questionnaire, available in 0.

The outcome of the survey of the three BeFlexible demonstrators is provided in Table 3.54, Table 3.55, Table 3.56. Please note that the information presented in Table 3.54, Table 3.55, Table 3.56 is preliminary and represents the project's status at the time of writing. The preferences and solutions chosen by the demonstrators are subject to change as the project progresses.

Table 3.54. Baselining methodology characteristics preference for the SOUTH-MID EU (Italy) demonstrator

Feature	Description
Methodology	Rolling average: last 15 days + adjustment factor based on last 2 hours
Responsible	Market Operator
Metering	By using the meter used for energy billing (main meter)
Service(s)	DSO congestion management and DSO voltage control
Approach	Baselining for single resources (i.e., not aggregated in a portfolio)
Motivation	Neutral methodology for any DERs, assessed after public consultation
Barriers	Definition of the calculation window and adjustment factor. Need to involve the stakeholder to achieve consensus.
Requirement	Metering device with adequate granularity (e.g., 15')

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Table 3.55. Baselining methodology characteristics preference for the North EU (Sweden) demonstrator

Feature	Description
Methodology	High X of Y, SP provided meter data is used for automatic calculation of averages for x and y in platform. Rolling average, SP provided meter data is used for automatic calculation of rolling average in platform. Self-reported, SP provided baseline values are applied in platform. Meter before/Meter after, SP provided meter data is used for calculation of delivered flexibility in platform.
Responsible	Single SP, Aggregator, Market Operator
Metering	By using the meter used for energy billing (main meter) By using behind the main meter submetering
Service(s)	DSO congestion management
Approach	Baselining for single resources (i.e., service providing unit) Baselining for portfolio of resources (i.e., service providing group)
Motivation	Motivation for picking a baseline methodology will be based on resource characteristics such as predictability and stability of the power levels. If these are both high, a calculated average could be used. Conversely if they are low or erratic, self-reported or meter before/after should likely be used to increase accuracy
Barriers	High X of Y and rolling average: No regulatory barriers, difficulties if the behaviour of the resource follows a random pattern. Self-reported: No regulatory barriers, difficult for SPs to calculate baseline. Risk for tempering. Meter before/Meter after: No regulatory barriers.
Requirement	High X of Y and rolling average: Meter data through API in near real time calculated by platform. Self-reported: data from SP in correct manner and time. Meter before/Meter after: manual work if it is not a producing resource and Meter data through API in near real time calculated by platform.

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Table 3.56. Baselining methodology characteristics preference for the SOUTH-MID EU (Spain, France) demonstrator

Feature	Description
Methodology	Self-reported Regression methods
Responsible	DSO, Single SP, Aggregator
Metering	By using the meter used for energy billing (main meter) By using behind the main meter submetering
Service(s)	DSO congestion management
Approach	Baselining for single resources (i.e., service providing unit) Baselining for portfolio of resources (i.e., service providing group)
Motivation	To test grid centric services, to ensure replicability of these services throughout all the EU
Barriers	To be identified
Requirement	To be identified

As shown in Table 3.54, Table 3.55, Table 3.56, the baselining methodologies adopted at project level are high x of y, rolling average, regression methods, self-reported, and meter before/meter after. The relevant services to be demonstrated are DSO congestion management and DSO voltage control. The identified responsible for the calculation of the SPs baselines are DSO, Single SP, Aggregator, Market Operator. Both service providing unit and service providing group baselining approaches are of interest for the demonstration activities. The metering solutions of interest are the use of the meter used for energy billing (main meter) and the use of the main meter submetering.

3.3.1.4 Interim conclusions

The BeFlexible project's demonstration potential of a diverse range of baselining solutions will enable a comparative evaluation of their effectiveness, paving the way for large-scale implementation. Aspects to be assessed may cover barriers, requirements, as well as identify from the demonstrators' experience the achieved accuracy, simplicity, and integrity. The BeFlexible demonstration experience can support policymakers and regulators in selecting specific baseline methods for various flexibility use cases, considering factors like SP type, DER presence, and multi-DER configurations.

3.3.2 Submetering usages for flexibility services

Metering performs key functions in electricity systems and markets. Transmitting and receiving data for information, monitoring, and control through electronic communication offers numerous advantages for both the energy system and its users. Smart meters, in particular, ensure that final customers receive precise, regular updates on their energy consumption, leading to billing based on actual usage [236]. This eliminates issues like inaccurate billing and retrospective billing, which are major consumer concerns. Furthermore, smart meters provide near-real-time insights into energy usage, empowering interested consumers to optimize their consumption, conserve energy, and reduce their bills.

Smart meters present additional opportunities for consumers eager to engage more directly in the electricity market, either independently or through an intermediary. They enable users to adjust their energy consumption in response to varying energy prices throughout the day, taking advantage of lower rates to reduce their energy costs. Smart meters also benefit individuals who generate their own electricity, such as through rooftop solar panels. These meters can accurately track the electricity supplied to the grid by a household and communicate this information to the grid manager. And where the regulatory framework is in place, smart meters can also help active customers offer flexibility to system operators, thereby helping to make the overall system more efficient.

Through smart metering, network operators gain enhanced understanding of network activities. This knowledge allows for more effective planning and management of infrastructure, catering to customer needs while reducing the costs of network operation and maintenance, which ultimately reflects in consumer network tariffs.

To get these roles effectively, smart meters must possess specific functionalities as outlined in the Electricity Directive (EU) 2019/944 [158]. Additionally, national authorities must ensure the implementation of these functionalities, guaranteeing that smart meters live up to their potential in enhancing the energy system for all stakeholders.

The EUDSO Entity and ENTSO-E Draft Proposal for Network Code on Demand Response [237] defines a submeter as a "metering device on customer's side, without its own connection agreement, which is placed behind the meter of the connection point with the transmission or distribution system operator as is defined in the connection agreement". These dedicated metering devices can measure granular electricity injections or withdrawals at a granular timeframe for specific electrical appliances.

Submetering usage has been widely discussed. Submetering has been used when "smart meters" or time-granular meters are not installed. In the European Union, some countries, such as Germany evaluated a negative cost-benefit ratio for smart meters deployment [236], in these countries submeters can enable customers to benefit from time-granular measurements. The literature has highlighted different benefits of submetering similar to the ones of smart-meters, [238] states that submeters provide data for different applications: billing, power quality analysis, load control, and energy management. In apartment buildings, the installation of submeters contributes to splitting electricity bills among tenants leading to energy savings, better awareness of energy consumption patterns, and facilitating energy management automation [239].

3.3.2.1 Submetering for flexibility services

Submeters can become a relevant instrument to enable the participation of small units in flexibility markets to increase the observability, controllability of such units and make settlement of flexibility provision. The Draft Proposal for Network Code on Demand Response [237] considers the use of submetering within the aggregators' models where submeters or the controllable units measures the withdrawals and/or the injections of the controllable units involved in the provision of such services as the balancing, congestion management and voltage control services. Controllable resources such as electric vehicles, batteries, controllable heating systems, and industrial processes are part of demand-side flexibility (DSF). DSF has a significant potential for the European Union system, estimated according to [240] in cost reduction for consumers of more than €71 billion plus €300 billion in indirect annual benefits to people, communities, and businesses from reductions in energy prices, generation capacity costs, investment needs for grid infrastructure, system balancing costs, and carbon emissions.

Although the most common and effective way to provide flexibility is through smart meters, if they are already installed (e.g., no need of additional devices, communications, management systems), the use of submetering can benefit both the provider as well as the SOs as buyers of services in different market phases [241]:

1. Prequalification of resources
2. Monitoring of the assets functioning
3. Controlling and activating service delivery
4. Measurement and settlement of service delivery

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In the previous market phases, the benefits could be used by both buyers and sellers, but the use could be different. For instance, for prequalification it allows the seller to aggregate different assets, for the aggregator the benefit can come from acceding by observing and controlling more resources that otherwise would not be available. Submeters give quasi-real-time visibility of the assets which again could benefit the aggregator which can adjust its portfolio with other resources to guarantee the commitments. Similarly, controllability and automatic activation can offer advantages for both providers and buyers. Additionally, the benefits of measurement and activation would vary depending on the market rules and whether the SOs utilize submeters for service settlement. Given these factors, the meter at the connection point could be the sole accepted device. Subsequently, the aggregator could leverage the submeter to facilitate the division of delivery and payments among the assets.

Another benefit for the asset's owner or representatives such as aggregators is to assess the flexibility potential from specific assets, having specific metering devices at each appliance which could increase the accuracy, reliability and forecasting of the flexibility potential.

The Electricity Market Reform proposal published in March 2023 [55], includes the possibility of system operators using data from "dedicated measurement devices", which can be also understood as specific sort of submeters since they are defined as linked to or embedded in an asset, to gain observability and make the settlement of flexibility provision. This would, on the one hand, increase the accuracy of the portfolio's baseline computed but, on the other, decrease its simplicity. Also, submetering devices and data would have to be certified.

3.3.2.2 Beflexible Survey

A survey was conducted among DSOs and a TSO to know the current use of submeters in SOs markets. In addition, if submeters are not already allowed, the objective was to understand from the SOs perspectives which role they could play and which technical requirements should fulfil.

The survey covered the three countries where there are demonstrators in the BeFlexible project: Spain (ES), Sweden (SE) and Italy (IT). In these countries, the survey was answered by all four participating DSOs (i-DE, e-distribución, e-distribuzione, ARETI and E.ON), one supplier (Iberdrola Clientes) and Terna the only TSO participating. In addition, thanks to the contribution from E.DSO, three additional DSO answered the survey from Greece (EL), Austria (AT) and the Netherlands (NL). Within Spain a "S" refers as supplier, the different view of both DSOs from Spain and Italy indicating with "1" or "2" whenever the DSOs differ in their opinion.

Smart meters deployment and policies differ in European as indicated in [236]. In the countries interviewed, digital meters apply to all customers and can record measurements every hour or quarterly hour in Spain, Sweden, the Netherlands and Italy.

However, in the Netherlands, an individual consumer has the right to refuse a smart meter. The meter can be set to "admin off", if the consumer doesn't want the DSO to read the index values. "Admin on" will set the meter to enable quarterly values (kWh) and hourly values (G) to be read by the Central System. "Default" means that the consumer gives permission to read the index values each month.

In Greece, a Cost Benefit Analysis is approved by Regulatory Authority to install smart meters to 7,5M LV customer. The relevant tender is issued and proposals are under evaluation process. The low voltage consumers in the Austrian DSO can choose between three options: (1) Austria annual readout (opt out), (2) daily readout of daily consumption (standard) and (3) daily readout of the 15 min load profile (opt in). The use of submetering would be definitely more relevant for consumers without smart meters.

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The survey asked for TSO and DSO include balancing services [3], [242]: Frequency Contingent Reserves (FCR), automatic Frequency Restoration Reserves (aFRR), manual Frequency Restoration Reserves (mFRR) and Replacement Reserves (RR), Congestion management at TSO and DSO networks, voltage control and emergency demand reduction.

Table 3.57 shows the current state of whether submeters can be used for each market phase for each SO service in the aforementioned European countries. Few countries use submetering in DSOs services as Austria and Sweden. Only Austria currently reported the use of submetering for other DSO services as voltage control for all market phases for local, being a responsibility of the SPs. In Spain for mFRR, submetering is allowed for small resources.

Table 3.57 Current use of submeters in different market phases and for different SO services

Submetering use	Congestion Management (TSO)	Congestion management (DSO)	Other (e.g. Voltage control)	FCR	aFRR	mFRR	RR	Emergency demand reduction
Prequalification	No: ES, IT	Yes: AT, SE NA: EL, ES, IT	Yes: AT NA: EL, ES, IT	No: ES, IT	Yes: IT No: ES	Yes: ES No: IT	No: ES, IT	No: AT, ES, IT
Need forecasts	No: ES, IT	Yes: AT, SE	Yes: AT NA: EL, ES, IT	No: IT	No: IT	Yes: ES No: IT	No: IT	No: AT, ES, IT
Bid collection	No: ES, IT	Yes: AT, SE NA: EL, ES, IT	Yes: AT NA: EL, ES, IT	No: ES	No: ES	Yes: ES	No: ES	No: AT, ES
Monitoring	No: ES , IT	Yes: AT, SE NA: EL, ES, IT	Yes: AT NA: EL, ES, IT	No: ES, IT	No: ES, IT	Yes: ES No: IT	No: ES, IT	No: AT, ES, IT
Activation	No: ES, IT	Yes: AT, SE NA: EL, ES, IT	Yes: AT NA: EL, ES, IT	No: ES, IT	No: ES, IT	Yes: ES No: IT	No: ES, IT	No: AT, ES, IT
Settlement	No: ES, IT	Yes: AT, SE NA: EL, ES, IT	Yes: AT NA: EL, ES, IT	No: IT, ES	No: IT, ES	No: IT Yes: ES	No: ES, IT	No: AT, ES, IT

NA: services currently not trading in the market

When the respondents were asked about the future use of submetering in flexibility market phases, there were no consensus on the potential use as shown in Table 3.58. In light blue are colored the cells where there is a favored view in using submeters for the different market phases in comparison with current use.

In general, the respondents consider that the submeters are useful for the phases of need forecast, monitoring and activation. Less support is given to prequalification, bid collection and even less for settlement where only two DSOs consider it can play a role for settlement purposes. As shown in Table 3.58, there is no agreement between DSOs from different countries and even within a country.

Table 3.58 Opinion on future submetering usage by market phases

Role	Congestion Management (TSO)	Congestion managemen t (DSO)	Other (e.g. Voltage control)	FCR	aFRR	mFRR	RR	Emergency demand reduction
Prequalification	Yes: IT Neutral: SE No: ES (DSO1, S)	Yes: SE, ES (DSO 2) No: AT, EL, ES (DSO 1, S), IT	Yes: ES (DSO 2) Neutral: SE No: AT, EL, ES (DSO1, S), IT	No: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT (TSO), ES (DSO 2) Neutral: SE No: AT, EL, ES (DSO 1, S), IT
Need forecasts	Yes: IT, ES Neutral: SE No: ES (DSO 1, S)	Yes: IT, SE, ES (DSO 2) Neutral: EL No: AT, ES (DSO 1, S)	Yes: IT, ES (DSO2, S) Neutral: EL, SE No: AT, ES (DSO1)	No: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT, ES Neutral: SE	Yes: IT Neutral: SE	Yes: EL, ES (DSO1, 2, S), IT Neutral: SE No: AT
Bid collection	Neutral: IT, SE, ES (S) No: ES (DSO1)	Yes: SE Neutral: EL, IT (DSO2), ES (S) No: AT, IT (DSO1), ES	Neutral: EL, IT (DSO2), SE, ES (S) No: AT, IT, ES (DSO 1, 2)	No: IT Neutral: SE	Neutral: IT Neutral: SE	Neutral: IT, SE	Neutral: IT, SE	Neutral: EL, IT (TSO, DSO2), SE No: AT, ES (DSO 1, 2 S), IT (DSO1)
Monitoring	Yes: IT, ES (S, DSO1) Neutral: SE	Neutral: AT Yes: EL, IT, ES (DSO 1, 2 S), SE	Neutral: AT, SE Yes: EL, ES (DSO1, DSO2, S), IT	No: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: EL, ES (DSO1, 2, S), IT Neutral: SE No: AT
Activation	Yes: IT, ES (S) Neutral: SE No: ES (DSO 1)	Yes: IT, SE, ES (DSO2) Neutral: AT No: EL, ES (DSO1, S)	Yes: IT, ES (DSO2, S) Neutral: AT, SE No: EL, ES (DSO1)	No: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT Neutral: SE	Yes: IT, ES (DSO 1,2, S) Neutral: EL, SE No: AT
Settlement	Neutral: SE No: IT, ES (S, DSO1)	Yes: AT, SE No: EL, ES (DSO1, 2, S), IT, SE	Yes: AT Neutral: SE No: EL, ES, (DSO1, 2, S) IT	No: IT Neutral: SE	No: IT Neutral: SE	No: IT Neutral: SE	No: IT Neutral: SE	Neutral: SE No: AT, EL, ES (DSO1, DSO 2, S), IT

Table 3.59 shows the answers regarding who is the best agent to install submeters. Although the TSO was provided as an option it was not chosen by any participant as even smart meters are installed by DSO or by an independent meter operator in case of resources connected to distribution networks. The respondents show a positive attitude toward the majority of additional options proposed. Only the Austrian DSO was against the DSO, independent aggregator or manufacturer to install submeters for congestion management or voltage control usages.

Table 3.59 Agents who could stall submeters

Agent responsible	Congestion Management (TSO)	Congestion management (DSO)	Other (e.g. Voltage control)	FCR	aFRR	mFRR	RR	Emergency demand reduction
DSO	Yes: ES (DSO1)	Yes: SE, IT (DSO2), ES (DSO1, 2) No: AT	Yes: IT (DSO2), ES (DSO1, 2) No: AT					Yes: ES (DSO1)
Independent Aggregator (or supplier)	Yes: EL, ES (DSO1, S), IT	Yes: EL, ES (DSO 1, 2, S), IT, SE No: AT	Yes: EL, ES (DSO1, 2, S), IT No: AT	Yes: EL	Yes: EL, ES, IT	Yes: EL, ES, IT	Yes: EL, ES, IT	Yes: EL, ES (DSO 1, S), IT
Meter operator (if different from TSO/DSO)	Yes: IT	Yes: IT (DSO2, requirements set by DSO)	Yes: IT (DSO2, requirements set by DSO)		Yes: IT	Yes: IT	Yes: IT	Yes: IT
Market operator	Yes: EL, IT, ES (DSO1)	Yes: EL, IT, SE, AT (if DSO), ES (DSO1)	Yes: EL, IT, AT (if DSO), ES (DSO1)	Yes: EL	Yes: EL, IT	Yes: EL, IT	Yes: EL, IT	Yes: EL, IT, ES (DSO1)
Consumer	Yes: ES (S)	Yes: ES (DSO2, S) SE, IT (DSO2,if requirements set by DSO)	Yes: ES (DSO 2, S), IT (DSO2, requirements set by DSO)		Yes: ES (S)	Yes: ES (S)	Yes: ES (S)	Yes: ES (S)
Manufacturer (embedded in a device)	Yes: IT, ES (DSO1)	Yes: IT (DSO2, requirements set by DSO), ES (DSO 1, 2) No: AT	Yes: IT (DSO2, requirements set by DSO), ES (DSO 1,2) No: AT		Yes: IT	Yes: IT	Yes: IT	Yes: EL., ES (DSO1), IT

Divergence of opinions of who should install submetering

Regarding the guarantee submeters should fulfil (see Table 3.60). Almost all respondents agree that they must fulfil the same requirements as smart meters for all services. Furthermore, with respect to the certification process, the respondents consider different options either certification bodies, grid operators themselves or a list of requirements specified by the grid operators. Only a few respondents consider that submeters should not be embedded in the devices and the majority agree that the submeter data can use the same smart-meter data infrastructure.

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Table 3.60 Submetering technical specifications requirements

Submetering devices must...	Congestion Management (TSO)	Congestion management (DSO)	Other (e.g. Voltage control)	FCR	aFRR	mFRR	RR	Emergency demand reduction
Have same requirements as smart-meters	Yes: ES (DSO1, S), IT	Yes: AT, EL, ES, IT, NL, SE	Yes: AT, EL, ES, NL, IT		Yes: ES (S), IT	Yes: ES (S), IT	Yes: ES (S), IT	Yes: IT, ES (DSO2, S) No: ES (DSO1)
Be certified by third parties	Yes: ES DSO1, S), , IT	Yes: AT, EL, ES, DSO1, 2, S), IT, NL, SE	Yes: AT, EL, ES DSO1, 2, S), , NL, IT		Yes: ES (S), IT	Yes: ES (S), IT	Yes: E (S)S, IT	Yes: ES (DSO1, 2, S), IT
Be certified by grid operators	Neutral: ES (DSO1, S), IT	Yes: AT, EL, SE, IT (DSO2) Neutral: ES DSO1, 2, S), IT (DSO1), NL	Yes: AT, EL, IT (DSO2) Neutral: ES (DSO1, 2, S), IT (DSO1), NL		Neutral: ES (S), IT	Neutral: ES (S), IT	Neutral: ES (S), IT	Neutral: ES (DSO1, 2, S), IT No: ES (DSO1)
Be specified in a list by grid operators	No: IT Neutral: ES (DSO1, S)	Yes: IT (DSO2, requirements set by DSO), Neutral: AT, EL, ES (DSO1,2, S), IT, NL, SE	Yes: IT (DSO2, requirements set by DSO); Neutral: AT, EL, ES (DSO1,2,S), IT, NL		Neutral: ES (S) No: IT	Neutral: ES (S) No: IT	Neutral: ES (S) No: IT	Neutral: ES (DSO2) No: IT, ES (DSO1)
Be embedded in devices, i.e. EV charging points	Yes: ES (DSO 1, S) Neutral: IT, ES (DSO2)	Yes: EL, IT (DSO2), ES (S) Neutral: ES (DSO1, 2), IT (DSO1), NL, No: AT, SE	Yes: EL, IT (DSO2), ES (S) Neutral: ES, IT (DSO1), NL, ES No: AT		Yes: ES (S) Neutral: IT	Yes: ES (S) Neutral: IT	Yes: ES (S) Neutral: IT	Yes: ES (S) Neutral: IT, ES (DSO1)
Communicate through smart-meter data infrastructure	Yes: IT, ES (DSO2) Neutral: ES (DSO1, S)	Yes: AT, IT (DSO1), ES (DSO 2) Neutral: EL, ES (DSO 1), S, IT (DSO2), NL No: SE	Yes: AT, IT (DSO1), ES (DSO 2) Neutral: EL, ES (DSO 1,S), IT (DSO2), NL		Yes: IT Neutral: ES (S)	Yes: IT Neutral: ES (S)	Yes: IT Neutral: ES (S)	Yes: IT, ES (DSO 2) Neutral: ES (DSO 1, S)

Divergence of opinions of who should certify submetering.

3.3.2.3 Interim conclusions

Metering is a key activity for the functioning of electricity markets and smart meters has open diverse opportunities for increasing efficiency and enable the participation of small agents in the system.

When considering the use of submeters (e.g. behind the connection point meter), they are emerging as crucial tools for enabling small-scale participation in electricity markets, especially with the shift towards shorter market intervals and also where smart meters are not yet deployed. They provide detailed measurements necessary for various market phases and they can play a key role as supported by surveyed TSO, DSOs and retail companies: prequalification, forecast of needs, bid collection, monitoring and activation. There is less consensus for settlement purposes as the effect in the network occur at the connection point.

The effective implementation of these metering technologies requires adherence to specific functionalities and standards, such as those outlined in the Electricity Directive (EU) 2019/944. National authorities play a crucial role in ensuring these standards are met. The responsibility for installing submeters and the technical requirements they must fulfil are subjects of consensus and debate among different stakeholders. Most agree that submeters should meet the same standards as smart meters and consider that the aggregator or supplier could install submeters or embedded in the devices.

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4 Proposal for flexibility mechanisms design: from standalone mechanisms to efficient combinations

4.1 Introduction

The transition towards a more sustainable energy system is a global priority. The need to reduce dependence on fossil fuels, mitigate climate change, and ensure energy security has driven significant changes across several sectors. Under these circumstances, the electrical sector plays a pivotal role because of its direct impact on the value chain of multiple processes. Enhancing the power system becomes critical for a more efficient energy future. However, this sector faces significant challenges [243].

The massive integration of renewable energy sources, such as solar and wind, both in centralized and distributed generation, presents issues in managing electrical supply and demand due to their intermittency and variability [244], [245]. The electrification of key sectors, such as transportation and industry, has a significant influence in reducing carbon footprint and promoting a cleaner energy system, however, it also introduces complexities in terms of infrastructure and grid capacity [245]. Furthermore, the paradigm shift among consumers who seek increasingly active participation and advances in technology and digitization enable them to access real-time information and make decisions about their energy consumption [246].

A viable strategy to tackle these challenges involves leveraging the flexibility provided by these distributed resources linked to distribution networks. This flexibility can be employed to offer services to distribution system operators, and when applied properly, it can offer a cost-effective and operative alternative compared to traditional network reinforcement. The provision of system services can be enabled by flexibility acquisition mechanisms, such as network tariffs, connection agreements, local markets, etc. [247]. Although several of these mechanisms are currently in operation, they were not designed initially considering their interaction to optimize power systems functionality. Typically, they have been conceived and implemented as independent entities. Therefore, this section commits to a thorough re-assessment and redesign process. It introduces and applies a qualitative methodology for developing a decision framework aimed at exploring the interaction of several mechanisms for acquiring distribution system operator services for improving their combined efficiency. In this section, among the system services defined in section 1.3, only the DSO system services for congestion management and voltage control are considered.

4.2 Methodological framework for the joint design of coexisting mechanisms for system service acquisition

This subsection aims to summarize the main steps of the methodology outlined in Figure 4.1. This methodology should enable the establishment of a decision framework, which is critical for evaluating the combination of different mechanisms to acquire distribution system operator services from distributed resources that can be employed by distribution system operators for solving network problems. The need for such a framework arises from the requirement to address the design of each individual mechanism independently by considering the context of the need, as well as to consider how different mechanisms can interact and potentially complement each other when properly designed. In fact, the methodological framework allows for the identification of synergies where one mechanism might compensate for the limitations of another, leading to a more efficient system. In conclusion, the proposed methodological framework for the joint design of coexisting mechanisms for acquiring system services aims to evaluate the feasibility of the resulting combined acquisition and to identify critical design dimensions with the goal of fostering a mechanism design oriented towards reducing inefficiencies in their interaction.

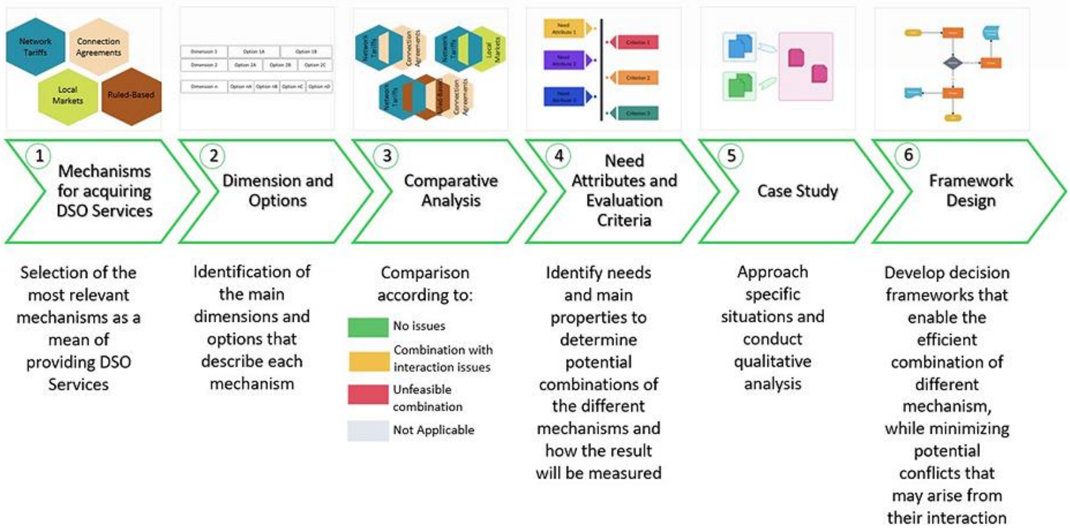

Figure 4.1 Methodological framework for the joint design of coexisting mechanisms for distribution system operator service acquisition

The methodological framework for the joint design of coexisting mechanisms for distribution system operator service acquisition consists of six steps:

1) **Selection of mechanisms for acquiring DSO services (Step 1)**: The first step (1) involves reviewing the current literature to gather insights from previous research to identifying the most relevant mechanisms for acquiring DSO services. This process also enables the identification of inefficiencies in the coexistence of these mechanisms when they are implemented as independent entities. This step is described in section 4.3.
2) **Identification of design dimensions and options for each acquisition mechanism (Step 2)**: In step (2) significant characteristics that describe each mechanism are classified as design dimensions, along with their feasible options for implementation. The design dimensions can be considered as variables that collectively describe the nature and functionality of this mechanism, and the options represent the potential implementation values (domain) that can be adopted for a particular dimension. It is important to highlight that some options within a dimension might be mutual exclusive (ME), which means they cannot be applied at the same time. Conversely, if they are not ME, more than one option can be applied simultaneously. Similarly, dimensions that share common properties are categorized into general meta-dimensions. These dimensions, options, and meta-dimensions act as characteristics for identified potential interaction among the different mechanisms. This step is described in section 4.4.
3) **Comparative analysis between the mechanisms (Step 3):** In the step (3), comparative analyses among the acquisition mechanisms are conducted to assess their interplay. Pairwise comparisons are performed by means of two-axis tables, with each axis representing a specific mechanism, and listing the design dimensions and options. It aims to identify four possible conditions for each cross-options (coordinate linking two or more options): it is feasibly applied the mechanisms simultaneously without apparent issues (green); the combination of the mechanisms presents issues that must be considered, e.g., double charging, uneven playing field for network users, market power issues, etc. (yellow); the mechanisms cannot be simultaneously applied due to misalignments (red), and the analysis between cross-options is irrelevant or not applicable (grey). This step is described in section 4.5.

4) **Determination of need attributes and evaluation criteria (Step 4):** Subsequent, in step (4) needs attributes for DSO services and evaluation criteria for the performance of the combined design of the acquisition mechanisms are delineated. The need attributes allow the identification of the technical characteristics to be considered in acquisition mechanism design. Thus, we define three categories: the first pertains to the current state of the network (voltage level, frequency and volume of the need, and network type), the second focuses on the capabilities of the SPs (SP size, SP nominal voltage and SP type), and the third aims to measure the relationship between characteristics of the network conditions and the service providers (volume of the service provided/ volume of the need). The evaluation criteria enable us to establish the way for conducting the evaluation of the results. For this analysis, we consider two groups of criteria: the first based on general regulatory principles such as economic efficiency, equity, implementability, and transparency and simplicity. The second group considers customer engagement, due to it is considered an important part of one of the main objectives of the subtask. This step is described in section 4.6.
5) **Definition of case study (Step 5):** Furthermore, moving forward to step (5), the case studies to be analysed are established considering specific situations to conduct a qualitative analysis. Each case is distinct and tailored, based on the information gathered from the partner involved in BeFlexible project. It offers a base of real-world information, ensuring that the case studies are grounded in the context of the demonstrators. Furthermore, the case studies serve as a valuable tool for extrapolating broader lessons and principles that can be applied in similar contexts, thereby contributing significantly to the body of knowledge in this field. This step is described in section 4.7
6) **Development of the framework design (Step 6):** Step (6) aims to propose a decision framework for evaluating the practicability of combining different acquisition mechanisms. This involves determining whether the mechanisms can be combined without issues, or if there might be inefficiencies or potential infeasibilities. This assessment is based on the design dimensions and options identified for each mechanism, ensuring a thorough and effective evaluation of their compatibility and efficiency in coexistence. Additionally, this step includes an applied analysis of the case studies, further enriching the decision framework with real-world insights. This step is described in section 4.8.

4.3 Analysis of mechanisms for acquiring DSO Services

According to [243] System Operator (SO) Services "*means market-based procurement of balancing, voltage control and congestion management".*

The system services examined in the BeFlexible project are aligned with the SO services detailed in [243]. However, since the scope of the current report is focused on distribution level, only the services described in Table 4.1 are considered, and they are defined as Distribution System Operator (DSO) services.

Table 4.1 Distribution System Operator Services. Source: [248]

DSO Services	Aims
Congestion management	Service to avoid or relieve congestion problems (physical limitations) in network components. Required to mitigate high energy flows: demand or generation. Service can be: Predictive (pre-fault), or Corrective (post-fault)

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Voltage control	Service to keep tension levels in appropriate ranges in buses. Required to minimize reactive power flows and reduce technical losses. Service can be: Predictive (pre-fault), Corrective (post-fault)

The integration of advanced technologies as flexible resources, like renewable energy, electrical vehicles, controllable loads, etc., by their very nature, gives them the potential to adjust both their generation and consumption patterns, offer promising opportunities for aligning with the specific needs of the system [245]. For instance, flexible resources can be utilized locally to address a grid congestion problem by shifting the network usage pattern of these resources.

In this context, suitable mechanisms are required for unlocking the flexibility that flexible resources can offer in the form of DSO services. According to [249], [250] four categories can be considered for acquiring flexibility: network tariffs, connection agreements, market-based procurement (bilateral contract, or markets as local markets), cost-based and rule-based approaches. For simplicity, we do not make distinctions between cost-based and rule-based, but the authors acknowledge that differences exist as cost-based receive a payment for the services provided while for rule-based mechanism it may not be the case. These mechanisms can be employed based on the signals provided to customers, which also define the way as the services are acquired, as is shown in Figure 4.2.

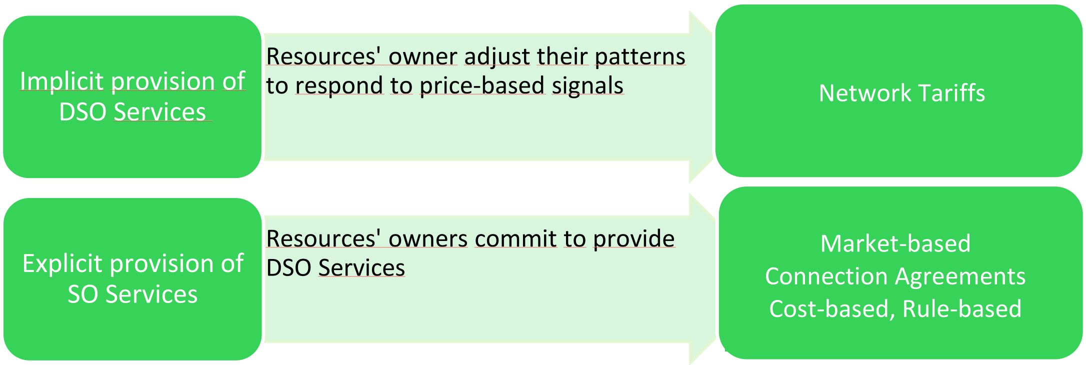

Figure 4.2 Classification of mechanisms for acquiring DSO service.

The terms “explicit” and “implicit” have been widely used in different projects to refer how mechanisms for acquiring system services can be employed [248], [251], [252]. The term “implicit” denotes that there is no explicit commitment to provide a service. Implicit provision of DSO Services refers to cases where resources adjust their patterns in response to price-based signals, such as those conveyed through network tariffs, leading consumers to modify their behaviours in reaction to price and charge fluctuations. On the other hand, the term “explicit” applies to a direct acquisition through a specific mechanism. Explicit provision of DSO Services refers to the cases in which the network resources actively commit to providing these services through trading changes in their energy profiles in market-based mechanisms or through obligations outlined in connection agreements or rule-based mechanisms.

Table 4.2 summarises the evaluation of the suitability of several mechanisms for acquiring distribution system operator services, based on the information detailed in [248]. Active power-based services are considered as measures for congestion management and reactive power-based services for voltage control.

Table 4.2 Applicability of the mechanisms for acquiring DSO Services. Based on: [248]

	Network Tariffs	Connection Agreements	Local Markets	Rule-Based
Congestion Management	High	High	High	High
Voltage Control	Low	Weak	High	High

Suitability: High / Weak / Low

Congestion management primarily involves the management of active power services, including injections and withdrawals. This service is required especially in scenarios where power lines or network components are at risk of overloading. On the other hand, voltage control can be achieved through both active and reactive power, which can be upwards or downwards from generation or demand. However, reactive power is particularly advantageous for addressing voltage issues due to its cost-effectiveness in networks with low R/X ratio values [253]. Two critical characteristics of voltage control services significantly influence the acquisition mechanism selection. Firstly, voltage control is inherently a local activity, requiring resources near the point of need. Secondly, voltage problems typically demand immediate solutions, making it challenging to predict the precise location and magnitude of such issues well in advance unless they stem from structural deficits or are due to predictable patterns in generation or demand.

Therefore, all the mechanisms described in Table 4.2 present a high suitability for congestion management. Additionally, for voltage control, a rule-based mechanism and local markets can be highly suitable. The use of connection agreements for voltage control is case-specific and it may be effective with the right design considerations. Network tariffs have a low suitability for voltage control. Further information can be found in [248].

In the following subsections, the description of the most relevant concepts regarding to the identified mechanisms for acquiring DSO Services is provided.

4.3.1 Network tariffs

Network tariffs are pricing structures designed to bill customers for their usage of electrical networks. Tariffs are required to recover operating, infrastructure maintenance, and investment network costs, while providing an efficient and fair method to charge customers based on their individual consumption patterns [246]. Network tariffs typically contains cost per unit of energy (kWh), cost per unit of capacity (kW), charges based on peak power usage, fixed fees, and other components that may impact the total bill amount. The specific structure of the tariff can vary depending on the location and regulations for allocating network costs.

However, some of these tariffs were initially established when the electrical system was entirely centralized, relying on large generators for power production, and household loads were easily predictable in aggregate [254]. With the increasing penetration of variable renewable energy sources, distributed generation, flexible loads and storage, these earlier designs are no longer valid [255]. Furthermore, the incorporation of active customers can contribute to a more efficient usage of networks, offering flexibility that could lead to a more cost-effective and sustainable electricity grid [256].

Therefore, innovative network tariffs should be designed and structured to balance the need for recovering network costs while providing signals to customers to adopt energy-efficient practices to reduce peak demands, supporting the integration of new stakeholders, and avoiding or delaying infrastructure investments.

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4.3.1.1 Objectives and design principles for network tariffs.

There is a diverse literature regarding the purposes of network tariffs, and most of them agree that the main objective is to recover network costs [1], [254], [257], [258], [259], [260]**.** Similarly, other goals can be outline as follows:

- Ensure the efficient and equitable operation of electrical networks, considering the requirements of the diverse stakeholders involved.
- It can be utilized to send economic signals to reduce network costs in the future. These signals impact customers' electrical behaviour, enabling them to reduce their network payments by aligning their electricity consumption with hours of lower prices.
- Encourage appropriate investments by ensuring that utilities can achieve reasonable returns, enabling them to enhance the electrical infrastructure consistently.

Moreover, tariff design principles should consider fundamentals guidelines and criteria employed to structure and implement tariff for the electrical networks. These principles ensure that tariffs are transparent, fair and encourage efficient use of the resources. Three main principles are identified in [257], [261], [262], and are explained considering some categories derived from each principle:

- Cost-reflectivity: Tariffs must reflect the actual cost of providing the electrical service, considering time, location, and quality. These tariffs should be set up considering that all parties involved contribute to the total cost accurately *(Cost additivity)*. Furthermore, they should be consistent across individual or aggregated consumption *(Robustness against consumer aggregation)*, and be predictable in both short and long terms *(Predictability),* offering certainty. Also, tariffs must remain impartial to the specific uses or technologies associated *(Technology neutral)*, with electricity consumption or production *(Symmetry)* and should ensure that the actions of one consumer don't adversely affect the charges of another *(Minimization of cross-subsidies).*
- Equity: Tariffs have to be designed to guarantee that all customers pay or earn a fair share based on their network usage. They must ensure that users with similar locations and patterns are billed equally *(Allocative equity),* regardless of the payer type or energy final utilization. Furthermore, tariffs should align charges with user's financial capacity *(Distributional equity),* and support the gradual shift from old to new tariff structures *(Transitional equity).*
- Transparency and simplicity: Tariffs should be straightforward and transparent, enabling most customers to easily their composition and impact on their bills.

Other tariff design principles found in additional literature are:

- Non-distortionary: Costs should be recovered without influencing decisions regarding network access, usage, and market propositions [263].
- Non-discriminatory: Network users should be treated without unjust bias [263].
- Accessibility to electricity: Every user should have network access as a necessary good, regardless of its profitability for the utility or not [254].
- Implementability**:** Tariff principles should protect customer welfare, ensuring transparency and fairness for all users. The structure should be simple, predictable, stable, and consistent [259].

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4.3.1.2 Network tariffs review

Table 4.3 presents an overview of the topics examined in the current literature, incorporating information from academic works, scientific papers, and technical documents from projects. The Table 4.3 encompasses references related to important network tariff analysis and characteristics, benefits, reports of stakeholders, network tariff modelling approaches, and some works that explore the interaction between network tariffs and other mechanisms to acquire system operator services.

Table 4.3 Overview of the main Network Tariffs (NT) topics discussed in the literature

Topic	Main Focuses	References
Concepts and characteristics	Concepts and Objectives	[264], [258], [254], [259], [265], [266]
	Dimensions and Options	[257], [267], [268], [269] , [270], [271]
Benefits	NT Design for DSO Services (Congestion Managements)	[272]
Reports of Stakeholders	Research projects	[273], [268]
	International Organizations	[266], [256]
Models	Pricing Methods for service providers	[274], [275], [276], [277], [270]
	Demand response applications	[278], [279], [280]
Interplay with other mechanisms	Smart Tariffs, Local Markets and Direct Control for Congestion Management	[281]
	Common TSO-DSO market-based, non-Market-based, and Local Market-based	[282]
	Contextual analysis to combine mechanisms for the procurement of flexibility needs and grid services	[248]

The current research overview focuses on identifying the most important characteristics that define network tariffs, considering its principle of designs.

Furthermore, the benefits that electrical networks can derive from using network tariffs as a mean for procuring system services, such as, congestion management and/or voltage control, are discussed in this document. It is also important to incorporate insights from representative projects framed at unlocking flexibility in the power grid, including recently completed initiatives like EUniversal [283], as well as those in early stages like BeFlexible [284]. Moreover, extensive literature employs modelling approaches to quantify the characteristics of several network tariff applications aiming to provide tariff allocation methods and incorporate consumer-oriented signals.

Finally, it is noteworthy that while this network tariff mechanism could provide a suitable procurement of system services with proper design, it may not efficiently leverage all its benefits alone. However, it can be mentioned that when it interacts with other mechanisms, it can enhance the overall system efficiency [248]. Despite there are still significant research gaps in this area, as shown in Table 4.3, particularly from a qualitative perspective, encourages deeper analysis regarding its interaction with other mechanisms.

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4.3.2 Connection agreements

Traditionally, electrical network users have secured 100% grid access to their contracted capacity through firm connection agreements. However, with increasing congestion risks and associated costs, due to the evolving dynamic of power systems, the guarantee of these firm connections is becoming less certain. In the EU, there is a growing trend towards adopting alternative connection agreements as a means to enhance flexibility, each accompanied by distinct regulatory challenges [285].

Alternative connection agreements (CA), also known as flexible connection agreements or non-firm connection agreements, can be considered a deviation from traditional firm capacity rights. These agreements may either limit the time periods allowed for injecting or withdrawing energy, or restrict the capacity that can be exported or imported [286]. Additionally, they can be structured as temporary or permanent solutions. Thus, system operators do not guarantee the continuous electricity supply for the full capacity whole the time to customers and may allow for interruptions or curtailments under specific conditions, particularly to manage congestion issues or balance the generation and demand. Service operators could agree with customers to provide the right to limit energy exchange in return for cheaper connections [287].

4.3.2.1 Objectives and design principles for connection agreements

Flexible connection agreements provide a solution for several challenges that may arise in the electrical network. They can allow new customers to access the grid, especially in areas with limited capacity, while waiting for reinforcement. They also provide the flexibility to defer network expansions until they become viable, such as, when there are enough customers to socialize the associated costs. Furthermore, they are particularly beneficial in high-impact situations where social, technical, ecological, or economic factors make grid reinforcement unfeasible.

According to [261], [286] there are some key principles for designing flexible connection agreements that can be summarized as:

- Voluntary: Customers retain the primary right to grid access. Therefore, they can decline, accept, or pay for grid reinforcement to be connected.
- Transparency: This principle is paramount in grid services procurement to prevent discrimination and ensure fairness among customers. It should include timely information sharing, open processes, and clear communication.
- Economic efficiency: The grid should be used optimally to avoid unnecessary investments. Therefore, it can influence deferring or avoiding expensive upgrades. Also, optimizing transaction costs could motivate new customers.
- Customer engagement: Customers should be incentivized through benefits like reduced costs or compensation for energy adjustments.
- Simplicity: Harnessing the network’s entire potential demands updated regulations, new tools, and possible harmonization to simplify processes, making them easy to understand and implement.
- Non-discriminatory: Distinction between system users must be based on objective criteria.
- Cost-recovery: It is necessary to recover network management costs efficiently. Introducing alternative connection agreements may require tariff adjustments due to increased capacity uncertainty.
- Not-distortionary: They should not distort system users’ network use and energy market behaviour.
- Predictability: Customers should be able to foresee the conditions under which they can engage and gain benefits.

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- Equity: It suggests that customers could experience differing treatment under public policy to ensure fair compensation.
- Implementability: This principle encompasses cost, complexities, and effectiveness. These include transaction costs, digitalization expenses, procedural differences, and diverse contributions to efficient network capacity usage.

4.3.2.2 Connection agreements review

Table 4.4 presents an overview of the primary topics examined in the current literature, incorporating information from academic works, scientific papers, and technical documents from international projects. The table encompasses references related to analysis and reviews, report of stakeholders, modelling approaches, and some works that explore the interaction considering other mechanisms to acquire system operator services.

Table 4.4 Overview of the main topics discussed in the literature for Connection Agreements (CA)

Topic	Main Focuses	References
CA Analysis and reviews	Concepts and Objectives	[288], [289], [290], [291], [245], [292], [293]
	Dimensions and Options	[248], [294], [295], [296], [297]
CA Stakeholders Reports	Research projects	[298], [283]
	International Organizations	[249]
CA Models	Demand response applications	[288], [299], [300]
Interplay with other mechanisms	Local Flexibility Market and a variable connection capacity for Congestion Management	[301]
	Interaction between connection agreements and other mechanisms for DSOs to access flexibility	[249]
	Contextual analysis to combine mechanisms for the procurement of flexibility needs and grid services	[248]

The current research overview focuses on identifying and defining the most important characteristics that describe this mechanism considering its design principles. This analysis has explored several concepts and objectives, along with identifying key factors, which have been categorized as dimensions and implementation options (details are also in the following sections).

Furthermore, it is also important to incorporate insights from representative projects framed at unlocking flexibility in the power grid, including recently completed initiatives like EUniversal [283], as well as those in early stages like Be Flexible [284]. Moreover, extensive literature employs modelling approaches to quantify the characteristics of several network tariff applications.

Importantly, while the connection agreements mechanism holds promise for effectively procuring system services with appropriate design, its full benefits might not be efficiently realized in isolation. Nevertheless, it is worth noting that when it interfaces with other mechanisms, it has the potential to enhance overall system efficiency [248]. Despite persistent research gaps in this domain, as shown in Table 4.4 especially those from a qualitative perspective, advocate for deeper analysis of its interaction with other mechanisms.

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4.3.3 Local markets for DSO services

In this section, market-based mechanisms for acquiring DSO Services are analysed, specifically those formulated to provide flexibility to power systems according to specific areas. They are widely known as local markets (LMs) for system services, or local flexibility markets. LMs have emerged as a solution for effectively integrating DERs and addressing the evolving challenges of grid management [250], [302].

According to [243], the term "local market for SO services" is defined as a market where service providers offer products for local SO (system operator) services, these services are referred to the market-based procurement of congestion management or voltage control. Therefore, it implies that flexibility buyers and sellers participate in processes like contracting, activation, and settlement [303]. These markets provide a platform for procuring flexibility through long-term and short-term mechanisms, tailored to specific grid characteristics [248]. This approach is efficient when markets are liquid, costs are lower than alternatives, and market distortion is manageable [304].

These markets can be operated by the system operators (SOs) or a neutral third party if permitted within the national regulations [243]. Although local flexibility markets offer flexibility connected to the distribution grid, they could be used to solve problems at the distribution, transmission, or both levels. When the flexibility services are used at the distribution level, the procurement is done by the distribution system operator (DSO). When it is used at the transmission level, the responsibility is on the transmission system operator (TSO). Due to this possibility, there are different schemes to coordinate between the TSOs and DSOs, including centralized markets, multi-level markets [305].

4.3.3.1 Local markets operations

As local flexibility markets are relatively new, the market designs are not yet harmonized across Europe. A first step towards harmonization of local market designs is the anticipated Network Code on Demand Response (NCDR) [306]. In the section below, the main stages of a local market operation are discussed.

- Prequalification: is the process by which the SO verifies the ability of a SP to offer, deliver, and validate a system service. Until recently, the prequalification processes included a complex set of procedures, which represented an entry barrier to small SPs. Acknowledging the need for simple prequalification procedures, especially for non-frequency system services, the NCDR draft proposes two distinct processes for balancing and non-balancing services [242], [306]. Product prequalification ensures SPs meet technical and data exchange requirements for service provision, including an activation test, to verify their capability in providing standard balancing services. Additionally, Product verification evaluates SPs' historical performance in service delivery, with temporary qualification status until meeting nationally defined criteria, crucial for specific balancing products, congestion management, and voltage control, with prequalification as an alternative in case of operational risks.
- Baselining: The flexibility offered by an SP is the difference between the meter reading at the time of activation and the estimated counterfactual position [307]. The latter is calculated in a process called baselining. The agent responsible for baselining and the associated methodology are determined nationally. As described in section 3.3.1, a few of the main methods are XoFY, Comparable day, Meter-before-meter-after (MBMA), and Regression methods [308]. The baseline methodology should be compliant with the regulations, recalculable, transparent, and minimize the effects of gaming. The SOs should develop a methodology to validate the resulting baseline. If SP is not the agent responsible for determining the baseline, they should provide all the necessary data needed for the calculation and forecasting of the baseline.

- Bidding: Bidding is the stage at which the SPs make an offer to the market for their service provision. The SPs offer the available volume of flexibility to the market, along with a price quote. Depending on the market design, the bids can be simple price-quantity pairs or complex structures, including intertemporal linkages and techno-economic constraints. Complex bidding formats can be relevant, especially for battery energy storage and demand response [309]. However, a large number of complex bids could increase the computational time and result in sub-optimal dispatches due to the presence of non-convexities.
- Market clearing: Market clearing is the stage in which the demand for flexibility is matched to reveal an equilibrium price and quantity [242]. Based on the market design, the clearing can be done on a first-come-first-serve basis (e.g., continuous trading markets) or using a merit-order list (e.g., auction markets). The exact criteria that are used for the selection and activation of bids have to be defined in the national terms and conditions [306]. Once the market is cleared following the rules, the agents are notified of their results. The uncleared bids from the local market may also be forwarded to the wholesale markets with compatible conditions, for example, from the local congestion management market to the intraday market [310]. Whether this is possible and under what conditions are points to be defined by the national terms and conditions [306].
- Verification and Settlement: The final stage in the local market operation is the verification and settlement. TSOs and DSOs are responsible for the validation of the baseline, collection, and processing of the meter data, validation of the activation, settlement of the delivered service, and sharing of costs between the involved SOs [306]. The method for calculating the financial settlements should be defined at a national level and may involve a regulated price, fixed price, a specific formula, or bilaterally agreed prices [306]. As discussed in 3.2, where an aggregator represents an SP, they are responsible for the financial settlements.

4.3.3.2 Local markets for DSO services review

Table 4.5 presents an overview of the topics examined in the current literature, incorporating information from academic works, scientific papers, and technical documents from projects. The Table 4.5 encompasses references related to important local markets for distribution system operator services analysis and characteristics, benefits, reports of stakeholders, local markets modelling approaches, and some works that explore the interaction between local markets and other mechanisms to acquire system operator services.

In this document, the provided overview focuses on identifying the most important characteristics that define local markets, considering its principle of designs. This analysis has explored several concepts and purposes, along with identifying key factors, which have been categorized as dimensions and options (details are also in the following sections). It is noteworthy that while this mechanism could provide a suitable procurement of system services with proper design, it may not efficiently leverage all its benefits alone. However, it can be mentioned that when it interacts with other mechanisms, it can enhance the overall system efficiency [248]. Even though there are still significant research gaps in this area, as shown in Table 4.5, particularly from a qualitative perspective, there is encouragement for further investigation into how it interacts with other mechanisms.

Table 4.5 Overview of the main Local Markets (LM) topics discussed in the literature

Topic	Main Focuses	References
Concepts and characteristics	Concepts and Objectives	[311], [312], [313], [314], [315]

	Dimensions and Options	[316], [317], [318], [319]
Benefits	LM Design for DSO Services (Congestion Managements and/or Voltage Control)	[320], [321], [322], [322]
Reports of Stakeholders	Research projects	[323], [324], [325], [326], [327], [328], [329], [330]
	International Organizations	[331], [332]
DSO services Models	DSO-owned flexibility resources	[333], [334]
	LMs for DSO services with multiple SPs modelling	[335], [336], [337]
Interplay with other mechanisms	Smart Tariffs, Local Markets and Direct Control for Congestion Management	[281]
	Common TSO-DSO market-based, non-Market-based, and Local Market-based	[282]
	Contextual analysis to combine mechanisms for the procurement of flexibility needs and grid services	[248]

4.3.4 Rule-based mechanisms

According to the EU Directive 2019/944, system operators have to procure ancillary services in accordance with transparent, non-discriminatory, and market-based procedures unless a market-based provision of those services is not efficient [338]. The exception can apply when there is not enough competition in the market, leading to gaming possibilities, or if operational constraints prevent the use of market-based solutions. In those cases, rule-based or regulated mechanisms may be applied. In a rule-based approach, the SO selects the agents for providing a service based on a predefined rule. Considering congestion management as an example, the SO can select the units for relieving congestion based on the generation shift factors (GSFs) instead of making the selection based on the available bids [339]. These agents may or may not be remunerated for the provision of the services. If it is not remunerated, it is considered as a mandatory service. Other examples of mandatory system service provision include frequency containment reserves (FCR) and black-start in the Spanish electricity markets [340]. Curtailment of generators and load can also be considered as a form of rule-based, non-paid service.

In other cases, remuneration would be present, calculated as the cost of providing the service. Taking the previous rule-based congestion management as an example, the units that are redispatches upwards receive their marginal costs and any foregone profits from other markets (e.g., profit from the day-ahead market) [341]. Similarly, the units that are redispatches downwards have to pay back the operational costs they saved. This type of cost-based compensation for redispatch is used in Germany and Austria [341]. Similar rule-based mechanisms with compensation can also be applied in local markets, especially when the pool of assets available for offering a service is limited.

4.4 Design dimensions and options for the mechanism to acquire DSO Services

4.4.1 Design dimensions and options for network tariffs

This section explores the principles of the design of network tariffs to identify design dimensions and options that describe this mechanism and allow the analysis of its interplay with other mechanisms for acquiring distribution system operator services. As indicated in section 4.2, design dimensions serve as variables that collectively characterize the nature and functionality of the mechanism, while the options act as possible implementation values (domains) that can be selected for a specific dimension. It is crucial to note that some options within a dimension may be mutually exclusive (ME), indicating that they cannot be implemented concurrently. On the other hand, if options are not ME, it is possible to apply multiple options at the same time. Likewise, they have been categorised into meta-dimensions based on shared characteristics among several dimensions and their common impact on other mechanisms. This information is shown in Table 4.6.

As outcome of the review described in section 4.4.1 and resumed in in Table 4.3. Eight dimensions are identified for the network tariff mechanism. However, network tariffs can vary based on the jurisdictions where they are applied. Their utilization depends on the specific regulatory context and scope, while considering a proper balance among the design principles of economic efficiency, equity, and transparency, in order to recover network costs and send accurate signals to customers [257].

Table 4.6 Design dimensions and options for network tariffs

Meta-Dimension	nº	Dimension	Options					ME
Charges	1	Cost Allocation methods	Average Costs	Long-term incremental + Residual Costs				Yes
	2	Charging variable	Fixed	Used Capacity (measured)	Capacity (contracted)	Capacity (physical)	Energy	No
Locational	3	Locational granularity	System-wide	Zonal	Nodal			Yes
Temporal	4	Temporal granularity of charges	Yearly	Seasonal (Monthly)	Blocks (Daily)	Hourly		Yes
	5	Price setting periodicity	Year ahead (static)	Day(s) ahead (dynamic)	Ex-post			Yes
	6	Temporal granularity of measurements	Yearly	Monthly	Blocks (Daily)	Hourly	Quarter hourly	Yes
Assets	7	Customer differentiation	By Voltage levels or network areas (Technology agnostic)	Specific tariffs according to technologies (Generation, Storage, EVs., etc.)				Yes
	8	Symmetry of charges (Energy o capacity components)	Same offtake and injection charges	Different offtake and injection charges				Yes

The cost allocation methods and charging variable dimensions present characteristics related to price and how these are charged to different customers, thus they are categorized into the meta-dimension “charges”:

1) The ***Cost allocation methods*** denotes the approaches employed for partitioning the recognized network costs that must be recovered and assigned to customers. It depends on the understanding of the economic efficiency principle, whether all costs should provide economic signals to customers or economic signals should be provided to lower future network costs. Thus, one option encompasses all recognized network costs as a whole and divided for the total demand forecasted *(Average costs)*. However, relying solely on past network costs can be inefficient

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in signalling to customers. Alternatively, another option *(Long-term incremental + Residual costs)* considers the present network costs associated with those incurred in the past and includes economic signals for customers aimed at reducing future network costs (Long-term incremental component), such as those needed for reinforcement or expansion due to the increment in the demand. Additionally, it also considers the remaining costs required to ensure the recovery of the total network costs (Residual component), as the incremental component alone may not recuperate the full costs. The latter option is more effective in incentivizing customers.

2) ***Charging variable*** depends on the cost driver (variable that contribute to increasing network costs) of the selected item. It can be a fixed value assigned per customer *(Fixed charge)*, allocated as a power-based (kW) charge (Capacity charge), or set based on energy (kWh) consumption *(Energy charge)*. In the case of the Capacity charge, there are three possibilities: based on the maximum peak demand *(Used Capacity (measured)),* and is determined ex-post, or according to a predetermined value in the connection contract *(Capacity (contracted)),* and if exceeded, a penalty is imposed, or dependent on the installation physical availability *(Capacity (physical)).*

The locational granularity due to its spatial characteristic have been grouped into "Locational" meta-dimension:

3) ***Locational granularity*** can be understood as how a location (connections in an electrical grid) is partitioned for allocating the network charges. It can be applied uniformly across an entire country *(System-wide)* or can be distinguished by differentiated areas *(Zonal)* or based on connection points *(Nodal).* Addressing location-specific tariff signals is crucial due to cost variations in serving grid users and the necessity to signal capacity constraints, influenced by factors like user density, distance from generation, and network asset characteristics. A greater locational granularity allows better cost estimation, which is especially important due to the rise of distributed resources, but the network tariff design process could become more complex.

The dimensions of temporal granularity of charges, price setting periodicity, and temporal granularity of measurement, due to their time-dependent attributes, have been categorized together in "Temporal" meta-Dimension.

4) ***Temporal Granularity of charges*** can be understood as how time is partitioned for allocating network charges, resulting from generation and demand profile changes and their impact on the network. It can be uniform throughout the year *(Yearly),* which may simplify billing but does not properly reflect variations in demand or generation costs over different times of the year. Also, it can vary between seasons in the year considering specific months *(Seasonal (monthly)),* allowing prices to be better aligned with the characteristic consumption and generation patterns of each season. Moreover, it can be divided into time blocks (Blocks (hourly)), such as hours within a day or across seasons, etc, offering a greater adaptation to varying profile patterns. Furthermore, they can be ranged by hours *(Hourly),* or shorter (which depends on the temporal Granularity of the measurements dimension), which encourages efficient energy use an enable more accurate system management.
5) ***Price setting periodicity*** measures how close to delivery time the network charges are re-calculated. The closer this is, better network charges can reflect the current grid state and the congestion risks, but it diminishes predictability from customers (network problems could arise because the signals sent are poorly handled). This periodicity can be set once a year *(Year ahead (static))*, or based on the forecast network usage for the next day *(Day(s) ahead (dynamic))*, or after network usage has occurred (*Ex-post).*
6) ***Temporal Granularity of Measurements*** pertains to how time is subdivided for capturing data using suitable equipment like smart metering. It can occur every 15 minutes *(Quarter hourly)*, hourly *(Hourly),* daily *(Daily),* or even more intermittently, such as monthly *(Monthly)* or annually *(Yearly),* depending on the level of granularity required. Less level of granularity provides highly detailed data, allowing for precise tracking of energy usage and generation. It is crucial to ensure that the temporal granularity of measurements is equal to or shorter than the temporal granularity of charges.

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Lastly, customer differentiation and the symmetry of charges (energy or capacity components) can be categorized under the "Assets" category.

7) ***Customer differentiation*** refers to the possibility of tailoring network tariffs based on specific technologies or equipment that customers may utilize *(Specific tariffs according to technologies (generation, storage, Electrical Vehicles, etc.))*. This approach can offer pricing structures to incentivize the adoption of cleaner or more efficient energy solutions. However, it may potentially have a negative impact on allocative equity and technology-neutral principles. Nonetheless, specific tariffs remain quite common in practice. Alternatively, tariff differentiation could be based on voltage levels or specific grid areas *(By voltage levels or network areas (technology agnostic))*. This approach considers factors such as the geographical location within the distribution network, voltage requirements, and some characteristics of customers based in a particular zone. It represents a more generalized approach that can help balance costs and revenues across different parts of the grid.
8) ***Symmetry*** states if network charges can be symmetric for energy withdraws and injections, i.e., the same charge but with the opposite sign *(Same network and injection charges)*, or energy withdrawals and injections can have different network charges *(Different network and injection charges).* In the case of symmetry, for example, if you pay a certain cost for injecting energy (supplying it to the grid), you would also receive an equivalent credit or reduction in cost when withdrawing energy (consuming electricity from the grid). This approach balances the cost structure, promoting fairness and neutrality in energy transactions. On the other hand, if they are different, this approach can be employed for various reasons, such as encouraging specific behaviours or technologies. For example, it might incentivize energy producers to inject more renewable energy into the grid by offering favourable injection charges while applying standard or higher charges for energy withdrawals. This approach can influence customer behaviour.

4.4.2 Design dimensions and options for flexible connection agreements

This section explores the design principles of flexible connection agreements to identify design dimensions and options that describe this mechanism and allow the analysis of its interplay with other mechanisms for acquiring distribution system operator services. As mentioned in section 4.2, design dimensions are variables that define the nature of the mechanisms and operational capabilities, and options are the conceivable implementation values (domain) for each dimension. It is important to emphasize that certain options within a dimension could be mutually exclusive (ME), meaning they cannot be enacted simultaneously. Conversely, when options are not ME, implementing several options concurrently is feasible. This information is shown in Table 4.7.

Twelve dimensions have been identified for the flexible connection agreement mechanism according to the review of this mechanism as reported in section 4.4.2 and summarised in Table 4.4. However, flexible connection agreements can differ based on the jurisdictions where they are applied. Consequently, not all dimensions and options outlined in Table 4.7 are implemented simultaneously, their employment depends on the specific regulatory context and scope.

Table 4.7 Design dimensions and options for flexible connection agreements

Meta-dimensions	nº	Dimension	Options				ME
Temporal	1	Duration of flexible connection	Temporary	Permanent			Yes
	2	Curtailment notification	Day-ahead	Intra-day	Real-time	Ex-post	Yes
	3	Connection Costs	Deep Connection costs	Shallow connection costs			Yes
	4	Benefit of the DSO allowing flexible connection	Avoid reinforcement (Network expansion is not possible)	Defer reinforcement (More economic than network expansion)	Preliminary connection (Network expansion is committed in a future year)		No
	5	Network connection criteria	Capacity limitation	Voltage level limitation	Other security criteria (N, N-1)	Short-circuit power rate	No
Product	6	Activation of the energy curtailment due to flexible connection	Emergency (Grid failure risk)	Maintenance	Congestion		No
	7	Pre-definition of curtailment	Peak/off-peak	Seasonality (Days or periods)			Yes
	8	Principle of access	Pro-rata	Last Input First Output (LIFO)	Auction	Curtailment proportional to level of congestion created	Yes
	9	Compensation payments for energy curtailment	Fixed	Set by the Local Flexibility Market where the flexible connection is participating as price taker	Local Market-indexed where the flexible connection is bidding a free price	None	Yes
	10	Possibility to sell the expected curtailed energy	Bilateral Contracts	Local Markets			Yes
	11	Maximum curtailment	Duration (hours)	Capacity limitation	Energy limitation	Monetary limitation	No
Assets	12	Eligible customers	Generation (Including hybrid installations)	Demand (Including active customers)	Storage (Stand-alone)		Yes

Considering the dimensions characteristics for this mechanism, three meta-dimensions have been identified. The first eleven are product-oriented, therefore, they are categorized under “Products”. However, the dimensions duration of flexible connection and curtailment notifications incorporate a temporal component, consequently, they are also categorized under “Temporal”. Similarly, “eligible customers” is categorized under the “Assets” meta-dimension.

1) Implementing an end-date, as a ***Duration of connection***, helps to introduce certainty to customers. In the case non-firm access is offered while reinforcement *(Temporary)* is being carried out, the connection then automatically converts into a firm connection when the network upgrade is finished. With flexible connections as a means to defer reinforcement, the flexible connection can be turned into a firm one once reinforcement of the grid is triggered. It may also be the case that the flexible connection arrangement is maintained in the long term *(Permanent)*. However, if sufficient customers connect under a non-firm scheme and agree to share the reinforcement expenses.
2) The ***Curtailment Notification*** indicates how much advance notice customers receive regarding the curtailment. The information of customers about the realisation of curtailment is an important aspect of transparency of network operation. The timing of the communication of required reinforcement might take place coupled to markets or ex-post. The notifications can occur in various timeframes depending on the network requirements: one day before *(Day-ahead),* hours before on the same day *(Intra-day),* or close to real-time *(Real-time),* such as in time intervals less than a fraction of an hour. Real-time decisions on curtailment are likely to require local flexibility markets to decide on which user to curtail. In some cases, notifications may also be made after the outage due to immediate response to unforeseen events *(Ex-post)*.
3) The dimension ***Connection costs*** can be defined as the amount of cost that should be recovered, and it is assigned to new customers or those who want to increase their current capacity, in order to satisfy network reinforcement requirements. The degree to which connection charges accurately represent the actual cost of providing a user with a new or upgraded connection depends on the type of connection charge. They will be determined by

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whether new customers can connect without added charges *(Shallow connection cost)*, or whether network reinforcement is required for accommodating the increment due to the upgraded capacity *(Deep connection costs)*.

4) Flexible electricity grid connections might be considered as a solution for different situations and set the ***Benefit of the DSO*** allowing flexible connection. Non-firm grid access allows DSOs to avoid network expansion when is not possible or unfeasible *(Avoid reinforcement)*. Alternatively, network upgrades can be deferred *(Defer reinforcement),* when this solution is more economic than network expansion, for example until sufficient customers are connected to share the associated cost. Also, interruptible connections can serve as a means for connection-seekers to connect to the grid already while reinforcement is being carried out due to the long-time frames required for committed grid expansions *(Preliminary connection).*
5) The ***network connection criteria*** encompass the grid requirements that determine the access to non-firm connections. The capacity of the grid *(Capacity limitation)* might be restricted during specific timeframes and under certain circumstances, such as congestion problems. In that sense, wind generation might be offered flexible connections in areas with high wind speeds and increased installed wind capacity already connected to the grid. Also, congestions are likely to occur in that network area when wind is producing at its maximum and new generators would require curtailment. Another criterion depends on whether the network access can be limited according to tension magnitude *(Voltage level limitation)*. Also, utilities typically plan network expansion according to specific measures, such as N or N-1 criteria *(Security criteria)*, which can impact access to firm capacity. Additionally, it is possible that the available capacity or voltage level meets requirements, but the short-circuit power rating may not be met *(Short-circuit power rate).*
6) The ***Activation*** of the energy curtailment due to flexible connection is not limited to specific events, and it can occur for several reasons. While the operation of electricity grids already includes that customer might be disconnected due to outages *(Emergency)*, flexible connections allow to expand the employment of injection or withdrawal reductions such as in the case of network maintenance *(Maintenance)*. Congestion-based reduction of grid access capacity can be triggered for meteorological reasons (e.g., high wind speeds in a network area with high participation of wind capacity) or due to variations in electricity demand *(Congestion)*.
7) ***Pre-definition of curtailment*** identifies the potential hours of curtailment and can be indicated in the connection contract if the occurrence of congestions can be forecasted. If congestions occur due to demand variations, flexible hosting capacity might be assigned as peak/off-peak capacity *(peak/off-peak)*. In grid areas with high wind speeds and increased installed wind capacity already connected to the grid. In this case, congestions are likely to occur in that network area when wind is producing at its maximum and new generators would require curtailment. The flexible connection could be bound to seasonality of resource availability that can be for days or time periods *(Seasonality).*
8) ***Principle of access*** considers the methodology to assign the curtailment when several customers are eligible. All customers connected can be curtailed equally (*Pro-rata),* e.g., the same % of available energy or the same amount of capacity. Although this approach increases the attractiveness of connection for new customers compared to LIFO, it introduces uncertainty for already connected customers as future levels of curtailment are unknown at the moment of connection. Other option considers that last non-firm customer to connect is the first to be curtailed (*Last-on-first-out (LIFO))*. Once this customer is curtailed entirely, or at the maximum curtailable capacity, the second last is curtailed. This option exposes the latest connections to high curtailment risks, but provides certainty for already connected non-firm customers. Additionally, curtailment can be assigned according to an auction scheme (*Auction)*. The auction might be integrated in the process of assigning hosting capacity. In that case, the connection seeker with the willingness to accept the highest curtailment is allowed to connect. Assigning curtailment via auctions can also imply the creation of a local flexibility market so that curtailment can be assigned according to the economic offer submitted by the participants for each hour of congestions. Furthermore, customer with the highest participation in triggering congestion is curtailed first *(Level of congestions created)*.

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Although this option appears to be the most effective in terms of solving congestion, it poses the risk of curtailment on those customers connected at grid locations with frequent congestions. In case the congestions are triggered by modifications, e.g., new connections, after the affected customer agreed on a non-firm connection, future levels of curtailment are difficult to predict for the customer.

9) ***Compensation Payments*** for energy curtailment introduces economic certainty for customers. Especially in a shallow connection charging regime, customers might require incentives to opt into flexible connections. If the magnitude of compensation payment can be arranged as a flat price in the connection agreement *(Fixed).* Furthermore, if curtailable connections participate in LM for system services as a price taker, the compensation payment is deduced from the LM price *(Set by the LM)*. Also, both DSO and customers are expected to prefer a variable payment amount to account for future changes of SPOT and flexibility prices *(Local Market-indexed)*. If the customer does not participate in the LM, a coupling of the compensation value to LM prices could represent an interesting solution. In certain regions, access to flexible connections may be granted with the requirement of curtailment, if necessary, without an assigned payment *(None).*
10) ***Possibility to sell*** the expected curtailed energy, refers that in the case of upstream congestions, how customers could be able to sell their electricity to others in the same feeder. If a congestion occurs at a transformer station connecting a distribution feeder to the wider network, customers might still trade electricity downstream of the congestion. This could be enabled via the introduction of LM. Another approach is allowing participating in negotiation process *(Bilateral Contracts).* Electricity could be sold downstream of the congestion at a lower price to incentivise the attractiveness of this option and allow both generators and demand to benefit.
11) The introduction of a ***Maximum Curtailment*** threshold within the connection contract provides certainty for customers. The definition of this maximum might be considering the maximum duration of all curtailments during a year (*Duration (hours)).* With this option, the SO and the customer agree on a maximum number of hours in which the connection might be subject to curtailment. This helps the SO for grid planning, but exposes the customer to the financial risk as all curtailment could be carried out in hours with high prices. Additionally, the maximum capacity curtailed, absolute, or relative (of nameplate capacity or available capacity each hour) (MW). Customers might be disconnected completely or only in parts with a minimum (non-curtailable) capacity agreed upon in the connection agreement *(Capacity limitation)*. This last option introduces certainty to customers, knowing that a certain part of assigned grid capacity is firm. Moreover, the maximum energy curtailed in a year (total or relative to available energy) (MWh or % of MWh available). Another option is the limitation of maximum energy *(Energy limitation)* subject to curtailment throughout the year. This might be expressed in terms of energy (MWh) or in terms of relative energy available (%) to account for variations that might occur due to changing demand patterns or different availability of RES resources. Furthermore, the maximum value of energy per year (€ or % of € potentially earned). All the above-mentioned options put the economic risk on the customer as curtailment might be carried out in hours with high prices *(Monetary limitation)*. Hence, certainty could be provided by introducing a maximum economic value of curtailed energy, i.e. relative to the expected income of a plant or relative to the average SPOT price of a given year to account for variations. This option appears to be of difficult implementation for SOs seeking to use curtailment to solve grid congestions independent from the SPOT prices in hours of congestion.
12) The ***eligible customers*** refer that, depending on the state of network congestions, flexible connections might be offered to customers of different technologies. It can cover generation, considering hybrid facilities *(Generation)*, consumption *(demand)* including active customers. Also, storage systems *(Storage)*, that operates as stand-alone. Small connection-seekers usually are less likely to be willing to take the risk of curtailment to connect to the network.

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4.4.3 Design dimensions and options for local markets for DSO services

This section explores the principles of design of local markets for DSO services to identify specific dimensions and options that describe this mechanism and allow the analysis of its interplay with other mechanisms for acquiring distribution system operator services. As is indicated in section 4.2, the dimensions can be shown as variables that collectively define the nature and functionality of this mechanism, and the options signify the potential implementation values (domain) that can be recognised for a specific dimension. Some options in a dimension might be mutual exclusive (ME), which means they cannot be applied simultaneously. Equally, if they are not ME, more than one option can be applied at the same time. Similarly, they have been categorised into meta-dimensions based on shared characteristics among some dimensions and their common impact on other mechanisms. This information is shown in Table 4.8.

According to the review of LMs for DSO services described in section 4.4.3 and resumed in Table 4.5, ten dimensions have been identified for the LM for DSO services mechanism. However, these local markets can differ based on the jurisdictions where they are applied. Consequently, not all dimensions and options outlined in Table 4.8 are implemented simultaneously, their employment depends on the specific regulatory context and scope.

Table 4.8 Design dimension, and options for local markets for system services

Meta-Dimension	nº	Dimension	Options					ME
Locational	1	Flexibility need Grid level	High Voltage	Medium Voltage	Low Voltage			Yes
Temporal	2	Negotiation time frame (Gate Opening and Closure for participation)	Long-term (Weeks-ahead to years-ahead)	Shot-term (Real-time, intraday, day-ahead)				Yes
Temporal	3	Contract length	Yearly	Monthly	Weekly	Daily	Hourly	Yes
Temporal / Product	4	Temporal bid granularity	> 1 hour	1 hour	30 min	15 min		Yes
Temporal / Product	5	Response Time (Activation)	> 1 hour	30 min – 1 hour	15 min – 30 min	< 15 min		Yes
Product	6	Transactional Object	Capacity (Availability)	Energy (Activation)				No
Product	7	Power	Active Power	Reactive Power				No
Product	8	Direction	Upwards	Downwards				No
Product	9	Symmetry Requirements (For upwards and downwards)	Symmetric products	Asymmetric products				Yes
Asset	10	Source (Flexibility assets)	Generation (Including hybrid installations)	Demand (Including active customers)	Storage (Stand-alone)			Yes

The dimension grid-level location due to its spatial characteristics within the network is considered as part of "Locational" meta-dimension:

1) The ***Grid-level location*** for flexibility needs relates to the specific voltage level on the electricity grid where local flexibility services are required. The most suitable solutions are those in which flexible resources are located as close as possible to the congested component, prioritizing those with a greater impact from both technical and economic perspectives. Therefore, in generation and transmission *(High Voltage),* there is a demand for flexibility services to manage high power flows. Also, flexibility needs could be associated with sub-transmission or distribution substation levels *(Medium Voltage),* where flexibility services may be required to keep voltage and frequency in appropriate values. Likewise, flexibility services can also be necessary for distribution networks

serving end-users *(Low Voltage),* where it's necessary to manage demand variations and distributed energy resources.

The dimensions of Negotiation time frame, contract length, temporal bid granularity and Response Time, incorporate temporary features, thus they are categorized under "Temporal". Furthermore, the last two dimensions stated, which also encompass product-related characteristics, along with Transactional Object, Power, Direction and Symmetry Requirements fall under the category of "Assets".

2) The **Negotiation time frame** refers to the specific time horizon throughout the bids for the provision of system services are developed. Market participants can plan and submit their flexibility offers during this window. At the gate opening the requirement objectives are released to service providers. The gate closure marks the end of the negotiation period, where the clearing process is conducted to match flexibility needs with resource offers that satisfy all technical constraints. It can occur over an extended period, typically weeks to years in advance *(Long-term)*, depending on services requirements. Alternatively, it can occur on a much shorter time scale, as real-time, intraday, and day-ahead markets *(Short-term),* mostly for addressing immediate grid operational requirements.
3) The ***contract length*** defines the duration for a service contract to be established with a commitment from the flexible resources to remain available. The choice of the contract duration depends on the specific requirements of the network and the capabilities of the service providers, addressing both long-term and short-term objectives. This period can be of one year *(Yearly),* occur on a monthly basis (*Monthly*), seven-day periods *(Weekly)*, cover a single day *(Daily),* or even real-time availability with short-term notice *(Hourly).*
4) The ***Temporal bid granularity*** corresponds to the temporal resolution, or the smallest time interval, at which flexibility needs change, and service providers must be capable of responding uninterruptedly. Market participants can make bidding decisions based on the granularity set by system operators to meet network requirements, and considering the characteristics of available resources. It can vary from greater than hour *(>1 hour)* providing bids in hourly or longer time-blocks, one-hour intervals *(1 hour),* 30-minutes intervals (*30 min*), or 15-minutes intervals *(15 min).* These options enable participants to address a wide range of scenarios, allowing them to tailor their bidding strategies to meet specific needs and network conditions.
5) The ***Response Time Activation*** encompasses the specific temporal interval required for a flexible resource to reach its operational level after receiving a trigger signal. In general, it corresponds to the time required for a ramping operation to respond an activation command, whether it involves an increase (ramp-up) or a decrease (ramp-down) in power or energy. Resources can be categorized based on their activation speed, including those with slower responses exceeding one hour *(> 1 hour),* those with moderate responses ranging from 30 minutes to one hour *(30 min – 1 hour)*, those responding within 15 to 30 minutes *(15 min – 30 min),* and those with nearly instantaneous responses *(<15 min).* The latter category of resources is exceptionally well-suited for addressing rapid changes in supply and demand.
6) The ***Transactional Object*** refers to the commodity that can be involved in transaction associated with the provision of system services using flexible resources. The object can represent a commitment of the resources to be available to provide its flexibility for a predetermined duration in the form of standby capacity *(Capacity (availability)).* This implementation option emphasizes the object's capability to remain in reserve and be prepared for deployment when required. Likewise, this commodity can encompass the active utilization of flexible resources to respond in real-time *(Energy (activation)),* comprising the injection or absorption of energy to address fluctuations in demand or generation while mitigating network congestion.
7) The ***Power*** corresponds to the specific type of power required to address network problems according to the component congested. Typically, when congestion issues arise in power lines or transformers, active power *(Active Power)* is required. This is because it directly influences the ability to meet the real-time demand of consumers

and serves as the primary focus of power generation. Additionally, concerning problems in buses, such as overvoltage or undervoltage, reactive power *(Reactive Power)* may be required as it contributes to manage voltage fluctuations and supports the operation of reactive elements connected to the grid. Recent EU projects such as EUniversal [342] and CoordiNet [343] are exploring the utilization of both active and reactive powers for congestion management and voltage control applications.

8) The ***Direction*** distinguishes the orientation in which the flexible resources are required. When additional power is needed, it can be provided by increasing generation or reducing consumption (Upwards). Upward flexibility primarily depends on the system's ramping capability. Conversely, when a reduction of excess power in the network is necessary, it can be achieved by decreasing generation or increasing consumption *(downwards).* Downward flexibility is closely related to the system's ability to reduce the output of conventional units and is a major contributor to wind and solar curtailment.
9) The ***Symmetry requirements*** address the need for uniformity in products and services. Symmetric *(Symmetric products)* are characterized by a high degree of balance, offering solutions that equally apply to both upward and downward flexibility needs. In contrast, Asymmetric *(Asymmetric products)* are tailored to address specific requirements that may differ between upward and downward scenarios.

Similarly, source is categorized under the "Assets" meta-dimension.

10) The ***Resource*** corresponds to the specific flexibility assets employed to deliver the system services. This can encompass a range of assets, including power generation sources *(Generation (Including hybrid installations))*, such as renewable energy installations and hybrid power plants, capable of adjusting their output to meet grid needs. Additionally, it can involve the utilization of demand-side management techniques and active customer participation *(Demand (Including active customers)),* allowing customers to adapt their electricity patterns to provide grid flexibility. Furthermore, it can consider stand-alone energy storage systems *(Storage (stand-alone))* such as batteries, which can store excess energy during periods of surplus and release it when needed.

4.5 Comparative analysis of mechanism for acquiring DSO Services

4.5.1 Methodology for the comparative analysis of the mechanisms for acquiring DSO services

Figure 4.3 depicts the general methodology for carrying out the comparative analysis between the different mechanisms for acquiring DSO services.

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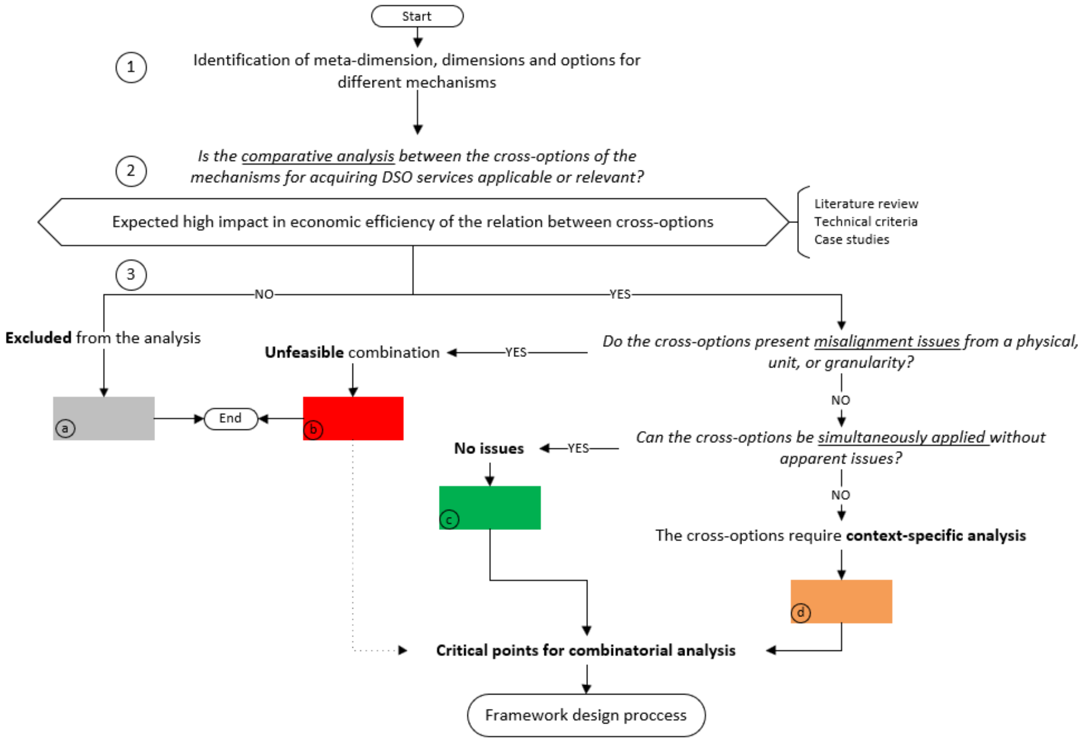

Figure 4.3 Flowchart of the methodology for the comparative analysis of the mechanisms for acquiring DSO services

1. The step (1) entails a comprehensive identification of the dimension and options that describe the selected mechanisms for acquiring DSO Services. These dimensions and options are established by conducting an analysis regarding how a specific mechanism can potentially impact others. Additionally, the dimensions are categorized based on similar characteristics into meta-dimensions. The design dimensions of the acquisition mechanisms of interest are defined in section 4.4.
2. The step (2) aims to identify possible interactions among the different mechanisms considering the options of each dimension. Hence, by aligning a specific option from one mechanism with an option from another mechanism, it can be identified characteristics that can be used to establish a linkage between these mechanisms. In this report, such options are referred to as cross-options for simplicity. For the relevance and applicability of this analysis, it is important to consider the high-level meta-dimensions since mechanisms may exhibit potential for interaction if their respective dimensions are categorized similarly (e.g., temporal, spatial, product-related dimensions). The critical condition in determining the interplay of cross-options is assessing the expected impact on economic efficiency as result of their feasible combination. It can be identified through a literature review, and considering both technical criteria and empirical evidence derived from outcomes of previous projects.
3. In step (3), if the analysis described by step (2) deems as not relevant the establishment of interaction between the mechanisms, the cross-options are excluded from the analysis, and they are visually represented in grey (a). On the other hand, when similarities suggest likely interplay, three alternatives are examined:

- Firstly, alignment challenges between cross-options are assessed and they cannot be combined. Misalignments may come from physical, units of measurement or granularities discrepancies. For instance, if in connection agreements the "curtailment notification" dimension is "day-ahead", and the customer is considering participating in local markets with their curtailed energy, but the "Negotiation time-frame" is "long-term (weeks-ahead to years-ahead)", this interaction is not possible due to significant differences in temporal granularity, due to the latter is much higher than the former. Therefore, this cross-option is visually represented in red (b).

- Secondly, the feasibility of simultaneous application of cross-options is evaluated. An example, if in network tariff is considered a charge "Fixed" in the "Charging Variable" dimension, and the customer could access to the electrical network by a connection agreement, its incorporation can be motivated by considering a "Compensation payments for energy curtailment" defined as "Set by the local flexibility market where the flexible connection is participating as price taker". Therefore, this cross-option is visually represented in green (c).
- Thirdly, if the interaction between cross-options is contingent upon the specific context condition. For example, if the "time granularity" of a local market is higher than the time in "temporal granularity of the charges" defined in the network tariff, it potentially results in cost allocation challenges. But, with a lower time resolution in the local market, it can enhance the economic efficiency of the signal received by customers. But it depends on the specific regulation established in the jurisdiction where this comparative is taking place. Therefore, this cross-option is visually represented in orange (d).

4. Finally, the cross-options established as green and orange serve as guide to the design of the combinatorial framework, ensuring that it addresses critical aspects effectively. Furthermore, it is imperative to recognize red ones to avoid unrealistic or unattainable situations.

4.5.2 Network tariffs vs local markets for DSO services

In this subsection, the interaction between network tariffs and local markets (LM) for DSO services for acquiring distribution system operator services is analysed. The overarching question to address is how a customer subject to a specific network tariff can be encouraged to participate in a LM for system service, leading to a significant impact on economic efficiency resulting in their interplay.

As highlighted in section 4.3.1, the objective of network tariffs is to recover network costs and, at the same time, to send economic signals to reduce network costs in the future. Future network costs, i.e. network reinforcements, are triggered when the usage of a network is close to the network capacity limit. Therefore, the aim of network tariffs is to engage customers to reduce network usage when the network is close to be congested. On the other hand, as discussed in section 4.3.3.2, the objective of LM for DSO services is to establish a market-based framework where customers can offer an adjustment on their network usage to the DSO in exchange for a payment. The DSO benefits from the LM for DSO services because it is an alternative to network reinforcements. However, depending on how network tariffs and LM for DSO services are designed, they could both send the same economic signal of reducing network usage. In this case, customers could be double-rewarded or double-charged, which eventually would distort the economically efficient customer behaviour. Therefore, network tariffs and LM for DSO services should be designed in a way that each mechanism signals an independent cost segment, clearly separated from the other mechanism.

Table 4.9 shows the comparative analysis between the different dimensions and options determined for these two mechanisms, and a description of this information is provided in what follows.

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Locational granularity (Meta-dimensions in blue)

The locational meta-dimension connects those design dimensions that describe space-based characteristics. The design dimension to be considered are locational granularity from network tariffs and flexibility need grid level from LM for DSO services.

Network tariffs are intended to recover network costs and to send economic signals to network users that reflect the costs caused by their network usage, incentivizing them to make an optimal use of the network. Ideally, economic signals sent by network tariffs should differ by time and location in order to be cost-reflective. In the end, this would mean a user-by-user network tariff design. However, the implementation costs of such a granular network tariff design are high and customer responses to economic signals are not granted. Consequently, in most jurisdictions, network tariffs are equal for all customers under the same connection type (LV, MV, or HV) in the country. In other cases, such as in UK, network tariffs differ by regions, or as in Germany, network tariffs differ by smaller zones.

A lower locational granularity in the network tariff design, i.e., same network charges for all regions, means a higher socialization of network costs, i.e., those customers connected to regions with lower network costs are subsidizing those customers connected to regions with higher network costs, and the true network costs are not reflected by network charges. In this case, customers are not aware of the specific congestion issues that may occur in their LV or MV networks, and they are not incentivized to reduce (or increase) consumption when the LV or MV networks are close to being congested. This creates a less-than efficient customer behaviour.

Under this environment of sub-optimal network tariff design, LM for DSO services try to extract local flexibility to solve local congestion issues. Therefore, LM for DSO services are only required for those cases when network tariffs are not locationally granular enough to extract local flexibility (blocks in green). On the contrary, if LM for DSO services are applied for solving congestion management issues that are already signalled by locationally granular network tariffs, then the cost segment signalled by the LM for DSO services should be eliminated from the network tariff design, to avoid double signalling (blocks in orange).

For example, there is a network tariff design differentiated by substations (MV networks) which is composed of three cost segments (HV network costs, MV network costs, and LV network costs), and there will be a congestion issue in a specific substation A. Then, a LM for DSO services for customers using substation A is triggered. In this case, customers using A would double signalled, facing 1) the network tariff (which includes their contribution to substation A costs, among others), and 2) the specific LM for DSO services incentives. This situation could cause an overreaction of customers which would lead to non-optimal behaviour. One alternative to solve double signalling would be to exempt all customers that can participate in the LM for DSO services from the network charges signalling their contribution to the costs of substation A.

Temporal granularity (Meta-dimensions in purple)

The temporal meta-dimension connects those dimensions identified that describe time-based characteristics. The dimensions related to temporal granularity in network tariff designs are temporal granularity of charges, price setting periodicity and temporal granularity of the measurement. Following the same structure, LM for DSO services have dimensions related to the temporal granularity on the negotiation time frame (gate opening and closure for negotiation), contract length, temporal bid granularity and response time (activation).

The temporal granularity of charges depends on the temporal granularity of measurements, i.e., if the temporal granularity of measurements is one hour, the temporal granularity of network charges cannot be lower than one hour.

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The same happens with LM for DSO services, their temporal bid granularity, contract length and the response time are subject to the available temporal granularity of measurements. Therefore, in cases where the resolution of the dimension of temporal granularity of the measurement is higher, it can create potential combinatorial infeasibilities (blocks in red). Also, when the granularities of the cross-options are closely aligned, it is essential to consider the specific characteristics of the context (blocks in orange). In other cases, both mechanisms can interact without apparent issues (block in green). Similarly, when considering the dimension of the negotiation time frame, their cross-options are more compatible, allowing interplay.

The dimension of temporal granularity of charges and the dimension of negotiation timeframe, have a high potential for interaction when the granularity of the latter is finer than the former (blocks in green). Additionally, temporal granularity of charges and temporal bid granularity and response time of LM for DSO services also interact. Local markets for DSO services could complement network tariffs in those cases where the latter are subject to restrictions in terms of temporal granularity. For example, if temporal granularity of network charges were daily due to regulatory decisions, LM for DSO services with hourly differentiation could improve the economic efficiency of the signal received by customers.

Similarly, the price setting periodicity interacts with the activation time of LM for DSO services. For the case of an annual price-setting periodicity, customers know one year in advance which are the network charges they will face for each time-period of the year, but predicted peak hours may not be coincident with actual peaks. Thus, a LM for DSO services activated a day ahead will predict more accurately the actual network peak periods. On the contrary, a network tariff design with an ex-post price setting already sends the accurate economic signals for the congestion management. Therefore, flexibility markets would not be necessary if other aspects such as locational granularity coincide, and, if applied, they should not distort the economically efficient signal sent by the ex-post price.

Assets (Meta-dimensions in yellow), Assets/Product (Meta-dimension in yellow/dark grey)

The design dimensions for analysis are those categorized as assets in both mechanisms. In network tariffs, these include the dimensions of customer differentiation and symmetry of charges, while in LM for DSO services the dimension of source of flexibility. Regarding the resources that can participate in the LM for DSO services and are aligned with the objective of BeFlexible project, the considered cases include hybrid generation, active consumers, and storage systems. In compliance with cost reflectivity and equity principles, network tariffs should be designed as neutral as possible regarding the type of technology employed (EVs, storage systems, rooftop PV systems), meaning that network tariffs do not have to benefit one technology over another. It can create an uneven playing field for traditional consumers or those who can access technology with greater advantages. Similarly, some technologies can benefit inappropriately if the withdraws and injection charges are the same. Therefore, these conditions require a more specific study (block in orange), otherwise no apparent problems are observed (blocks in green).

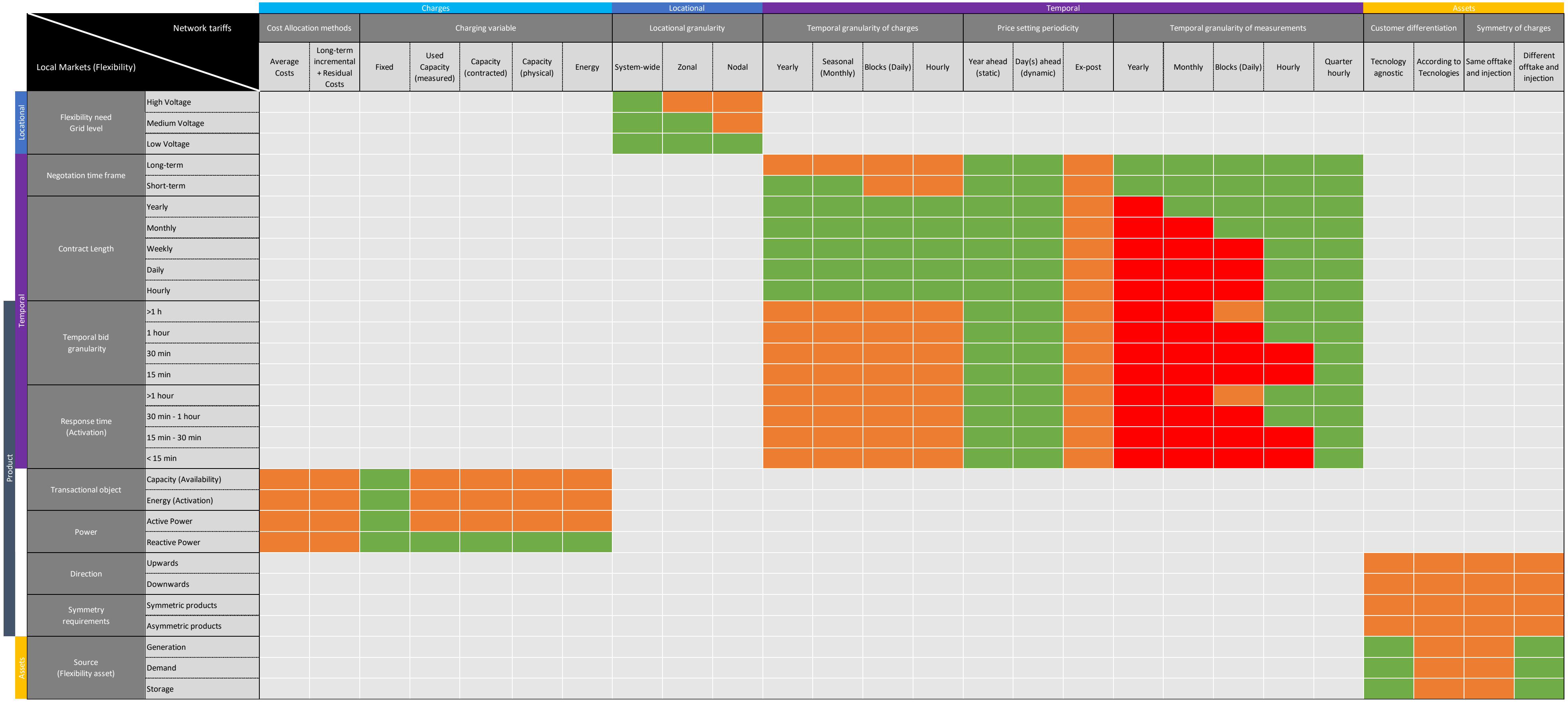
Additionally, the dimensions of direction, and symmetry requirements categorized in the meta-dimension of product in LM for DSO services, also required analysis due to common characteristics with the dimensions of customer differentiation and symmetry of charges in network tariffs. This analysis may be relevant for storage systems, as these technologies can easily manage their injections and withdrawals compared to traditional generation and demand. This is critical because LM for DSO services can distort the signals sent by network tariffs creating an uneven playing field for other technologies, such as distributed generation or consumers (block in orange).

Charges/Product (Meta-dimensions in cyan/dark grey)

The dimensions of cost allocation methods and charging variable in the meta-dimension charges in network tariffs, alongside the dimensions of transactional object and power in the meta-dimension of product in LM for DSO services, are being classified under different meta-dimensions. However, they have attributes that require examination, given the potential influence they exhibit.

When the charges lack of granularity, it could fail to accurately reflect the varying costs and usages patterns across different customers, location, or time periods, then the LM for DSO services can fill these gaps. On the other hand, when the charges are too granular, both network tariff and LM for DSO services could overlap, charging or rewarding customers twice for the same service or resource use. Therefore, these analyses require better understanding of the conditions (blocks in orange). When charging variable in network tariffs are based on flat value, LM for DSO services may incorporate long-term cost signals. Also, since network tariffs are limited to incorporated signal for reactive power provision, LM for DSO services can cover these gaps (blocks in green).

Table 4.9 Pairwise comparison in terms of design dimensions between network tariffs and LM for DSO services



4.5.3 Network tariffs vs flexible connection agreements

In this subsection, the interaction between network tariffs and flexible connection agreements for the provision of distribution system operator services is analysed. The overarching question under examination is the mean through these two acquisition mechanisms interact, potentially resulting in an important impact on economic efficiency.

As discussed in section 4.3.1, the purpose of network tariffs is to recover network costs and, at the same time, to send economic signals to reduce network costs in the future. Future network costs, i.e. network reinforcements, are triggered when the usage of a network is close to the network capacity limit. Network tariffs usually include fixed charges and variable charges based on usage, encouraging users to reduce their consumption during peak hours, reducing the risk of congestions. As highlighted in section 4.3.2, flexible connection agreements represent strategic approach to address several challenges in the network, offering important benefits in locations of limited capacity and traditional network reinforcement is not immediately feasible. It enables to new customers to access to the electricity without the need for immediate and costly infrastructure upgrades.

Therefore, it is clear there exist an interplay between these two mechanisms, mainly due to both must be aligned with economic efficiency principles, ensuring that network expansions are undertaken only when they are most needed and financially optimal. Additionally, tariffs tailored to particular conditions have the potential to incentivize customers to reduce their injections or withdrawals, thereby minimizing the curtailments required for those consumers with flexible connections when they need to remain in operation. Also, a customer under a flexible connection agreement could opt to reduce their capacity demanded or injected during peak times, benefiting from lower network tariffs due to reduced stress on the network. This synergy allows for more efficient network management.

The Table 4.10 shows the comparative analysis between the different dimensions and options determined for these two mechanisms, and a description of this information is provided in what follows.

Temporal granularity (Meta-dimensions in purple) and temporal granularity/product (Meta-dimensions in purple/dark grey)

The temporal category connects those dimensions identified that describe time-based characteristics. The dimensions related to temporal granularity network tariff designs are temporal granularity of charges, price setting periodicity and temporal granularity of the measurement. Following the same structure, connection agreements have dimensions related to the temporal granularity of the duration of flexible connection and curtailment notification.

The temporal granularity of the charges shares common characteristics with the dimension of duration in flexible connection due to both aspects relating to how time considerations influence energy exchanges. However, the conditions under analysis vary depending on the specific contexts in which their cross-options may be implemented (blocks in orange). For instance, when compensations or penalties are associated with curtailments, whether permanent or temporary, this could result in either double reward or double charging, respectively, especially for network tariffs that include a high granularity of the charges.

Similarly, it is also important to highlight that the predefinition of the curtailment in connection agreements, although linked to product characteristics, highly correlates with the dimensions of temporal granularity of charges and temporal granularity of the measurements in network tariffs. Misalignments may occur when the granularity of the charges and measurement are finer than the resolution of the curtailment predefinition, blocking the simultaneous applications of both mechanisms (blocks in red). Furthermore, it is important to ensure that the temporal granularity of the charges should be equal to or greater than the granularity of the measurements.

Assets (Meta-dimensions in yellow) and assets/product (Meta-dimensions in yellow/dark grey)

The design dimensions for analysis are those categorized as assets in both mechanisms. In network tariffs, these are the dimensions of customer differentiation and symmetry of charges, while in flexible connection agreements, the dimensions are eligible consumers. Moreover, in flexible connection agreements the dimension of network connection criteria, activation, and principle of access, even though they are classified under the meta-dimension of products, they also should be analysed with customer differentiation and symmetry of charges in network tariffs, because their common characteristic.

Although network tariffs should be technological agnostic, there are still some jurisdictions that consider giving incentives to certain technologies. In these conditions, there may be some challenges when preferences through network tariffs are given to specific technologies and, at the same time, with compensatory connection payments for the type of customers, which could lead to potential double-charging or double reward (blocks in orange). Additionally, an uneven playing field may also emerge when preferential treatments are given to particular technologies over others for network access. Regarding the symmetry of charges, while for storage assets these mechanisms can interact without apparent issues (blocks in green), due they can have more control over their injections or withdraws, eligible customers categorized as generation or demand may face conditions of unlevel playfield when they are curtail, or also potential double-charging or double reward may arise when compensatory payments are considered, therefore, analyses according these scenarios have to be made (blocks in orange).

The customer differentiation dimension interacts with network connection criteria, activation of the energy curtailment, and the principle of access dimensions of flexible connection agreements. Some issues to be analysed may arise (blocks in orange), particularly in the dimension of principle of access, concerning the congestion option, mainly when a standalone generator is involved (it does not pay for network tariffs). Furthermore, when incentives are given to some technologies, specific analyses may need a more detailed examination according to the type of assets regarding the criteria and principles employed to allow network access (blocks in orange). For instance, if some technologies receive inappropriate incentives in the network tariffs, as is still the case in some jurisdictions, especially important for storage, an uneven playing field may arise, benefit these types of consumers over others. While emergency or maintenance-related curtailment activation generally does not cause important interplay issues (blocks in green), congestion-related curtailment activation could lead to double charging or double rewarding conditions (blocks in orange) when compensation payments are associated. The activation of the energy curtailment also interacts with the symmetry of the charges dimension in network tariffs, this requires analysis in contexts where the symmetry of charges is identical for both offtake and injection (blocks in orange). If curtailment activation occurs due to congestion issues, it may create an uneven playing field among customers, especially for those who own generation facilities.

Charges/product (Meta-dimensions in cyan/dark grey)

The dimension of cost allocation methods in network tariffs can interact with the dimension of connection costs and the benefit of the DSO in flexible connection agreements. When system operator is responsible for the connection costs, it does not present issues with the cost allocation method (blocks in green). However, if the new customers partially or fully assume the connection costs in shallow connection conditions, case specific considerations are needed to avoid double charging through the network tariffs (blocks in orange), by socializing the costs.

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Additionally, the dimensions of compensation payments and maximum curtailment can interact with the dimension of charging variable. When charges in network tariffs lack granularity, they might not accurately represent the diverse cost structures and usage patterns among different customers, locations, or times. In such scenarios, flexible connection agreements can bridge these gaps. Thus, when the dimension of charging variable in network tariffs is set as fixed, it does not lead to significant complications concerning the principles of access and maximum curtailment (blocks in green). Meanwhile, in cases where the dimension of compensation payments is none, it can interact with different options within the charging variable dimension (blocks in green), since it does not lead to situations where double rewarding might occur. Moreover, the relationship between the dimensions of maximum curtailment and charging variable, particularly in the options of used capacity and energy cannot lead issues of misaligned or double charging or double rewarding (blocks in green), except in instances where both dimensions share similar characteristics, for capacity or energy that require more detailed examinations to identified overlaps in cross-options could lead to misalignment in the interaction (blocks in orange). However, other cross-options, which considers the options of capacity (contacted) and capacity (physical) in the dimension of charging variable in network tariffs, with the dimension of maximum curtailment in flexible connection agreement require a detailed analysis due to potential concerns that may arise. Thus, it depends on the specific case study, wherein overlaps in these interactions may occur, leading to a double charging or double rewarding when compensation payments are associates (blocks in orange).

Locational/product (Meta-dimensions in blue/dark grey)

The dimension of locational granularity in network tariffs can interact with the dimension of compensation payments and downstream trade allowed in connection agreements. Low spatial granularity in network tariffs, such as those that are defined as system-wide, facilitates the provision of DSO services through bilateral contracts or participation in local markets for DSO services in downstream trade allowed dimension. It can reduce the losses that some customers might face due to compliance outlined in their connection contracts. However, a higher spatial granularity for network tariffs, such as defined as nodal, more accurately reflects changes in the energy supply. In such cases, a detailed examination is required. Similar situations can be observed with the option of compensation payments dimension when there is payment associated with curtailments (blocks in orange). In instances where the connection contracts do not include compensation payments, no significant issues seem to arise concerning the spatial granularity of network tariffs.

Table 4.10 Pairwise comparison between network tariffs and flexible connection agreements

		Network tariffs	Charges							Locational			Temporal												Assets			
			Cost Allocation methods		Charging variable					Locational granularity			Temporal granularity of charges				Price setting periodicity			Temporal granularity of measurements					Customer differentiation		Symmetry of charges	
	Connection Agreements (Flexible)		Average Costs	Long-term incremental + Residual Costs	Fixed	Used Capacity (measured)	Capacity (contracted)	Capacity (physical)	Energy	System-wide	Zonal	Nodal	Yearly	Seasonal (Monthly)	Blocks (Daily)	Hourly	Year ahead (static)	Day(s) ahead (dynamic)	Ex-post	Yearly	Monthly	Blocks (Daily)	Hourly	Quarter hourly	Tecnology agnostic	According to Tecnologies	Same offtake and injection	Different offtake and injection
Temporal	Duration of flexible connection	Temporary																										
		Permanent																										
	Curtailment notification	Day-ahead																										
		Intra-day																										
		Real-time																										
		Ex-post																										
Product	Connection costs	Deep connection costs																										
		Shallow connection costs																										
	Benefit of the DSO	Avoid reinforcement																										
		Defer reinforcement																										
		Preliminary connection																										
	Network connection criteria	Capacity limitation																										
		Voltage level limitation																										
		Other security criteria (N, N-1)																										
		Short-circuit power rate																										
	Activation	Emergency																										
		Maintenance																										
		Congestion																										
	Pre-definition of curtailment	Peak/off-peak																										
		Seasonality (Days or periods)																										
	Principle of access	Pro-rata																										
		LIFO																										
		Auction																										
		Congestion Created																										
	Compensation payments	Fixed																										
		LFM																										
		LFM-indexed																										
		None																										
	Downstream trade allowed	Bilateral Contracts																										
		LFM																										
	Maximum curtailment	Duration																										
		Capacity limitation																										
		Energy limitation																										
		Monetary limitation																										
Assets	Eligible customers	Generation																										
		Demand																										
		Storage																										

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4.5.4 Flexible connection agreements vs LM for DSO services.

In this subsection, the interaction between flexible connection agreements and local markets for the provision of distribution system operator services is analysed. The overarching question to address is how a customer subject to a specific connection agreement (contract) can participate in a local market (LM) for DSO services, leading to a significant impact on economic efficiency resulting in their interplay.

The LM for DSO services represent a valuable opportunity for customers under flexible connection agreements to reduce their losses to some extent due to established curtailments. For example, in a certain zone with wind farms operating under a flexible connection agreement, it may be required to trigger the predefined curtailment to balance the excess energy production against demand in times of high wind resources. To reduce their losses, these wind generators can participate in a LM for DSO services downstream with part of the surplus generated, ensuring that excess energy is utilized rather than wasted. Moreover, the combination of these mechanisms can also serve as incentives for new customers, encouraging them to connect via flexible arrangements, particularly as a temporary solution while waiting for network reinforcements.

The Table 4.11 shows the comparative analysis between the different dimensions and options determined for these two mechanisms, and a description of this information is provided in what follows.

Temporal granularity (Meta-dimensions in purple)

The temporal category connects those design dimensions that describe time-based characteristics. The dimensions related to temporal granularity in local markets are Negotiation timeframe (Gate Opening and Closure for participation), contract length, temporal bid granularity, and response time (activation). Following the same structure, connection agreements have design dimensions related to the temporal granularity of the duration of flexible connection and curtailment notification.

The curtailment notification dimension in flexible connection agreements significantly impacts all temporal dimensions in LM for DSO services mechanism. The level of interaction is directly related to the time resolution of both mechanisms. Curtailment notification serve as a means to enable customers for making informed decisions about participating in a LM for DSO services. Thus, if the curtailment notification time is sufficiently ahead regarding to the granularity of the LM for DSO services dimensions, both mechanisms can be implemented simultaneously without any issues (blocks in green). Conversely, misalignment between these timeframes can create challenges (blocks in orange). In such cases, adaptation to the specific context under analysis is necessary. Likewise, when curtailment notification is provided ex-post, it adds complexity to participate in local markets (blocks in red), due to it is not known in advance when the curtailment may occur. This uncertainty derived from a lack of timely information, which is crucial for making informed decisions about market participation. For, instance, if a customer receives a curtailment notification after the market has already activated some bids, customer may not be able to adjust its strategy in response to the new information. This misalignment can lead to inefficiencies and potential losses for both the customer and the market.

Additionally, the dimension of duration of the flexible connection in flexible connection agreements relates closely to the dimensions of negotiation timeframe and contract length in LM for DSO services. If the flexible connection agreements are permanent, customers know their timeframes, and can handle it according to LM for DSO services windows (blocks in green). However, for temporary flexible connection, lower temporal granularities can lead misalignment in timeframes between both mechanisms, creating potential conflict which must be analysed in accordance with the specific conditions (blocks in orange).

Product (Meta-dimensions in dark grey)

The dimensions of activation of the energy curtailment, pre-definition of the curtailment, and principle of access in flexible connection agreements can interact with the dimension of contract length in LM for DSO services. Most cross-options, considering the interaction between these dimensions, are highly context-dependent (blocks in orange). For instance, if the curtailment is defined by pro-rata, customers have more knowledge of the availability to be involved in LM for DSO services processes, but if LIFO, it depends on the position of the customer in receiving the curtailment order. Similarly, if the temporal resolution of the contract length increases (from hours to years), considering the several options of the principle of access, it is more likely that misalignment issues between both mechanisms may arise. Additionally, if the activation of the curtailment is given on an emergency basis, and contract length ranges from daily to yearly, misalignments appear, making the combination infeasible due to insufficient time for informed market decision-making (blocks in red). Similar situations may arise when activation is given by congestion or if the pre-definition of curtailment is by seasonality aligned with an annual contract length.

The dimensions of compensation payments and temporal bid granularity can show interaction. If there are no compensation payments associated with flexible connections, both mechanisms can be applied simultaneously without apparent issues (blocks in green), due customers cannot be doubly signalling. However, for the other cross-options, they must be examined considering the specific conditions. For instance, when receiving payment for curtailment and depending on the temporal granularity of the bids, challenges may arise when both cross-options overlap (blocks in orange), for example, customers can be double rewarded creating distortion in the interaction of both mechanisms.

Other dimensions that interact are the network connection criteria and maximum curtailment in connection agreements, coupled with the transactional object in LM for DSO services. The integration of these mechanisms is related to the specific context of application and aligns with the specific requirements of the needs.

Assets (Meta-dimensions in yellow) and assets/product (Meta-dimensions in yellow/dark grey)

The dimensions for analysis are those categorized as assets in both mechanisms. The dimensions for LM for DSO services are the source of the flexibility assets, while in the flexible connection agreements the dimension is the eligible customers. The analysis here involves understanding how these assets can be strategically utilized, their availability and the potential impact in the network dynamics considering both mechanisms. If the customer in a flexible connection correspond to generation, and the LM for DSO services requires generation, both mechanisms can interact simultaneously. Also, the same applies when the cross-option corresponds to demand (blocks in green). However, if they are opposite, misalignments occur due to the type of technology (blocks in red). In the case of storage, the specifics depend on the study case and whether the operation in both mechanisms is identical (blocks in orange). Additionally, the dimension of eligible customers in flexible connection can interact with the dimension direction in LM for DSO services on case-basis (blocks in orange), since different types of technologies can provide flexibility in both directions, depending on the requirements of the network needs.

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Table 4.11 Pairwise comparison between flexible connection agreements and LM for DSO services

			Temporal						Product																												Assets		
		Connection Agreements (Flexible)	Duration of flexible connection		Curtailment notification				Connection costs		Benefit of the DSO			Network connection criteria				Activation			Pre-definition of curtailment		Principle of access				Compensation payments				Downstream trade allowed		Maximum curtailment				Eligible customers		
		Local Markets (Flexibility)	Temporary	Permanent	Day-ahead	Intra-day	Real-time	Ex-post	Deep connection costs	Shallow connection costs	Avoid reinforcement	Defer reinforcement	Preliminary connection	Capacity limitation	Voltage level limitation	Other security criteria (N, N-1)	Short-circuit power rate	Emergency	Maintenance	Congestion	Peak/off-peak	Seasonality	Pro-rata	LIFO	Auction	Congestion Created	Fixed	LFM	LFM-indexed	None	Bilateral Contracts	LFM	Duration	Capacity limitation	Energy limitation	Monetary limitation	Generation	Demand	Storage
Locational	Flexibility need Grid level	High Voltage																																					
		Medium Voltage																																					
		Low Voltage																																					
Temporal	Negotiation time frame	Long-term																																					
		Short-term																																					
	Contract Length	Yearly																																					
		Monthly																																					
		Weekly																																					
		Daily																																					
		Hourly																																					
	Temporal bid granularity	>1 h																																					
		1 hour																																					
		30 min																																					
		15 min																																					
	Response time (Activation)	>1 hour																																					
		30 min - 1 hour																																					
		15 min - 30 min																																					
		< 15 min																																					
Product	Transactional object	Capacity (Availability)																																					
		Energy (Activation)																																					
	Power	Active Power																																					
		Reactive Power																																					
	Direction	Upwards																																					
		Downwards																																					
	Symmetry requirements	Symmetric products																																					
		Asymmetric products																																					
Assets	Source (Flexibility asset)	Generation																																					
		Demand																																					
		Storage																																					

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4.6 Need attributes and evaluation criteria

4.6.1 Definition of the general need attributes

The success and efficacy of a combination of mechanisms for acquiring DSO services is significantly influenced by the context-specific need attributes. For congestion management and voltage control, the aspects identified as relevant for describing the needs and contexts have been divided into three general categories. The first concerns network conditions, such as voltage level, frequency and volume of the need, and network type. The second one concerns the capabilities of the service providers, like SP size, SP nominal voltage and SP type. Lastly, the third category focuses on quantitatively assessing the relationship between the network conditions and the characteristics of the service providers via the ratio of volume of the service provided and the volume of the need**.** These need attributes enable a more structured understanding of the conditions under which the analysis is performed. In Table 4.12, a brief description of each need attribute is provided, considering also the different sub-categories identified as pertinent to the current analysis.

Table 4.12 General need attributes relevant for the acquisition mechanisms combinatorial framework

Need Attributes	Description	Sub-categories
Voltage level of the need	Nominal voltage at the point where the service is required.	1. High 2. Medium 3. Low
Frequency of the need	Number of times that the service is required within a predefined time interval.	1. Very High (daily) 2. High (once or more per week) 3. Medium (less than once per week) 4. Low (less than once per month)
Volume of the need	Amount of active/reactive power required for providing a service. This characteristic is case specific; therefore, it is better to express in relative terms.	1. High (more than 80% of the maximum total capacity of the SPs) 2. Medium (around 20% to 80%) 3. Low (Less than 20% of the maximum total capacity of the SPs)
Network Type	Network Topology. A higher degree of interconnection has the potential to meet the system's needs more effectively.	1. Radial 2. Meshed
SP size	Specific size of potential services providers.	1. Large/Aggregation of smalls (equal or more than 10 MVA) 2. Small/ No Aggregation (less than 10 MVA)
SP nominal voltage	Nominal Voltage of the network to which SPs are connected	1. High 2. Medium 3. Low
SP Type	Classification of resources for providing services, based on their characteristics.	1. Generation 2. Demand 3. Storage

Volume of the service provided/ Volume of the need	It quantifies the relationship between the quantity of services supplied and the level of demand, as a measure of competition and liquidity	1. High 2. Medium 3. Low

The most straightforward method for classifying power systems is according to their different voltage levels, which influence the choices of assets connected and the operational strategies required. Consequently, the appropriate response due to a contingency varies based on the voltage level of the need because it determines the capability of the resources to offer a service. For instance, if a service is required at low voltage, the service providers connected to medium or high voltage may not contribute effectively.

Furthermore, it is important to identify the frequency of the need because it determines how many times the resources (distributed generation, active demand, or storage) are required to be activated for providing a system service over time. This aspect is particularly significant for recurring events like daily network problems, which need frequent responses, denoting that relying solely on one mechanism might not be adequate. This last aspect is similarly linked to the volume of the need because it directly affects the capability of the resources to deliver system services for solving grid problems. For instance, a minor disturbance in one section of the grid might require a limited response capacity, while a large-scale failure might require an extensive mobilization of resources. The larger the magnitude of the problem, the higher the capacity or number of service providers required. These attributes, namely the frequency and volume of the need, exert a significant influence on the economic viability for all parties involved. Hence, it is imperative to devise more efficient solutions that incorporate suitable signals to customers, in accordance with the acquisition mechanisms (or combinations) under consideration.

The network topology notably influences the capability of the resources to address grid issues. A high degree of connections points, like in meshed networks, potentially increase the range of potentially available service providers, enhancing the feasibility of fulfilling the service requirements. Conversely, a radial network restricts the number of service providers that can participate, limiting the possible options for addressing a grid problem. The network topology can either be obtained in real or represented in a simplified model based on the sensitivity factors, depending on the available data. Conducting an analysis of the network allows understanding of interactions among assets and supports in delineating the area of influence for each service provider [248].

The SP size is a key attribute for categorizing service providers, significantly influencing the strategies employed to tackle network problems through their utilization. It may be either a single large entity or a group formed through the aggregation of several small ones. Nevertheless, small customers can also operate independently, behaving in a non-aggregated manner. The SP size and whether the SPs are aggregated or not strongly impacts the mechanisms to be employed and how the signals should be incorporated for the service provision. For instance, in local markets, service operators within pre-qualification processes may establish minimum capacity requirements for participants, thus aggregation is necessary. Despite this, network tariffs and connection agreements could be more single-customer tailored.

The SP nominal voltage attribute enables the identification of potential actions to address contingencies. For instance, resolving a voltage issue on a high voltage may be more effectively achieved using resources at the transmission level rather than relying on low-voltage network resources.

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The SP type impacts the acquisition mechanisms to be exploited: whether demand, energy storage, and generation capabilities for the SP defines the range of potential services for the system operator. This diversified approach allows for more versatile and efficient coordination of the network. For example, employing demand-side management, considering active demand or storage offers a suitable alternative to curtailing renewable generation.

Finally, the ratio between volume of the service provided and volume of the need provides a measure of the competition level and liquidity**.** This ratio is also crucial in determining the suitability of acquisition mechanisms. A high ratio suggests that the mechanisms are feasible, whereas a low ratio might necessitate the use of long-term contracts, flexible connection agreements, or obligations.

4.6.2 Definition of the evaluation criteria

The guiding principles for designing the combination of acquisition mechanisms, identified in the current analysis, include five main principles divided in two groups. The first group encompasses principles such as economic efficiency, equity, implementability, and transparency and simplicity. The second group correspond to customer engagement. Table 4.13 provides a general description of the first groups criteria considering different sub-criteria for each criterion. The Table 4.13 is adapted according to the work carried out in [248]. In the ongoing analysis, particular attention has been given to the criterion of customer engagement, as outlined in Table 4.14, given its significance within this objective of the sub-task. Although the solutions for combination of mechanism for acquiring system services have to comply with the general regulatory principles, each solution addresses these principles distinctively.

Table 4.13 Evaluation criteria relevant for the acquisition mechanisms combinatorial framework

Evaluation Criteria	Description	Sub-Criteria	Description of the sub-criteria
Economic Efficiency	It aims to maximize social welfare by ensuring services are utilized by those who benefit most, minimizing both short-term and long-term system costs.	Cost-reflectivity	It measures if the chosen solution accurately reflects the associated costs, considering time, location, and quality of the system services provided.
		Predictability	Efficient solutions are achieved from a degree of knowledge of the relevant factors, effectively diminishing the impact of uncertainty.
		Technology neutrality	It guarantees the reduction of technical barriers to providing a system service.
		Low entry barriers	It allows for a high level of competition, which means greater efficiency, innovation, and choice of available solutions.
		Low exercise of market power	It prevents specific service providers from dominating all offerings by fostering competition.
Equity	It aims to guarantee that all stakeholders pay or earn a fair share based on their network usage.	Allocative equity	Customers with similar locations and patterns are charged/paid equally. It can be assumed cost-reflective and increase efficiency.
		Distributional equity	It evaluates if the customer is burden is aligned with their economic capability.
		Transitional equity	It supports the gradual shift from old to new structures.
Implementability	It points to the feasibility of implementing the solutions.	Minimize implementation Costs	It measures that all the costs for deploying the solutions are as economically efficient as possible.
		Effectiveness	It measures the capability of the solution for providing a service while avoiding potential under/over procurement
		Complexity	It measures how straightforward the capability of the implementation solution is
Transparency and simplicity		Transparency in design methodology	It measures the level of transparency considering the process design.

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	Solutions should be understandable by all stakeholders to encourage their participation	Provision of comprehensive grid data	To be able to access the complete grid description to accurately measure its dynamics and impact of service providers.
		Provision of partial grid data	By using sensitivities of flexibilities towards critical V/I constraints and V/I margin in the grid.
		Simplicity	The solution has been designed to be easy comprehend and use, reducing unnecessary considerations.

Table 4.14 Evaluation criteria relevant for the acquisition mechanisms combinatorial framework

Evaluation Criteria for Customer engagement	Description	Sub-Criteria	Description of the sub-criteria
Benefits for active participation	It allows to measure the effectiveness for incorporating signals in terms of tangible benefits or financial incentives for customer participation	Monetary rewards	Customers can receive specific payments for the service provision
		Energy cost reduction	Customers can reduce costs in the electrical bills for changing your behaviour of appliance usage
		Avoid penalties	Customers can prevent network infractions that could results in penalties
Integration of diverse customer segments	It refers to the process of effectively bringing together and coordinating several groups or categories of customers.	Customer's type	Develop strategies to address the specific requirements of different customer types (residential, commercial, and industrial), for increase competition and potentially reducing costs.
		Technology agnostic	Benefits should not be linked to a particular technology. For example, storage or electrical vehicles should not receive preferential treatment.
		Equity in participation	Small customers and businesses should have equal opportunities to participate.

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		Social inclusion	Promote for the participation of disadvantaged communities.
		Environmental inclusion	Promote the adoption of clean technologies.
Customer easiness of participation	It refers to how easily customers can engage with flexibility services provision.	Simplicity	Being able to participate in the different options for flexibility provision should be as understandable as possible.
		Accessibility and transparency of information	The information is easily accessible, regardless of their background or abilities, and that it states all the process clearly.
		Customer education and training	The processes of providing customers with information, knowledge, and skills necessary to understand, use, and maximize the benefits of the service provided. It can include about technical topics like activation frequency, notice time, available activation methods, etc.
Installation of assets	It involves providing customers with the means to have more control over their energy patterns in order to make informed decisions, utilizing tools like smart devices, automatization, multidevice app, etc	Customers buy the devices required	Customers are responsible for acquiring the equipment and their maintenance, but receive the total benefits for the provision of services
		Customers rent the devices required	Customers must pay a fee for the installation of the equipment and their maintenance, but receive the total value of the service provided. Customers have the freedom to end the contract without additional payments
		Devices are installed by third parties	The equipment and maintenance are commissioned by third parties, but the service provision contract is discounted. The contract is long term, until the device cost is recovered
Reduction of controllability	It allows to measure to what extent customers are willing to reduce their controllability due to the provision of a service.	Customers have total control	Customers can opt-out of events or actions that may reduce their comfort, providing them with control over their participation, even though profits are reduced.
		Customers have control over some appliances	Customers have access to offer customization options that allow you to specify comfort preferences regarding appliances, for example, heating, cooking, etc.

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		Customers have control over some time-periods	Customers have access to offer customization options that allow you to specify comfort preferences regarding time in the day or week.
		Notification and alerts	There are effective notification and alert tools to inform customers in advance of any actions that may affect their comfort, allowing customers to prepare accordingly.

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4.6.3 Need attributes and evaluation criteria assessment

Assessing suitable solutions for acquiring system services heavily relies on understanding and analysing the context, which is case specific. This specificity makes the achievement of a universal solution particularly challenging. To address these complexities, a survey was conducted among project partners, focusing on identifying critical need attributes and evaluation criteria aligned with the information depicted in section 4.6.1 and section 4.6.2. This process was divided into two stages. The first stage, undertaken from the perspective of DSOs, aimed to determine the most pertinent need attributes and evaluation criteria while excluding considerations related to customer engagement. The second stage focused on gathering information specifically related to customer engagement but with the viewpoint of the system service providers, since it is within the objective of the BeFlexible initiative.

The partners have conducted a review of the proposed definitions for each need attribute and evaluation criteria and their respective qualitative values. This evaluation process is outlined in the questionnaire templates attach in Annex 8.7 and Annex 8.8, where project partners assessed the appropriateness of each attribute and its corresponding values. For the first stage, information has been gathered from DSOs in Spain (SOUTH-MID EU (Spain, France) demonstrator), Sweden (North EU (Sweden) demonstrator), and Italy (SOUTH-MID EU (Italy) demonstrator), designated as DSOs #1, DSOs #2, and DSOs #3, respectively. This information is deemed significant as it is related to the demonstrators and pilots that will be tested within the project.

Table 4.15 shows the results obtained for the assessment of the need attributes and their qualitative values defined in this case as subcategories. As mentioned in section 4.6.1, the need attributes have been subdivided into three groups. The first group (light blue) is related to the network need conditions. The second group (light green) aligns with the characteristics of flexibility providers. The third group (white) is oriented to assess the level of competition and liquidity, primarily in the context of local markets. This last aspect is especially pertinent because, according to the responses gathered, local market mechanism is mainly considered for implementation in the different demonstrators, as well as it holds significant influence over the performance that can be obtained from other acquisition mechanisms, both individually and in combination. Table 4.15 presents the choices made by each evaluated DSOs. A colour scale has been established to identify the suitability of the need attributes and their sub-categories. Green indicates that both the need attributes and their sub-categories are appropriate for the DSOs. Orange signifies that the proposed need attributes are suitable, but not their sub-categories for the DSOs. Red denotes that the proposed need attributes are not relevant to the DSOs contexts. The underlined subcategories reflect the individual decisions made for each sub-category.

Table 4.15 Assessment of the need attributes from DSOs perspectives

	Need Attributes	DSOs #1	DSOs #2	DSOs #3
Network conditions	Voltage level of the need	1. High	1. High	1. High
		2. Medium	2. Medium	2. Medium
		3. Low	3. Low	3. Low
	Frequency of the need	1. Very High	1. Very High	1. Very High
		2. High	2. High	2. High
		3. Medium	3. Medium	3. Medium
		4. Low	4. Low	4. Low
	Volume of the need	1. High	1. High	1. High
		2. Medium	2. Medium	2. Medium
		3. Low	3. Low	3. Low
	Network Type	1. Radial	1. Radial	1. Radial
		2. Meshed	2. Meshed	2. Meshed
Service providers	FSP size	1. Large/Aggregation of smalls	1. Large/Aggregation of smalls	1. Large/Aggregation of smalls
		2. Small/ No Aggregation	2. Small/ No Aggregation	2. Small/ No Aggregation
	FSP nominal voltage	1. High	1. High	1. High
		2. Medium	2. Medium	2. Medium
		3. Low	3. Low	3. Low
	FSP Type	1. Generation	1. Generation	1. Generation
		2. Demand	2. Demand	2. Demand
		3. Storage	3. Storage	3. Storage
	Volume of the service provided/ Volume of the need	1. High	1. High	1. High
		2. Medium	2. Medium	2. Medium
		3. Low	3. Low	3. Low

Legend:

- appropriate need attribute and sub-categories
- appropriate need attribute but not the sub-categories
- not appropriate

sub-category selected

sub-category not selected
sub-category not selected
sub-category not selected

Moreover, some additional important insights were given by some DSOs; for example, they suggested including seasonal periods in temporal need attributes as the frequency of the need. Similarly, some DSOs indicated that certain characteristics of the need attributes will be defined after the demos are fully established. Therefore, the results are subject to change.

After assessing the need attributes, an evaluation of their significance was also conducted. Each respondent was required to rank the proposed context attributes in ascending order (1 being the most important) based on their perceived relevance, for both congestion management and voltage control. Nevertheless, it has been consistently noted in all received responses that voltage control is not being considered at this time. Table 4.16 shows the rankings given for the different DSOs to each need attributes for congestion management, and in the last column (Final rank), the final ranking is calculated.

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The final rank was stablished based on the individual assessment outcomes employing two methods. The first method involved calculating the arithmetic mean [344] for each item, with the order determined by these means arranged from lowest to highest. The second method entailed assigning weights to each possible response, with the highest weight given to the most important value for the survey (1) and the lowest weight to the last possible value in the evaluation [345]. The final rank is established by first multiplying the position of each outcome by its designated weight and then adding these products for each need attribute, then organizing the outcomes in descending order, from the highest to the lowest, based on their cumulative weighted scores. Additionally, it is important to highlight that for the final rank, since some need attributes were not deemed relevant by the respective DSOs, penalties adjusted to be just above the maximum value on each scale is added during this process. By employing both methods to determine the final rank, the same order is achieved, indicating a consistent evaluation process across the differing analytical approaches.

Table 4.16 Ranking of the assessment of the need attributes from DSOs perspectives for congestion management

	Need Attributes	Rank DSOs #1	Rank DSOs #2	Rank DSOs #3	Final Rank
Network conditions	Voltage level of the need	3	7	9	6
	Frequency of the need	1	1	1	1
	Volume of the need	1	2	1	2
	Network Type	3	6	1	3
Service providers	FSP size	-	5	1	5
	FSP nominal voltage	-	8	9	8
	FSP Type	-	4	5	7
	Volume of the service provided/ Volume of the need	-	3	1	4

A similar process is undertaken for the evaluation criteria and their qualitative values, in this case defined as sub-criteria, proposed in the first stage of the survey (excluding customer engagement). In this instance, each proposed sub-criteria were ranked independently, as well as the entire set of criteria. Table 4.17 illustrates the assessment carried out for the proposed sub-criteria. Notably, input was received from the partners, resulting in the addition of the "Defined by Regulation" (underlined) sub-criterion within the equity criterion, as suggested by DSO #1, which underscores the importance of regulatory considerations in the assessment of equity aspects. Similarly, the DSOs indicated that providing additional information necessitates a more mature state of analysis regarding the mechanisms to be implemented. They also noted that, as of the survey time, there are still some aspects that remain to be defined.

Furthermore, Table 4.18 shows the overall evaluation ranking for the set of evaluation criteria. It is important to note that for those values not evaluated due to being deemed less relevant in the context of the DSOs, the value just above the highest extreme on the scale was allocated to ensure consistency in the evaluation process. According to the final ranking, as shown in the last column (Final rank), the most critical criterion is Economic Efficiency, followed by Transparency and Simplicity. Implementability ranks third, with Equity positioned at the end. These results suggest that economic efficiency as the most relevant criterion, signifying the paramount importance of cost-effectiveness for the DSOs. Following by transparency and simplicity, underscoring the importance of clear, straightforward processes and decision-making criteria. Regarding implementability, suggesting a pragmatic focus on the practicality of implementing the feasible solutions. And finally, equity, which, while important, seems to be of lesser priority compared to the other criteria. This positioning could imply a focus on efficiency and practicality over equitable outcomes.

Table 4.17 Assessment of the evaluation criteria from DSOs perspectives

Evaluation criteria	Sub-criteria	Rank by sub-criteria		
		DSOs #1	DSOs #2	DSOs #3
Economic Efficiency	Cost-reflectivity	7	5	6
	Predictability	-	1	6
	Technology neutrality	-	3	6
	Low entry barriers	-	2	3
	Low exercise of market power	-	5	2
Equity	Allocative equity	-	-	5
	Distributional equity	-	-	1
	Transitional equity	-	-	1
	Defined by regulation	5	-	-
Implementability	Minimize implementation costs	5	2	5
	Effectiveness	5	1	4
	Minimize implementation complexity	3	3	4
Transparency and simplicity	Transparency in design methodology	5	1	4
	Provision of comprehensive grid data	-	2	4
	Provision of partial grid data (sensitivities)	-	3	4
	Simplicity	5	4	2

Table 4.18 Ranking of the assessment of the evaluation criteria from DSOs perspectives

Evaluation criteria	Sub-criteria	General rank			
		DSOs #1	DSOs #2	DSOs #3	Final rank
Economic Efficiency	Cost-reflectivity Predictability Technology neutrality Low entry barriers Low exercise of market power	6	2	5	**1**
Equity	Allocative equity Distributional equity Transitional equity Defined by regulation	-	4	5	**4**
Implementability	Minimize implementation costs Effectiveness Minimize implementation complexity	-	3	5	**3**
Transparency and simplicity	Transparency in design methodology Provision of comprehensive grid data Provision of partial grid data (sensitivities) Simplicity	-	1	5	**2**

During the second stage of the survey, several criteria and their corresponding sub-criteria were examined to assess customer engagement. Since most demonstrators are still in the development stage and several aspects still need to be defined, direct access to customers was not possible. Therefore, to quantify these criteria, the survey was evaluated from the perspective of the service providers, considering aggregators and large consumers.

In this condition, five service providers are identified, encompassing two from the Spanish demo (SPs #1, SPs #2), two from the Swedish demo (SPs #3, SPs #4), including one large consumer, and one from the Italian demo (SPs #5). Table

4.19 compiles the information gathered from the survey. This includes an evaluation of the relevance of each sub-criterion on an individual basis, categorized as highly relevant, somewhat relevant, or not relevant. Moreover, each service provider assigned a ranking based on their required context, as denoted by the numbers. In addition to the individual assessments, there was an overarching consideration of general criteria focused on customer engagement. The findings display a notable level of consistency, especially among service providers within the same national context.

Table 4.19 Assessment of the customer engagement criteria from flexibility service provider perspectives

Evaluation Criteria	Sub-criteria	Rank by sub-criteria				
		Relevance				
		FSPs #1	FSPs #2	FSPs #3	FSPs #4	FSPs #5
Benefits for active participation	Monetary rewards	1	2	1	1	1
		highly relevant	not relevant	highly relevant	highly relevant	highly relevant
	Energy cost reduction	2	1	2	3	2
		highly relevant	somewhat relevant	highly relevant	not relevant	somewhat relevant
	Avoid penalties	3	3	3	2	3
		somewhat relevant	not relevant	highly relevant	somewhat relevant	not relevant
Integration of diverse customer segments	Customer's type	1	5	3	3	1
		highly relevant	not relevant	highly relevant	somewhat relevant	highly relevant
	Technology agnostic	2	4	1	1	3
		highly relevant	not relevant	highly relevant	highly relevant	highly relevant
	Equity in participation	4	3	4	4	2
		highly relevant	somewhat relevant	somewhat relevant	not relevant	highly relevant
	Social inclusion	5	1	5	5	5
		highly relevant	highly relevant	somewhat relevant	not relevant	not relevant
	Environmental inclusion	3	2	2	2	4
		highly relevant	highly relevant	highly relevant	highly relevant	highly relevant
Customer easiness of participation	Simplicity	2	1	3	3	1
		highly relevant	somewhat relevant	highly relevant	highly relevant	highly relevant
	Accessibility and transparency of information	1	2	2	2	3
		highly relevant	somewhat relevant	highly relevant	highly relevant	somewhat relevant
	Customer education and training	3	3	1	1	2
		somewhat relevant	somewhat relevant	highly relevant	highly relevant	highly relevant
Installation of Assets	Customers buy the devices required	2	2	1	3	2
		highly relevant	somewhat relevant	highly relevant	not relevant	highly relevant
	Customers rent the devices required	3	3	2	3	3
		not relevant	not relevant	highly relevant	not relevant	somewhat relevant
	Devices are installed by third parties	1	1	3	3	1
		highly relevant	highly relevant	highly relevant	not relevant	highly relevant
Reduction of controllability	Customers have total control	4	4	1	1	1
		somewhat relevant	not relevant	highly relevant	highly relevant	highly relevant
	Customers have control over some appliances	2	3	4	4	4
		somewhat relevant	not relevant	highly relevant	not relevant	highly relevant
	Customers have control over some time-periods	1	2	3	3	3
		highly relevant	not relevant	highly relevant	not relevant	highly relevant
	Notification and alerts	3	1	2	2	2
		somewhat relevant	not relevant	highly relevant	highly relevant	highly relevant

Table 4.20 the weighted ranking of general criteria for customer engagement from flexibility service provider perspectives. The highest rank is given to customer easiness of participation, highlighting the need for straightforward and accessible engagement processes. This is followed by the benefits for active participation, which emphasizes the

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need for tangible profits for customers. The integration of diverse customer segments ranks third, emphasizing inclusivity in engagement strategies. The fourth criterion, installation of assets, deals with the practical aspects of equipping customers for participation. Lastly, the reduction of controllability, although ranked lowest, remains significant in considering how participation impacts customers.

Table 4.20 Ranking of the assessment of the customer engagement criteria from flexibility service provider perspectives

Evaluation Criteria	Sub-criteria	General Rank					
		FSPs #1	FSPs #2	FSPs #3	FSPs #4	FSPs #5	Final Rank
Benefits for active participation	Monetary rewards Energy cost reduction Avoid penalties	1	2	3	1	2	**2**
Integration of diverse customer segments	Customer's type Technology agnostic Equity in participation Social inclusion Environmental inclusion	4	4	1	3	3	**3**
Customer easiness of participation	Simplicity Accessibility and transparency of information Customer education and training	2	1	2	2	1	**1**
Installation of Assets	Customers buy the devices required Customers rent the devices required Devices are installed by third parties	3	3	4	4	5	**4**
Reduction of controllability	Customers have total control Customers have control over some appliances Customers have control over some time-periods Notification and alerts	5	5	5	5	4	**5**

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4.7 Case studies

4.7.1 Case Study 1

The first case study is proposed based on the information collected from the survey, the format of which is attached in annex 8.7. This case study specifically analyses data pertaining to the SOUTH-MID EU (Spain, France) demonstrator. The mechanisms for acquiring system operator services available for this scenario are network tariffs and local markets.

Table 4.21 details the dimensions and options set for network tariffs according to the Spanish scenario. The network tariff is designed to average costs, undergoing annual revisions for price adjustment. This entails an analysis and adjustments for static price setting. Similarly, this tariff includes charges comprising a component based on contracted capacity, and a component based on energy consumption. Charge allocation is determined by time blocks, aligning with the granularity of measurements taken every 15 minutes. These tariffs are standardized at a country-wide level. Differentiation in costs for customers varies according to voltage levels, and there are also asymmetrical charges for off-take and injection.

Regarding the dimensions and options of local markets for DSO services, this information was obtained in the first stage of the survey and analysed from the perspectives of the DSOs, based on the information available, and it is shown in Table 4.22. According to this data, the services are provided primarily towards high and medium voltage levels. Scenarios for negotiation time can be either long or medium-term, with contract durations varying from hourly to monthly, and a bid granularity of charges that, depending on the case, could be one hour, 30 minutes, or 15 minutes, without limitations on response time. It is also considered that flexibility service providers can offer both availability and activation. The services will mainly consist of upward and downward active power adjustments, which can be either symmetrical or asymmetrical. The sources for these services can be provided from loads, storage, or generation.

Table 4.21 Dimensions and options for the Spanish network tariffs in SOUTH-MID EU (Spain, France) demonstrator (Case study 1)

nº	Dimension	Options	
1	Cost Allocation methods	Average Costs	
2	Charging variable	Capacity (contracted)	Energy
3	Locational granularity	System-wide	
4	Temporal granularity of charges	Blocks (Daily)	
5	Price setting periodicity	Year ahead (static)	
6	Temporal granularity of measurements	Quarter hourly	
7	Customer differentiation	By Voltage levels or network areas (Technology agnostic)	
8	Symmetry of charges (Energy o capacity components)	Different offtake and injection charges	

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Table 4.22 Dimensions and options for local markets for DSO services in SOUTH-MID EU (Spain, France) demonstrator (Case study 1)

<table>
<tr><th>nº</th><th>Dimension</th><th colspan="12">Options</th></tr>
<tr><td>1</td><td>Flexibility need
Grid level</td><td colspan="6">High Voltage</td><td colspan="6">Medium Voltage</td></tr>
<tr><td>2</td><td>Negotiation time frame
(Gate Opening and Closure for participation)</td><td colspan="6">Long-term
(Weeks-ahead to years-ahead)</td><td colspan="6">Shot-term
(Real-time, intraday, day-ahead)</td></tr>
<tr><td>3</td><td>Contract length</td><td colspan="3">Monthly</td><td colspan="3">Weekly</td><td colspan="3">Daily</td><td colspan="3">Hourly</td></tr>
<tr><td>4</td><td>Temporal bid granularity</td><td colspan="4">1 hour</td><td colspan="4">30 min</td><td colspan="4">15 min</td></tr>
<tr><td>5</td><td>Response Time
(Activation)</td><td colspan="3">> 1 hour</td><td colspan="3">30 min – 1 hour</td><td colspan="3">15 min – 30 min</td><td colspan="3">< 15 min</td></tr>
<tr><td>6</td><td>Transactional Object</td><td colspan="6">Energy (Activation)</td><td colspan="6">Capacity (Availability)</td></tr>
<tr><td>7</td><td>Power</td><td colspan="12">Active Power</td></tr>
<tr><td>8</td><td>Direction</td><td colspan="6">Upwards</td><td colspan="6">Downwards</td></tr>
<tr><td>9</td><td>Symmetry Requirements
(For upwards and downwards)</td><td colspan="6">Symmetric products</td><td colspan="6">Asymmetric products</td></tr>
<tr><td>10</td><td>Source
(Flexibility assets)</td><td colspan="4">Generation
(Including hybrid installations)</td><td colspan="4">Demand
(Including active customers)</td><td colspan="4">Storage
(Stand-alone)</td></tr>
</table>

4.7.2 Case Study 2

The second case study is proposed based on the information collected from the survey, the format of which is attached in annex 8.7. This case study specifically analyses data pertaining to the North EU (Sweden) demonstrator. The mechanisms for acquiring system operator services available for this scenario are network tariffs, connection agreements (conditional agreements), and local markets for DSO services.

Table 4.23 presents the structure and options for tariffs in the Swedish context, incorporating insights from distribution system operators. For the regional grid, covering 130 kV-20 kV, tariffs comprise a fixed component, a capacity charge based on either contracted or actual (measured) usage, and an energy component, the specifics of which vary with the contract model. In the local grid scenario, network tariffs include a fixed component and a capacity charge, either contracted or based on actual usage (measured). This is determined by the power capacity of the connection, along with an energy component. These network tariffs are typically set annually. Additionally, some regional grid contract types may incur a winter tariff from November to March. Post-January 1, 2027, a mandatory time differential will be introduced, potentially on an hourly basis, although the implementation details are still under evaluation. Some DSOs have already started hourly differentiation in tariffs. Tariff adjustments are made as needed, largely influenced by fixed costs, leading to an annual revision being most common. The temporal granularity for measurements is currently hourly, transitioning from the previous smart meter generation. However, new regulations are moving towards settlement periods of 15 minutes. There is no differentiation based on technology; however, variations exist depending on load curves. Distinct charges for offtake and injection are also in place, ensuring that customers do not pay double tariffs. Instead, they are charged the higher of the two, should they both inject into and withdraw from the system.

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In the context of connection agreements are categorized as conditional agreements, with their dimensions and options detailed in the Table 4.24. However, not all dimensions have been fully defined yet, such as connection cost, pre-definition of the curtailment, principle of access, and possibility to sell the expected curtailed energy. Despite this, some general conditions have already been established. The duration of flexible connections is temporary, to offer opportunities to new customers to access to the network, until the network reinforcement becomes the most economically viable option. Regarding curtailment notifications, they can be issued either intraday or in real-time. The main criteria to be considered in this process involve capacity limitations or other security-related criteria. The primary reason for issuing an activation order is usually tied to the risk of network failure. Curtailments are to be executed without any form of compensation. Any resource, be it generation, demand, or storage, depending on the network connection access point and its specific requirements, is required to comply with a connection agreement.

Regarding local markets, the Table 4.25 outlines the dimensions and options established for this mechanism. It indicates that the network to be considered operates across medium and low voltage levels. The negotiation timeframe can be either long or short-term, with contract lengths varying from hourly to annual. The bid granularity is set at either 1 hour or 15 minutes. The services to be provided can include both availability and activation of active power, which can be either upward or downward and are considered asymmetrical. Participants in the local market can include a variety of resources such as generation units, demand management, or storage solutions.

Table 4.23 Dimensions and options for network tariffs in the North EU (Sweden) demonstrator (Case study 2)

<table>
<tr><th>nº</th><th>Dimension</th><th colspan="12">Options</th></tr>
<tr><td>1</td><td>Cost Allocation methods</td><td colspan="12">Long-term incremental + Residual Costs</td></tr>
<tr><td>2</td><td>Charging variable</td><td colspan="3">Fixed</td><td colspan="3">Used Capacity (measured)</td><td colspan="3">Capacity (contracted)</td><td colspan="3">Energy</td></tr>
<tr><td>3</td><td>Locational granularity</td><td colspan="12">Zonal</td></tr>
<tr><td>4</td><td>Temporal granularity of charges</td><td colspan="4">Yearly</td><td colspan="4">Seasonal (Monthly)</td><td colspan="4">Hourly</td></tr>
<tr><td>5</td><td>Price setting periodicity</td><td colspan="12">Year ahead
(static)</td></tr>
<tr><td>6</td><td>Temporal granularity of measurements</td><td colspan="6">Hourly</td><td colspan="6">Quarter hourly</td></tr>
<tr><td>7</td><td>Customer differentiation</td><td colspan="12">By Voltage levels or network areas
(Technology agnostic)</td></tr>
<tr><td>8</td><td>Symmetry of charges (Energy o capacity components)</td><td colspan="12">Different offtake and injection charges</td></tr>
</table>

Table 4.24 Dimensions and options for conditional agreements in the North EU (Sweden) demonstrator (Case study 2)

nº	Dimension	Options		
1	Duration of flexible connection	Temporary		
2	Curtailment notification	Intra-day	Real-time	
3	Connection Costs	Not Defined		
4	Benefit of the DSO allowing flexible connection	Defer reinforcement (More economic than network expansion)	Preliminary connection (Network expansion is committed in a future year)	
5	Network connection criteria	Capacity limitation	Other security criteria (N, N-1)	
6	Activation of the energy curtailment due to flexible connection	Emergency (Grid failure risk)		
7	Pre-definition of curtailment	Not Defined		
8	Principle of access	Not Defined		
9	Compensation payments for energy curtailment	None		
10	Possibility to sell the expected curtailed energy	Not Defined		
11	Maximum curtailment	Capacity limitation		
12	Eligible customers	Generation (Including hybrid installations)	Demand (Including active customers)	Storage (Stand-alone)

Table 4.25 Dimensions and options for local market for DSO services in the North EU (Sweden) demonstrator (Case study 2)

nº	Dimension	Options				
1	Flexibility need Grid level	Medium Voltage		Low Voltage		
2	Negotiation time frame (Gate Opening and Closure for participation)	Long-term (Weeks-ahead to years-ahead)		Shot-term (Real-time, intraday, day-ahead)		
3	Contract length	Yearly	Monthly	Weekly	Daily	Hourly
4	Temporal bid granularity	1 hour		15 min		
5	Response Time (Activation)	Not defined				
6	Transactional Object	Energy (Activation)		Capacity (Availability)		
7	Power	Active Power				
8	Direction	Upwards		Downwards		
9	Symmetry Requirements (For upwards and downwards)	Asymmetric products				
10	Source (Flexibility assets)	Generation (Including hybrid installations)		Demand (Including active customers)		Storage (Stand-alone)

4.7.3 Case Study 3

The third case study is proposed based on the information collected from the survey, the format of which is attached in annex 8.7. This case study specifically analyses data pertaining to the SOUTH-MID EU (Italy) demonstrator. The mechanisms for acquiring system operator services available for this scenario are network tariffs, and local markets.

Table 4.26 details the dimensions and options set for network tariffs in the Italian context. The network tariff structure is formulated to average out costs, with yearly revisions implemented for price adjustments. The tariff is composed of several charges: a fixed component, a capacity-based component determined by the contracted capacity, and an energy consumption-based component. The allocation of these charges is structured yearly, consistent with the granularity of 15-minute interval measurements. These tariffs are standardized at a country-wide level. Differentiation in costs for customers varies according to voltage levels, and there are some added components according to certain technologies. Moreover, the tariff incorporates asymmetrical charges for off-take and injection.

Similarly, Table 4.27 outlines the dimensions and options set for local markets. The flexibility need at the grid level focuses on medium and low voltage networks. The negotiation timeframe can be either long-term or short-term, with contract durations being monthly or annually. The temporal granularity of bids is set at 15 minutes, allowing response times from 30 minutes. The services offered can be either for availability or activation, specifically concerning active power. These services can be asymmetric, and either upwards or downwards. The resources that can participate in the local market include generation, demand, or storage capabilities.

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Table 4.26 Dimensions and options for network tariffs in the SOUTH-MID EU (Italy) demonstrator (Case study 3)

<table>
<tr><th>nº</th><th>Dimension</th><th colspan="4">Options</th></tr>
<tr><td>1</td><td>Cost Allocation methods</td><td colspan="4">Average Costs</td></tr>
<tr><td>2</td><td>Charging variable</td><td>Fixed</td><td colspan="2">Capacity (contracted)</td><td>Energy</td></tr>
<tr><td>3</td><td>Locational granularity</td><td colspan="4">System-wide</td></tr>
<tr><td>4</td><td>Temporal granularity of charges</td><td colspan="4">Yearly</td></tr>
<tr><td>5</td><td>Price setting periodicity</td><td colspan="4">Year ahead (static)</td></tr>
<tr><td>6</td><td>Temporal granularity of measurements</td><td colspan="4">Quarter hourly</td></tr>
<tr><td>7</td><td>Customer differentiation</td><td colspan="2">By Voltage levels or network areas (Technology agnostic)</td><td colspan="2">Specific tariffs according to technologies (Generation, Storage, EVs., etc.)</td></tr>
<tr><td>8</td><td>Symmetry of charges (Energy o capacity components)</td><td colspan="4">Different offtake and injection charges</td></tr>
</table>

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Table 4.27 Dimensions and options for LM for DSO services in the SOUTH-MID EU (Italy) demonstrator (Case study 3)

<table>
<tr><th>nº</th><th>Dimension</th><th colspan="6">Options</th></tr>
<tr><td>1</td><td>Flexibility need
Grid level</td><td colspan="3">Medium Voltage</td><td colspan="3">Low Voltage</td></tr>
<tr><td>2</td><td>Negotiation time frame
(Gate Opening and Closure for participation)</td><td colspan="3">Long-term
(Weeks-ahead to years-ahead)</td><td colspan="3">Shot-term
(Real-time, intraday, day-ahead)</td></tr>
<tr><td>3</td><td>Contract length</td><td colspan="3">Yearly</td><td colspan="3">Monthly</td></tr>
<tr><td>4</td><td>Temporal bid granularity</td><td colspan="6">15 min</td></tr>
<tr><td>5</td><td>Response Time
(Activation)</td><td colspan="3">> 1 hour</td><td colspan="3">30 min – 1 hour</td></tr>
<tr><td>6</td><td>Transactional Object</td><td colspan="3">Energy (Activation)</td><td colspan="3">Capacity (Availability)</td></tr>
<tr><td>7</td><td>Power</td><td colspan="6">Active Power</td></tr>
<tr><td>8</td><td>Direction</td><td colspan="3">Upwards</td><td colspan="3">Downwards</td></tr>
<tr><td>9</td><td>Symmetry Requirements (For upwards and downwards)</td><td colspan="6">Asymmetric products</td></tr>
<tr><td>10</td><td>Source
(Flexibility assets)</td><td colspan="2">Generation
(Including hybrid installations)</td><td colspan="2">Demand
(Including active customers)</td><td colspan="2">Storage
(Stand-alone)</td></tr>
</table>

4.8 Framework Design

4.8.1 Description of the framework

The current chapter within the BeFlexible project initiative focuses on proposing a decision framework for combining mechanisms for acquiring distribution system operator services. It examines several mechanisms including network tariffs, connection agreements and local markets. The combination of acquisition mechanisms can be understood as the simultaneous application of these mechanisms in a specific jurisdiction. Each combination of mechanisms offers advantages and challenges that should be carefully evaluated to maximize efficiency and meets specific grid requirements. The insights from this analysis provide valuable tools for effectively managing the flexibility that some resources connected to the distribution network can offer to the power systems.

According to the methodology depicted in Figure 4.1, several dimensions and options are defined for each mechanism. Section 4.4.1 describes the 8 dimensions and 26 options identified for network tariffs. Section 4.4.2 describes the 12 dimensions and 37 options identified for connection agreements. Section 4.4.3 describes the 10 dimensions and 29 options identified for local markets. Moreover, section 4.5 explains the comparative analysis process, which provide insights into how the interplay thought these different mechanisms are be evaluated. Furthermore, Figure 4.4 illustrates how the decision framework can be employed in the overall application.

Figure 4.5 outlines the proposed decision framework. It starts considering that there are some requirements within the electrical network that can be categorized as DSO needs, which necessitate corresponding DSO services (to avoid or delay network updates). The aim is to employ a combination of mechanisms (network tariffs, connection agreements, and local markets), not only to acquire these DSO services, but also to enhance the overall efficiency of the system as result of their interplay. Moreover, potential inefficiencies that may arise from their interaction can be identified, which add complexity to the simultaneous implementation of these mechanisms.

The conditions under analysis can be based on greenfield or brownfield scenarios. In brownfield conditions, the existing acquisition mechanisms are evaluated. Then, the dimensions and options for each mechanism are limited in line with the information from the country (or jurisdiction) according to the tables provide in section 4.5 (Table 4.10 Pairwise comparison between network tariffs and flexible connection agreements, Table 4.11 Pairwise comparison between flexible connection agreements and LM for DSO services, Table 4.12 General need attributes relevant for the acquisition mechanisms combinatorial framework). For example, consider a case study with a network tariff structured on quarter-hourly temporal granularity of measurement, and local markets where the temporal bid granularity can be either hourly or every 30 minutes, these specific options are chosen from the available alternatives, and the others can be discarded. A similar analysis is carried out for the other dimensions and options in each mechanism. On the other hand, in the absence of acquisition mechanisms, it represents a greenfield scenario, leading to an initial mechanism design process. This scenario offers significant advantages as the mechanism design process can be tailored to promote the combination of the considered mechanisms according to the current proposed methodology. Alternative conditions also can arise whether existing mechanisms are to be analysed alongside those still in developmental stages, where a design process must also be considered. This approach also provides opportunities to facilitate a combination of mechanisms with existing mechanisms.

Once the acquisition mechanisms are defined, and the dimensions and options limited, a comprehensive set of cross-options is generated. However, not all cross-options are pertinent to the analysis. Those cross-options deemed

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insignificant or irrelevant to the analysis (marked in grey) are excluded, resulting in a refined set of relevant cross-options. At this stage, the framework adopts an iterative evaluation process, which systematically assesses the relevant cross-options one by one, and concludes once all relevant cross-option are evaluated. This assessment is guided by predefined criteria:

- If the cross-option being assessed indicates that both mechanisms can interact without apparent issues (cross-option in green), it maximizes the simultaneous implementation of the acquisition mechanisms considered.
- Otherwise, if the cross-option being assessed indicates that both mechanisms cannot be implemented simultaneously (cross-option in red), it signals that there may be significant inefficiencies or a potential infeasibility. Additionally, in scenarios where new (non-existing) mechanisms are evaluated, a redesign phase may be considered. If redesign is feasible, the process restarts under the new dimensions and options. Otherwise, the evaluation continues with the remaining cross-options, keeping this restriction in mind. All these impacts will be quantitatively evaluated in Work Package 7 within the BeFlexible Project.
- Under other conditions, it is required an analysis according to specific dimensions in conflicts (cross-option in orange), which represent cases that are not immediately clear-cut. This type of cross-option requires a more detailed analysis, as they might turn out to be either feasible (green) or infeasible/inefficient (red). Figure 4.4 provides an example applying this framework in the assessment of temporal dimensions in network tariffs and local markets. If the value of temporal granularity of charges in the network tariff operates on an hourly basis but the local market operates on a different temporal scale, this discrepancy needs to be evaluated. For instance, if the value of temporal bid granularity in local market is two hours, and the cost allocations-mechanism overlaps creating inefficient as the bid does not capture correctly the tariff value. Conversely, if this option varies every 15 minutes, the local market can complement the tariff more efficiently, which means that they can be applied at the same time. Eventually, if an orange cross-option is reclassified as green, it is integrated into the set of viable cross-options for implementation of combined acquisition mechanisms. If it turns red, it joins the set of infeasible options. At the end of the iterative process all orange cross-options from the relevant set must be reclassified, ensuring a comprehensive evaluation of all possible conditions.

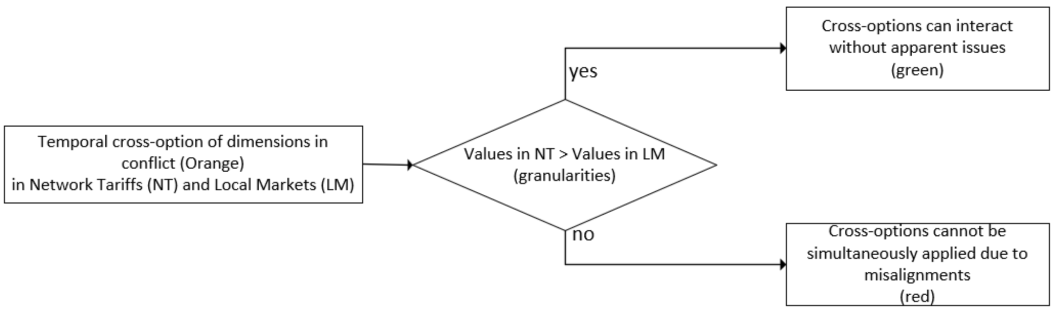

Figure 4.4 Example of evaluation for specific dimensions in conflicts

Once the evaluation process is completed, the outcome hinges on the classification of all relevant cross-options. The overarching goal is to achieve a condition where all cross-options allow the combination of the acquisition mechanisms under analysis without apparent issues, leading to maximize the overall efficiency. This condition is highly desirable as

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it ensure that the combined acquisition mechanisms complement each other, enhancing the signals sent to customers and the performance of the distribution system. On the other hand, if inefficiencies or infeasibilities are identified, requires careful attention, as it indicates conflicts or operational challenges within the considered acquisition mechanisms. It suggests that certain combinations of mechanisms may not be implementable together, or their simultaneous implementation could lead to suboptimal outcomes, such as increased costs, reduced customer signalling, or regulatory non-compliance. It is important to note that the presence this condition while highlighting challenges, also provides opportunities for continuous improvement. Thus, this might involve redesigning certain mechanisms, varying operational parameters, or even at least reconsidering the feasibility of certain combinations (it is not the most efficient solution). The implications of these inefficiencies and the strategies to address them will be quantitatively analysed in Work Package 7 within the BeFlexible Project.

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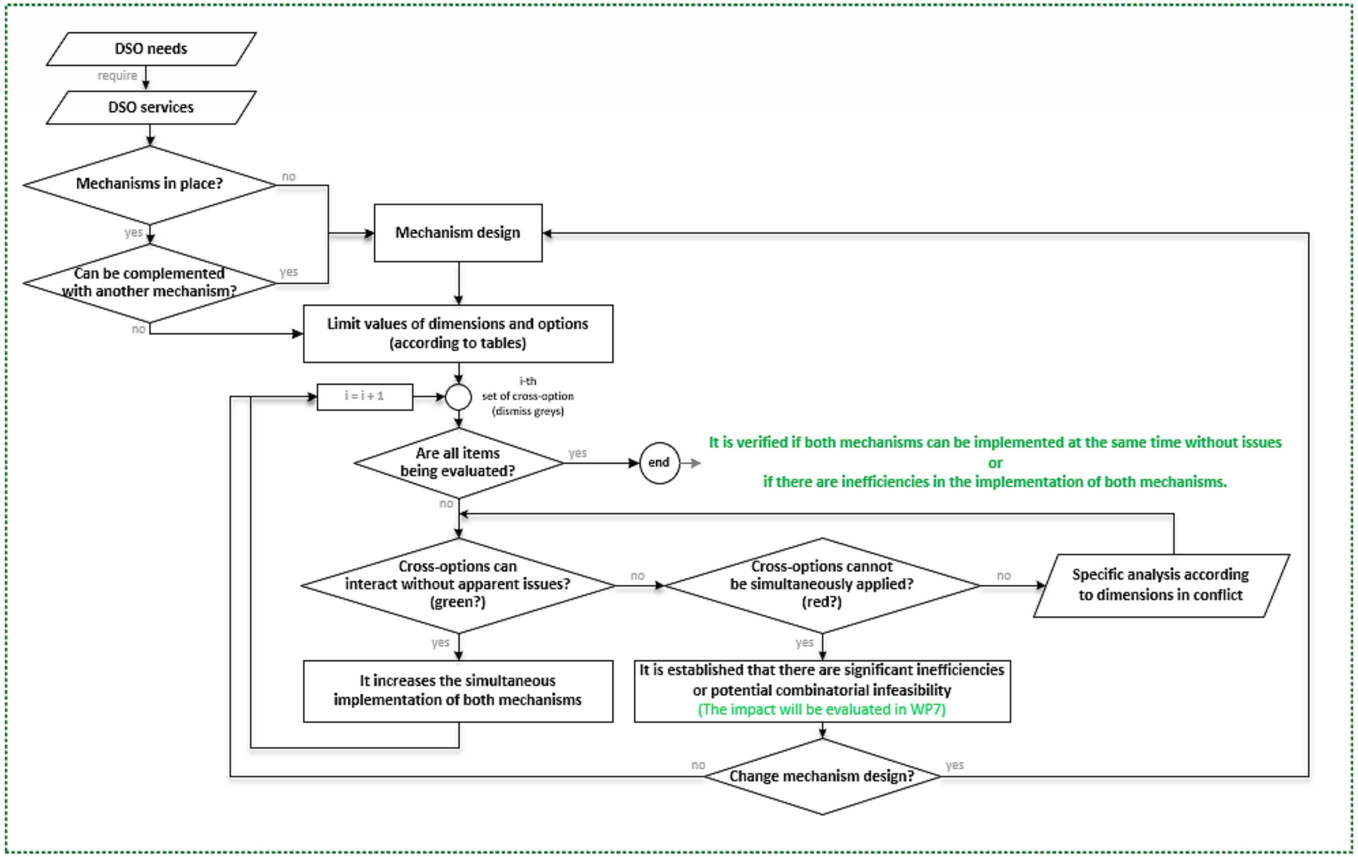


Figure 4.5 General Framework for combined mechanisms for acquiring distribution system operator services

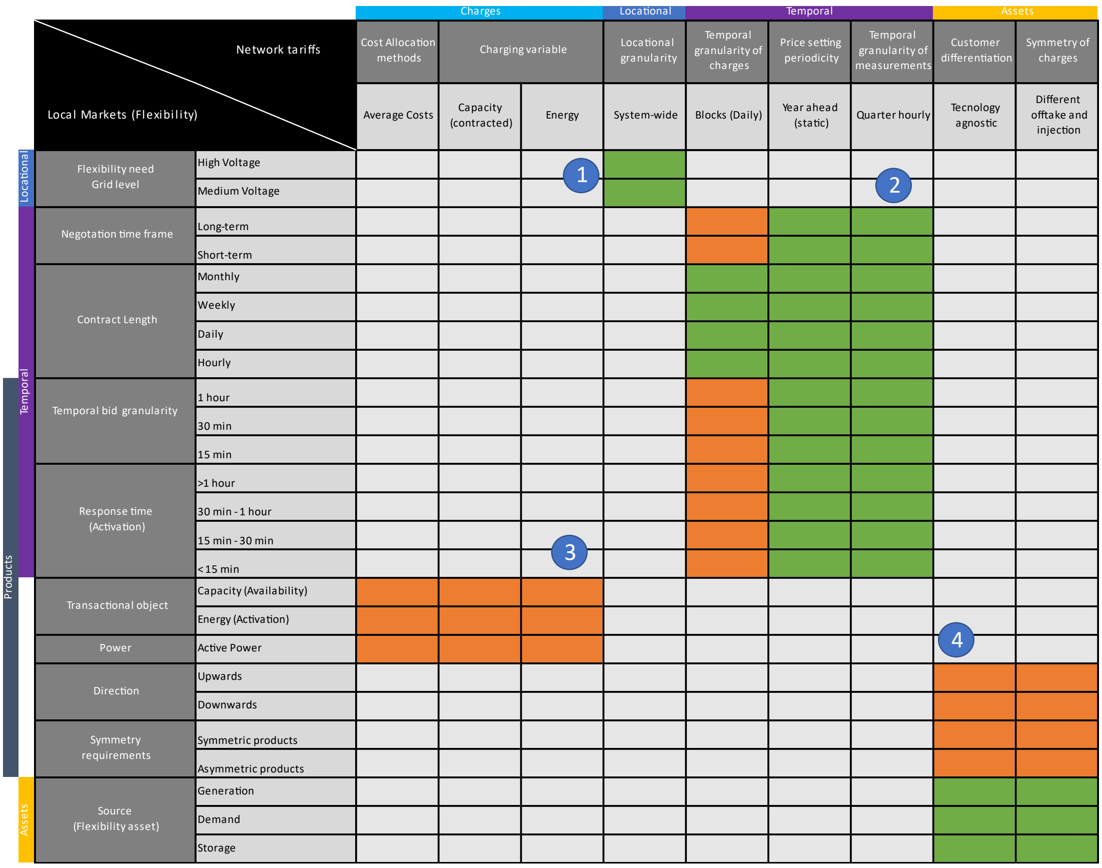
4.8.2 Analysis of applications

Based on the information displayed in section 4.7, the next step is to apply the decision framework as depicted in the Figure 4.5, considering the dimensions and options for each case. The analysis begins by considering the are some needs of DSOs, thus it is necessary to acquire DSO services. Once the mechanisms are defined, the iterative process begins to analyse each cross-option, determining if the set of relevant cross-options can maximize the simultaneous application of both mechanisms, or if significant inefficiencies or potential combination problems may arise. In the following case studies, these conditions are analysed.

4.8.2.1 Study Case 1

The analysis of the current case synthesizes the information gathered regarding the SOUTH-MID EU (Spain, France) demonstrator. In this instance, according to the information obtained from the survey as explained in section 4.7, the mechanism principally considered in the present state of the pilots is local markets for congestion management. Similarly, dimensions and options are defined in accordance with the Spanish network tariff. This approach enables the study of interaction between these two mechanisms: one that is already deployed at the country level, and another that is in an advanced stage of design but not yet fully implemented. According to the framework, the next step involves limiting the options of both mechanisms in the different dimensions according to the tables proposed in section 4.5. Table 4.28 shows the simplified table where dimensions and options are limited.

Table 4.28 Limited values of the dimensions and options for the analysis of case study 1: Network tariffs and local markets for congestion management



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The total set of cross-options consists of 250; however, the subset of relevant cross-options is significantly smaller, comprising only 67 cross-options to be analysed according to the procedure established in sub-section 4.8.1. The evaluation begins by comparing each cross-option individually. For example, the coordinate formed by the dimension in network tariffs locational granularity and its option of system-wide, and with the dimension in local markets Flexibility need grid level and its option high voltage, in the block 1 (blue), indicates that both mechanisms in this specific case can interact without apparent issues (green). As shown in the Figure 4.5, all green cross-options increase the simultaneous application of both mechanisms. In absence of red coordinates, the focus shifts to those requiring specific analysis according to the dimension in conflicts (orange).

In the block 2, given the structure of the network tariffs in Spain which are segmented into blocks, situations where the dimensions of negotiation time frame, temporal bid granularity, and response time (Activation), are smaller than the period in each block, flexibility markets could enhance the economic efficiency of the signals received by customers. However, if these mechanisms overlap, such as when activating the local market requires operation across two consecutive time blocks for tariffs, it could lead to averaging the tariff price signal from the blocks to the market time unit. This overlap might also result in double charging or double rewarding. This could lead to inefficiencies in the combination of these mechanisms.

In block 3 of the Table 4.28, the cross-option formed by average cost and capacity (availability), present some issues that need to be analysed. A network tariff based on average costs suggests that network costs are determined by projected demand. Furthermore, it has a lower granularity, if the local market can incorporate long-term cost signals that cannot be covered by the tariffs, this condition increases the efficiency of both mechanisms. However, if this tariff structure significantly affects projected demand and some users are unable to respond to these signals, it could lead to an uneven playing field among network users. Similar situations may occur for the energy (activation) and active power options, and for the cross-options between the dimensions of customer differentiation, and symmetry of charges with direction, and symmetry requirements in block 4. These conditions could generate inefficiencies in their combination.

Finally, when analysing the acquisition mechanisms network tariffs and local markets in the Spanish context, it is generally observed that they can potentially be combined. While interaction challenges may arise, leading to some inefficiencies in their combination, there appears to be no significant evidence of situations that would lead to infeasibility.

4.8.2.2 Study Case 2

The analysis of the current case synthesizes the information gathered regarding the North EU (Sweden) demonstrator. In this instance, according to the information obtained from the survey as explained in section 4.7, the mechanisms considered in the present state of the demos are local markets and conditional agreements for congestion management. Similarly, dimensions and options are defined in accordance with the Swedish network tariff. This approach enables the study of interaction between these three mechanisms: network tariffs with local markets, network tariffs with connection agreements and connection agreements with local markets.

According to the framework, the next step involves limiting the options of both mechanisms in the different dimensions according to the tables proposed in section 4.5. Table 4.29 presents a simplified version where the dimensions and options are limited for network tariffs and local market combinatorial analysis.

The total set of cross-options consists of 280; however, the subset of relevant cross-options is significantly smaller, comprising only 83 cross-options to be analysed according to the procedure established in sub-section 4.8.1. The evaluation begins by comparing each cross-option individually. For example, the coordinate formed by the dimension

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in network tariffs locational granularity and its option of system-wide, and with the dimension in LM for DSO services Flexibility need Grid level and its option medium voltage, in the block 1 (blue), indicates that both mechanisms in this specific case can interact without apparent issues (green). The evaluation proceeds in this manner. As shown in the Figure 4.5, all green cross-options increase the simultaneous application of both mechanisms.

Moving on to the analysis of block 2, there are two cross-options coloured in red, indicating potential incompatibilities. In the case of tariffs in Sweden, measurements are currently taken on an hourly basis. However, as mentioned in the section 4.7.2, there is a regulatory transition towards 15-minute measurements, for this reason, both situations are considered. Furthermore, when considering a local market with a 15-minute temporal bid granularity, this presents a feasibility problem. Technically, it creates a measurement challenge that cannot be reconciled under the current system, due to that the time granularity of the bids must be higher than the time granularity of the measurements.

In block 3 of the Table 4.29, the cross-option formed by long-term incremental + residual costs and capacity (availability), present some issues that need to be analysed. A network tariff based on long-term incremental cost component considers sending economic signals to customers to reduce future network cost. Furthermore, if local market also incorporates long-term cost signals scenarios of double charging or double rewarding can arise. Similar condition can occur considering the dimension of charging variable, especially relevant in conditions where the same type of requirement is present, such as capacity contracted aligning with capacity (availability). Similar situations may occur for the energy (activation) and active power options, and for the cross-options between the dimensions of customer differentiation, and symmetry of charges with direction, and symmetry requirements in block 4. These conditions could generate inefficiencies in their combination.

Finally, when analysing the acquisition mechanisms network tariffs and local markets in the Swedish context, the potential combination of the two mechanisms is primarily influenced by the temporal granularity of the measurements. However, as previously mentioned, there is a shift towards 15-minute interval measurements. Under 15-minute interval measurements, the simultaneous application of these two mechanisms would be feasible if no interaction issues arise that could lead to inefficiencies in their combination.

Table 4.29 Limited values of the dimensions and options for the analysis of case study 2: Network tariffs and local markets for congestion management

			Charges					Locational	Temporal						Assets	
		Network tariffs	Cost Allocation methods	Charging variable				Locational granularity	Temporal granularity of charges			Price setting periodicity	Temporal granularity of measurements		Customer differentiation	Symmetry of charges
Local Markets (Flexibility)			Long-term incremental + Residual Costs	Fixed	Used Capacity (measured)	Capacity (contracted)	Energy	Zonal	Yearly	Seasonal (Monthly)	Hourly	Year ahead (static)	Hourly	Quarter hourly	Tecnology agnostic	Different offtake and injection
Locational	Flexibility need Grid level	Medium Voltage					1									
		Low Voltage														
Temporal	Negotiation time frame	Long-term													2	
		Short-term														
	Contract Length	Yearly														
		Monthly														
		Weekly														
		Daily														
		Hourly														
	Temporal bid granularity	1 hour					3									
		15 min														
Product	Transactional object	Capacity (Availability)														
		Energy (Activation)														
	Power	Active Power														
	Direction	Upwards												4		
		Downwards														
	Symmetry requirements	Asymmetric products														
Assets	Source (Flexibility asset)	Generation														
		Demand														
		Storage														

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The next case to be analysed pertains to the combinatorial analysis of network tariffs and connection agreements. According to the framework described in section 4.8.1, the next step involves limiting the options of both mechanisms in the different dimensions according to the tables proposed in section 4.5. It is important to note that some dimensions have been excluded because they are not defined. This exclusion is crucial for maintaining the clarity and relevance of the analysis, ensuring that only the currently established aspects are considered in the combinatorial analysis.

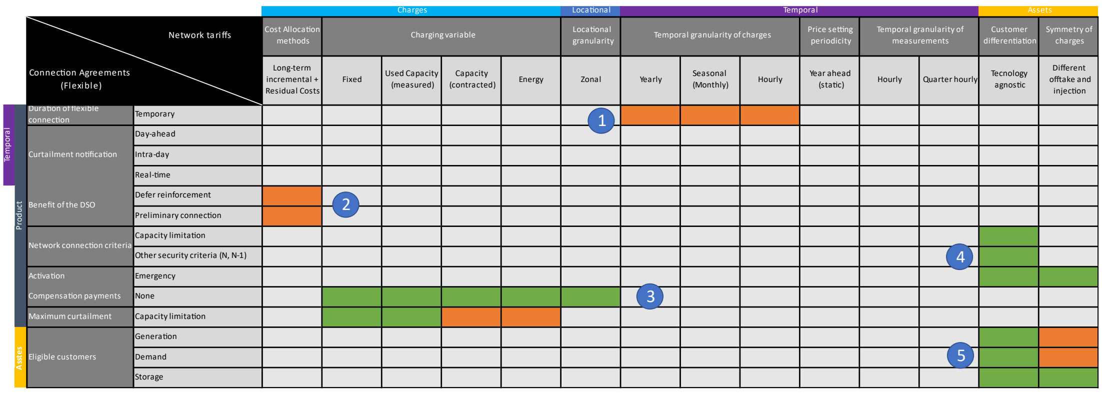
Table 4.30 displays a simplified version of these acquisition mechanisms. The total set of cross-options consists of 196; however, the subset of relevant cross-options is significantly smaller, comprising only 24 cross-options to be analysed according to the procedure established in section 4.8.1. In absence of red coordinates, the focus shifts to those requiring specific analysis according to the dimension in conflicts (orange).

In block 1, if the duration of the flexible connection is temporary and there are compensations associated with curtailment, conditions of double charging or double rewarding could arise. However, for this specific case, according to the compensation payment dimension, it appears that no compensations are involved (as the none option is selected), suggesting that significant interplay issues are unlikely to occur. A similar situation is observed in block 2, where both mechanisms send long-term signals. Thus, the alignment of both mechanisms could potentially facilitate integration, implying that the mechanisms are likely to be complementary.

In block number 3, if the maximum curtailment is determined by capacity limitations, it is important when considering variable charging to ensure that it adheres to the limits of the contracted capacity. Additionally, it should be ensured that the provided energy does not negatively impact these capacity constraints. Moreover, in block 5, challenges can arise when specific technologies are favoured through tariffs, and simultaneously, compensatory connection payments are made based on customer type, potentially leading to scenarios of double-charging or double rewarding. However, in this condition, such issues are unlikely to occur as there are no compensations for curtailment involved. This absence of curtailment compensations helps to mitigate the risk of overlapping charges or rewards.

Finally, when analysing the acquisition mechanisms of network tariffs and connection agreements in the Swedish context, it is generally observed that they can potentially be combinable. Interaction challenges may arise, leading to inefficiencies in their combination, but there appears to be no significant.

Table 4.30 Limited values of the dimensions and options for the analysis of case study 2: Network tariffs and flexible connection agreements



The following condition to be analysed corresponds to the combinatorial analysis of connection agreements with local markets. According to the framework in section 4.8.1., the next step involves limiting the options of both mechanisms in the different dimensions according to the tables proposed in section 4.5. It is important to note that some dimensions

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have been excluded because they are not defined. This exclusion is crucial for maintaining the clarity and relevance of the analysis, ensuring that only the currently established aspects are considered in the combinatorial analysis.

Table 4.31 displays a simplified version of these acquisition mechanisms. The total set of cross-options consists of 240; however, the subset of relevant cross-options is significantly smaller, comprising only 51 cross-options to be analysed according to the procedure established in section 4.8.1.

In block 1, there are several cross-options indicating the potential for significant interaction issues between these two mechanisms for this case study. Curtailment notification serves as a tool to enable customers to make informed decisions about participating in a local market. If the notification time for curtailment is sufficiently in advance relative to the granularity of the local market dimensions, both mechanisms can be implemented simultaneously without issues. However, a misalignment between these timeframes can lead to challenges, potentially resulting in inefficiencies in the combination of these two mechanisms and even more crucially, causing potential infeasibility. Similar conditions are observed in block 2. When curtailment activation occurs due to an emergency, with contract durations being long-term, it becomes challenging for customers to make informed decisions regarding the market. This situation highlights the importance of aligning curtailment notifications with market operations to facilitate effective customer participation and decision-making.

Block 3 offers more adaptability, if the proposed transactional object is within the required capacities in the dimensions of network connection criteria and maximum curtailment, both mechanisms can interact without apparent issues. Otherwise, there might only be potential drawbacks in terms of reduced efficiency. A similar situation arises in the last block, where it is primarily essential to ensure that the assets within flexible connections align with market requirements. However, typically in current local flexibility markets, the focus is mainly on the direction (upwards or downwards) in which the services are required.

Finally, when analysing the acquisition mechanisms of connection agreements and local markets in the Swedish context, significant problems could arise, ranging from major inefficiencies to potential infeasibilities. These challenges are influenced by a variety of factors, including market dynamics, regulatory constraints, and technical limitations. In this case, following the decision framework outlined in the Figure 4.5, it might be advisable to consider a re-adaptation of the dimension of the mechanisms.

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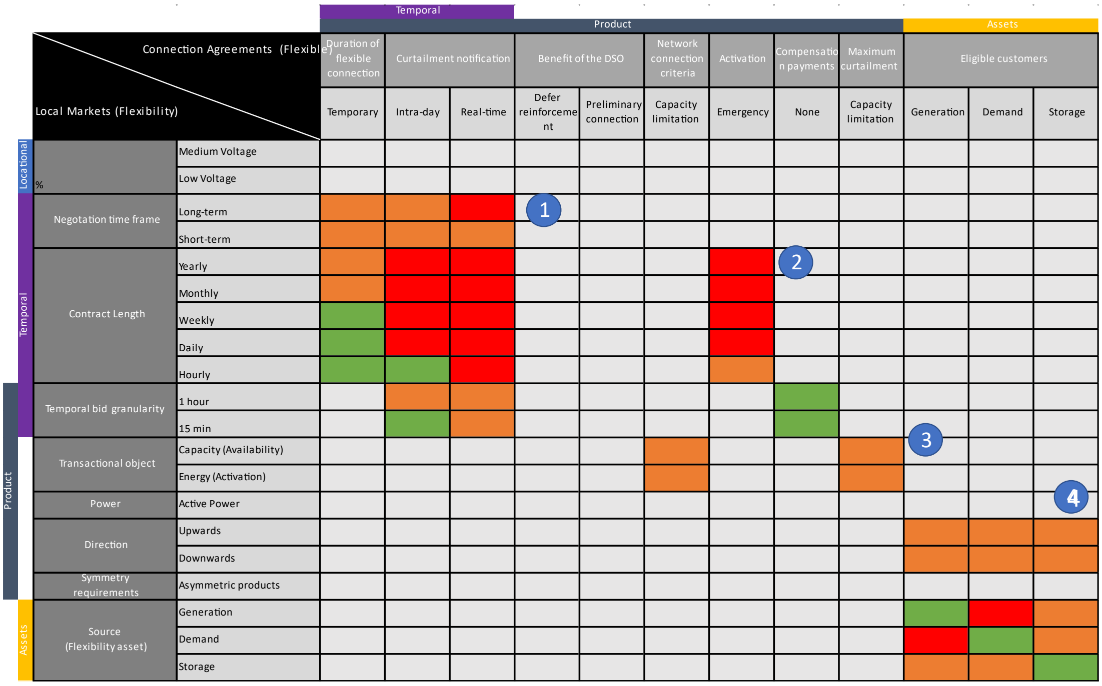
Table 4.31 Limited values of the dimensions and options for the analysis of case study 2: Flexible connection agreements vs local markets for congestion management



4.8.2.3 Study Case 3

The analysis of the case 3 synthesizes the information gathered regarding the SOUTH-MID EU (Italy) demonstrator. In this instance, according to the information obtained from the survey as explained in section 4.7, the mechanism principally considered in the present state of the pilots is local markets for congestion management. Similarly, dimensions and options are defined in accordance with the Italian network tariff. This approach enables the study of interaction between these two mechanisms. According to the framework, the next step involves limiting the options of both mechanisms in the different dimensions according to the tables proposed in section 4.5. The Table 4.32Table 4.28 shows the simplified table where dimensions and options are limited.

The total set of cross-options consists of 198; however, the subset of relevant cross-options is significantly smaller, comprising only 53 cross-options to be analysed according to the procedure established in sub-section 4.8.1. The evaluation begins by comparing each cross-option individually. For example, the coordinate formed by the dimension in network tariffs locational granularity and its option of system-wide, and with the dimension in local markets Flexibility need Grid level and its option medium voltage, in the block 1 (blue), indicates that both mechanisms in this specific case can interact without apparent issues (green). The evaluation proceeds in this manner. As shown in the Figure 4.5, all green cross-options increase the simultaneous application of both mechanisms. In absence of red coordinates, the focus shifts to those requiring specific analysis according to the dimension in conflicts (orange).

In the block 2, given the structure of the network tariffs which are segmented yearly, situations where the dimensions of long-term negotiation time frame, temporal bid granularity, and response time (Activation), are smaller than the period in each block, flexibility markets could enhance the economic efficiency of the signals received by customers. However, if these mechanisms overlap, such as when activating the local market requires operation across two consecutive time blocks, it could lead to issues in cost allocation. This overlap might also result in scenarios of double

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charging or double rewarding. This could lead to inefficiencies in the combinatorial process of these mechanisms designs.

In block 3 of the Table 4.32, the cross-option formed by average cost and capacity (availability), present some issues that need to be analysed. A network tariff based on average costs suggests that network costs are determined, in general terms, by the total costs divided by projected demand. Furthermore, it has a small granularity, if the local market can incorporate long-term cost signals that cannot be covered by the tariffs, this condition maximises the efficiency of both mechanisms. However, if this tariff structure significantly affects projected demand and some users are unable to respond to these signals, it could lead to an uneven playing field among network users. Similar situations may occur for the energy (activation) and active power options, and for the cross-options between the dimensions of customer differentiation, and symmetry of charges with direction, and symmetry requirements in block 4. These conditions could generate inefficiencies in their combination.

Finally, upon examining the acquisition mechanisms of network tariffs and local markets within the Italian context, it is generally observed that they have the potential to be compatible. Although there may be challenges in their interaction, which could result in some inefficiencies in their combination, there seems to be no significant evidence suggesting situations that would render their combination completely infeasible.

Table 4.32 Limited values of the dimensions and options for the analysis of case study 3: Network tariffs and local markets for congestion management

			Charges				Locational	Temporal			Assets		
		Network tariffs	Cost Allocation methods	Charging variable			Locational granularity	Temporal granularity of charges	Price setting periodicity	Temporal granularity of measurements	Customer differentiation		Symmetry of charges
	Local Markets (Flexibility)		Average Costs	Fixed	Capacity (contracted)	Energy	System-wide	Yearly	Year ahead (static)	Quarter hourly	Tecnology agnostic	According to Tecnologies	Different offtake and injection
Locational	Flexibility need Grid level	Medium Voltage				1							
		Low Voltage								2			
Temporal	Negotation time frame	Long-term											
		Short-term											
	Contract Length	Yearly											
		Monthly											
	Temporal bid granularity	15 min											
	Response time (Activation)	>1 hour											
		30 min - 1 hour				3							
Procut	Transactional object	Capacity (Availability)											
		Energy (Activation)											4
	Power	Active Power											
	Direction	Upwards											
		Downwards											
	Symmetry requirements	Asymmetric products											
Assets	Source (Flexibility asset)	Generation											
		Demand											
		Storage											

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4.9 Interim Conclusions

This chapter outlines a qualitative analysis methodology for assessing the feasibility of a combined design of several mechanisms to acquire DSO services to address network problems. Initially, the focus is on identifying those mechanisms that are most impactful in power systems and are mature enough in the pilots associated with the BeFlexible project. These mechanisms include network tariffs, connection agreements, local markets for DSO services, and rule-based approaches, as indicated in section 4.3.

The next step involves determining the design dimensions and options for each mechanism, which characterize and collectively describe each mechanism, as described in section 4.4. Therefore, utilising the identified design dimensions and options, the methodology involves a comparative analysis. This process includes comparing different dimensions of the acquisition mechanisms: network tariffs with local markets for DSO services, network tariffs with connection agreements, and local markets for DSO services with connection agreements, as developed in section 4.5. At this stage, the analysis of rule-based mechanisms has been neglected due to their case-specific nature and the fact that the project demonstrators within the project have not established these conditions in their current developmental phase. These comparative analyses propose detailed assessments of how the different mechanisms interplay and align with each other to identify potential synergies that guide the integration of these mechanisms more efficiently. It should be noted that when mechanism design sends the same economic signals to customers to reduce network usage, customers may face scenarios of being double rewarded or double charged, leading to distortions in economically efficient behaviours of customers. Moreover, results from preferential access to information, more favourable mechanism structures, or the ability to influence market conditions could create market power issues, or an uneven competitive landscape. These remarks underscore the necessity for careful mechanism design to prevent redundant incentives that could interfere with the desired efficient behaviours of stakeholders.

In addition, to complete the methodological framework for assessing the feasibility of a combined design of several mechanisms to acquire DSO services, the definition of need attributes and evaluation criteria is presented in section 4.6. A survey was conducted with partners to assess the relevance of the proposed need attributes and evaluation criteria alongside their qualitative values. This survey was strategically structured in two stages to gather information encompassing two perspectives. The first stage considered the viewpoint of DSOs to establish the technical parameters for the analysis, such as need attributes and evaluation criteria relevant according to each demo. The second stage was tailored to the perspective of the service providers, with an emphasis on assessing several criteria regarding customer engagement. Regarding the significance of the need attributes, the attribute classified as most significant is the frequency of the need, highlighting the availability that service providers should have to respond to the network requirements. Based on the results obtained for the evaluation criteria, it suggests that economic efficiency is the most relevant criterion, signifying the paramount importance of cost-effectiveness for the DSOs. On the other hand, equity, while important, seems to be of lesser priority compared to other criteria. This positioning could imply a focus on efficiency and practicality over equitable outcomes. Regarding the results of the evaluation conducted on customer engagement criteria, the highest position corresponds to customer easiness of participation, highlighting the need for straightforward and accessible engagement processes. Lastly, the reduction of controllability by the end-users on their equipment, although ordered lowest, remains significant in considering how participation impacts customers. Additionally, from the first stage of the survey, information was also collected about the dimensions and options considered in the Spanish, Swedish, and Italian demos. This information is then used to develop case studies in section 4.7, which are evaluated within the decision framework.

From the case studies and applying the proposed methodology, it is possible to derive some broadly applicable conclusions from a general point of view. For instance, it is observable that at this stage in the BeFlexible project, the

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mechanism most considered for obtaining flexibility from third parties is local flexibility markets for DSO services. This mechanism is chosen by all survey participants, indicating they are in critical phases of development. However, it is crucial to analyse how interaction with other mechanisms can increase efficiency during the combination process, or, if applicable, identify potential inefficiencies that may arise. Examining the interplay between existing tariffs and developing local markets for DSO services, as specified by the demonstrations, reveals that these mechanisms are highly compatible under the currently studied conditions. This compatibility is mainly constrained by the considered temporal and spatial granularities, potentially leading to issues that diminish efficiency or result in infeasibilities, primarily due to technical limitations (e.g., when measurement devices cannot comply with local market for DSO services conditions). A similar observation is made regarding tariffs and flexible connections, particularly when the latter lacks associated compensations. The potential interaction largely hinges on the granularity of specific dimensions. Lastly, analysing the interaction between local markets and flexible connections might expose conditions ranging from inefficiencies to potential infeasibilities. In some scenarios, flexible connection agreements could detrimentally affect local markets for DSO services by diminishing their liquidity. In general, the analyses conducted based on the collected information have facilitated a better understanding of the interaction of mechanisms for acquiring DSO services from third parties, considering fundamental characteristics such as dimensions and options.

Finally, the decision framework proposes a strategic methodology to assess the feasibility for a combined design of mechanisms for acquiring distribution system operator services, as is explained in section 4.8. The framework considers their constitutive characteristics as dimensions and options and evaluates different conditions based on predefined criteria, aiming to achieve effective interaction while addressing potential inefficiencies. It acknowledges that while the integration of mechanisms can offer substantial benefits, it also poses challenges and risks that need to be carefully managed. By identifying these issues early in the assessment process, the framework enables stakeholders to make informed decisions on how to enhance and adjust the mechanisms to better serve their intended purpose of improve the overall efficiency. Finally, this exploratory assessment could act as a reference to propose quantitative analyses that provide measurable and evaluable results. Thus, any identified inefficiencies offer opportunities for improvement, which could be quantitatively analysed in Work Package 7 of the BeFlexible Project.

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5 Strategies to address regulatory experimentation

As discussed in sections 2 and 3, innovation in the energy sector will require regulation to evolve; otherwise, regulatory barriers may limit the potential benefits of new technologies and the rise of new business models. Enabling innovation may drive down prices, resulting in new products and services for consumers, facilitate the integration of new technologies, and achieve emission targets. At the same time, one principle of regulation is that it should be stable and predictable [23] to attract the necessary funds to a critical sector (i.e., the power sector) and ensure the provision of an essential service. Therefore, there is a need to achieve both objectives simultaneously. Regulatory experimentation allows testing innovative solutions for a limited time in a controlled real environment. This approach aims to give room for innovation while minimizing the impact on regulatory stability and quality of supply.

Regulatory experimentation is a popular tool NRAs have gradually adopted in Europe during recent years [346]. This tool aims to support innovative solutions and promote regulatory learning [347], inform the revision of existing regulation, or inspire new regulation [348]. Solutions should be tested in a controlled real-world environment [346] and should have an advanced TRL 7-9 [347]. As highlighted by the European Commission, regulators need to keep pace with innovation and understand its impact [346].

Since there is no one-size-fits-all solution, NRAs with different objectives have adopted different approaches for implementing a regulatory experimentation framework. [346] describes the choices made by different EU member states. Some countries (e.g., Belgium, Croatia, Italy, Austria, and Sweden) implemented a top-down/policy-lead approach, where experiments are targeted to address specific goals or topics, while others (e.g., Denmark, Spain, France, Hungary, the Netherlands, and Portugal) implemented a bottom-up/innovator-lead approach, where experiments are open to topics suggested by innovators facing regulatory barriers. Other aspects of the experimentation framework design may fit for different purposes (e.g., the decision to provide funding or not, open-call or dedicated-call). Regulators should establish their objectives based on their current context and make a fit-for-purpose design of a sandbox. We will discuss the implications of the potential choices by the authorities in the design of a regulatory experimentation framework based on past experiences and current research and give some recommendations for regulators.

5.1 The advisory role of national regulatory authorities

5.1.1 Why should NRAs offer an advisory service for innovators?

Experiences in the UK and France showed that innovators need advice from the NRA. As Ofgem noticed during the first application window of their sandbox program, most applicants needed regulatory advice rather than a sandbox, as their pursued activities were already allowed by current regulation [349].

Even if there is a regulatory barrier, it is challenging for applicants to identify the regulatory barriers to their project, and the advisory role can help them in this task [350]. This need for regulatory advice is supported by the experience during the first application window in France, after observing that many applicants did not correctly identify the regulatory barrier [351]. Previous studies also considered providing regulatory advice as a best practice in regulatory frameworks for promoting innovation [350], [352].

Other countries, such as Sweden and Australia, have already considered previous experiences and decided to offer regulatory advice in their current framework as an enabler for innovation.

The Swedish NRA deeply studied the topic of regulatory experimentation, as shown in [353]. After this study, they decided to implement an innovation center to facilitate innovation by giving regulatory advice to innovators. No

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experimentation framework has been implemented yet in Sweden. Besides guiding innovators through existing legislation, the Swedish NRA expects innovators' questions to shed light on how well the current regulation works and the current regulatory development needs. This insight is an additional benefit of the advisory service, allowing the regulator to keep pace with current innovators' needs.

Implementing an advisory service for innovators

The Australian Energy Regulator presents an interesting case as they decided to implement the Energy Innovation Toolkit[79] . This toolkit comprises three different services, two of them are related to the advisory role:

- Guidance with instant answers for common energy regulation questions: this service includes illustrative use cases showing how regulation may apply to hypothetical business models. It also includes an interactive tool where innovators answer pre-defined questions about their business model and receive an automated initial assessment about what licensing, registration, and authorization requirements might apply to their business model. As highlighted by Ofgem [352], these guides can significantly reduce the burden on the regulatory authority.
- Tailored informal guidance through the Innovation Enquiry Service: This service is a first stop for innovators seeking informal regulatory guidance and a pathway to regulatory relief. This service helps innovators understand what regulations and market entry requirements might apply to their projects. The service also helps innovators explore options to adapt their business ideas under the current framework. Finally, this service also helps innovators understand what agencies they might need to contact and what processes and applications they might need to undertake.

In the UK, the advisory role is implemented through the 'Fast Frank Feedback' service, designed to help innovators understand the regulatory implications of their propositions [349]. The advisory role is resource-intensive [346], so adequate staffing is critical in terms of the number of people and their skills. A recommended practice is to develop guides for navigating regulation, like the Australian case, to reduce the administrative burden.

5.2 Fit for purpose framework design for regulatory experimentation

As highlighted in [346], experimentation should not be an objective by itself. Therefore, the regulatory agency designing the framework should establish policy targets for the activity. Once the mission is defined, a fit-for-purpose framework design is recommended, ensuring sufficient mandate and adequate staffing for the administrator. Based on the framework proposed by [348] and extended by [350], we analyzed several dimensions for the design of the regulatory experimentation framework. We included a dimension for the regulatory learning mechanism (i.e. top-down vs bottom-up approach). Two dimensions are not discussed here: eligible promoters and length of derogation. First, the eligible promoters dimension is not discussed as the majority of countries in Europe allow a wide range of stakeholders to apply for regulatory experiments [353]. Second, the length of derogations is not discussed because, despite usually having an upper limit established by the framework, the trial duration is generally defined on a case-by-case basis, and the duration of a particular trial can be extended if deemed necessary [346].

Regulatory learning mechanism: Top-down vs. bottom-up approaches & NRAs collaboration

As described by the Swedish NRA and the Council of European Energy Regulators [17], [353] in a top-down (or policy-driven) approach, the regulator designs the exemptions/derogations/developments that market participants can test

[79] https://energyinnovationtoolkit.gov.au/about

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to address specific goals. In a bottom-up (innovation-driven) approach, the innovators identify and apply for exemptions for new business ideas they want to try during the experiment.

The top-down approach enables the NRA to take a proactive role. This approach provides better opportunities to effectively progress from regulatory experiments to permanent regulation, favoring regulatory learning [346], [352]. This is not a surprise because the objectives of the experiment are aligned with the priorities of the regulatory authority. The experience in Italy suggests that the top-down approach allows for testing more radical innovations [348]. This approach tends to mitigate discrimination and distortion of competition.

The bottom-up approach enables innovators to identify and apply for regulatory exemptions/derogations/developments [353]. This approach facilitates the regulator being aware of the current needs of innovators, it can be argued that this is why the innovators' need for regulatory advice was noticed under bottom-up approaches (e.g. the case of UK and France). However, the bottom-up approach tends to have a less straightforward contribution in terms of regulatory learning [353].

As recognized by the European Commission [346]: "there is a risk that top-down schemes might become too rigid and not correspond to the needs of market actors.". Therefore, combining the two approaches in a hybrid framework may be interesting [346]. The Swedish NRA has left the door open for the hybrid approach [353]. The downside is that this hybrid approach can result in a big administrative burden for the NRA.

Ofgem noticed the difficulty in translating experiment results under a bottom-up approach to permanent changes in the regulation, back in 2018: *"Changing policy for all companies involves more consideration than allowing one innovator to temporarily adopt a different approach. This is an interesting challenge that we are glad to be aware of."* [354]. Later, during a webinar in December 2023, Ofgem explained that they plan to move to a top-down approach to facilitate experiment results translating into regulatory changes. They plan to maintain the regulatory advisory service for innovators. This combination is an interesting approach, as the advisory service would help the regulator to be aware of regulatory barriers that innovators are facing, while the top-down approach for experimentation increases the chances of permanent, well-functioning regulatory changes after experimentation. The approach may result in similar benefits compared to the hybrid approach with less administrative burden.

Collaboration between NRAs of different countries is a complementary learning experience for NRAs that may help avoid unnecessary errors and duplication efforts. In a recent JRC survey [355], most NRAs confirmed that exchanging best practices between national authorities is desirable. To support this, during an ISGAN online meeting of the Sandbox Community of Practice in May 2023, the Australian regulator recognized the value of exchanging experiences and views with the Ontario and UK regulators while designing their current framework for regulatory experimentation.

5.2.1 Funding

Regarding the funding aspect of regulatory experiments, [350] analyzed sandbox programs of various European countries. Funding is not included in the initial scope in most countries, but projects are allowed to be funded through other channels. As noted by [352], direct funding for regulatory experiments may not result in optimal resource allocation, because business models requiring regulatory changes would not necessarily have a greater potential to generate social welfare than other business models. Among the risks of direct funding for regulatory experiments, participants may look for funding rather than a regulatory experiment [356]. Direct funding may pose challenges to the continuation of the initiative when the funds are no longer available [356]. The risk of discrimination and distortion of competition should also be considered, as it may result in a particular actor gaining a competitive advantage. This discrimination risk is aggravated under bottom-up approaches where the regulatory exemption/derogation/development is given to specific actors (i.e. the applicants).

In the case of regulated entities (i.e. TSOs and DSOs), it may be reasonable to link the experiment to an innovation funding program or innovation incentives. The revenues of the regulated companies are allowed revenues and testing new products/technologies/services may result in a net loss for the regulated entities, discouraging innovation. This is the situation described by an Austrian DSO after some discussions with regulators [347]. The DSO argued that regulators showed no interest in accepting additional money expenses in the tariff calculation, making the DSOs unwilling to invest in innovative pilot projects. As discussed in Section 2.7.6, indirect incentives present in the current regulatory framework for DSO remuneration (e.g., efficiency incentives, quality incentives, the CAPEX-bias, etc.) may discourage some innovation initiatives. Therefore, NRAS should align direct and indirect incentives for innovation to promote innovation in the activity of regulated entities.

5.2.2 Transparency and reporting

Knowledge dissemination is a key aspect of regulatory experiments as it facilitates regulatory learning. It is important to consider that participants of a sandbox may act in non-realistic ways that pay off best for them [353]. Therefore, a high degree of transparency and the participation and consideration of opinions from different actors (consumer associations, other market players, research institutions, etc.), as well as periodic evaluations from the regulatory authority during the experiment, facilitates a smooth transition between a sandbox and a well-functioning permanent regulation. In addition, knowledge dissemination prevents individual players from being given market advantages due to information dominance [353].

It has been observed that most countries include public reporting obligations in their experimentation frameworks, but sometimes, these obligations are challenging to complete [356]. This is the case of the Netherlands, where the lack of detail in the reporting resulted in missing regulatory learning of some innovations [356], [357].

5.2.3 Scope of regulatory changes and framework administration

The scope of derogations/exemptions/developments tested during a regulatory experiment are limited to the regulation under the responsibility of the administrative party (e.g. Ministry of energy, independent regulatory authority, etc.) [350], [358]. Additionally, for countries inside the European Union, experiments must comply with European Union legislation [350].

Once the mission of the regulatory experimentation framework is defined, the administrators of the sandbox must have a sufficient mandate. One recommendation for extending the scope of the potential regulatory changes tested is the involvement of different regulatory bodies in the regulatory experimentation framework based on the defined mission. This involvement facilitates the recommended one-stop-shop approach for applicants [346].

5.2.4 Application process: Open call vs dedicated call

The application process for regulatory experimentation may be defined as a dedicated-call with a specific deadline for applicants or an open-call approach, where applications can be received anytime, not complying with specific time windows. Under dedicated-calls, the administrator of the regulatory experimentation framework typically introduces a specific regulatory theme [350]. It has been observed in the UK that this dedicated-calls under a bottom-up approach may lead to innovators rushing into applications [349], resulting in poor quality applications and an excessive administrative burden for the administrators. After this experience, Ofgem decided in 2020 to move to an open-call approach with no specific application window, moreover, stating that *"We may, if demand is high, pause receiving new applications from time to time."* [349]. A similar experience in France, under a bottom-up approach with dedicated calls, led the French regulator to move to open calls [359].

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Combining a dedicated call application process with no specific theme for experimentation under a bottom-up approach may result in an excessive administrative burden for the regulatory body. Dedicated calls are best suited to a policy-led approach because the regulatory body introduces a specific theme for the applications, limiting the potential administrative burden.

5.2.5 Staffing capacity in the regulatory body

Regulatory experimentation aims to foster innovation by having a regulatory framework that keeps pace with the needs of innovators. Therefore, being agile in responding to innovators' needs is essential for a successful experimentation framework. As described in [352], staffing needs of the regulatory body tend to diminish over time as more experience is gained. Therefore, the step-by-step approach taken by the Swedish regulator seems reasonable, as they decided first to implement the advisory service and plan to later design the regulatory experimentation framework [353], by that time, they should have gathered some experience in the advisory role, reducing the burden of this task, and helping to design a regulatory experimentation framework better suited to the needs of innovators in their country.

5.3 Considerations for successful experimentation

Participation in experiments is decided on a case-by-case basis, so the criteria for eligibility and selection need to be clear [346]. Regulatory agencies can establish some requisites for applicants to ensure the experiment is relevant and favours regulatory learning. Next, we discuss some aspects regulatory agencies should consider when evaluating applications for regulatory experiments. This is not an exhaustive list, as some relevant aspects are not included (e.g., the capacity of the applicants to run the experiment, customer protection, warranties).

5.3.1 Make sure It is appropriate to experiment

A proposal for regulatory change should be aligned with the general principles of regulation described in [23]:

- Regulation should steer an industry's performance towards improving "general welfare".
- Regulation deals with correcting monopolistic markets or imperfect competition that may enable monopolies and oligopolies to set unjustifiably high prices or lower the quality of their goods or services.
- Regulation seeks to protect investors from the State, which might act opportunistically by setting supply tariffs and obligations that would preclude recovery of the investment.
- Regulation attempts to correct externalities (e.g., information safety and environmental-related problems).

Additionally, regulation should aim for simplicity and clarity.

Regulatory experimentation should not be a theoretical exercise. It is key to enable real transactions and test the proposal down to monetisation with the active involvement of all actors, including the end-user [347]. Otherwise, motivating the regulatory change based on the experiment results is difficult.

As described by the JRC [355], clear identification of the regulatory obstacle helps the regulatory authority to simplify and speed up the eligibility check. Still, it represents a burden for applicants, who do not always have a clear picture of the regulatory framework and the regulatory barriers that may affect their business model. Therefore, it seems reasonable to complement the requirement of identifying the regulatory obstacle with the advisory role from the regulator described in section 2 to help innovators identify the regulatory barrier.

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5.3.2 Exit strategy

Regular legislation may come into force when the trial period for experimentation ends. Therefore, regulatory agencies should require applicants to include an exit strategy to plan their actions after the trial period, contemplating the possibility of no regulatory change as an outcome of the experiment. This is considered a key aspect of successful experimentation [352]. Applicants for regulatory experimentation in the UK must include an exit strategy [360]. Other countries such as France, Germany and Netherlands do not explicitly require applicants to define an exit strategy, while in Italy adjustments to the proposed regulatory changes, along with periodic evaluation, are allowed during the trial period in order to create a smooth transition between the trial and permanent regulation [353]. The Swedish NRA plans to request an exit strategy for applicants, describing how the test operations are terminated and the associated risks [353].

5.3.3 Evaluation strategy

As described in Section 5.2.2, periodic reporting of experiment results by the participants and evaluation by the regulatory authority is a practice for successful experimentation. Applicants should include a hypothesis to test and a detailed methodology for collecting and analysing key data [346]. As noticed by the Swedish regulator [353]: "An elaborated evaluation strategy should help to protect opposing interests and can form the basis for regulatory learning for the supervisory authority." The European Commission recommends involving a wide range of stakeholders (public authorities, industry experts, technology providers, consumers, citizens, etc.) [346], [347] during the planning, the execution of the project, and the final evaluation. Experiments should be evaluated against the pre-defined methodology. Cost-benefit analysis and ensuring replicability and scalability are critical aspects of the experiment evaluation [346], [347].

5.3.4 Experimentation period

As described in section 5.2.3, it is recommended to involve a wide range of stakeholders during the execution, planning, and evaluation of the experiment [346], [347]. Experience shows that involving stakeholders, especially the end-user, tends to be more difficult than anticipated [347]. Therefore, it is crucial to allow sufficient time to produce results and to evaluate them. Some jurisdictions allow for an extension of the experimentation period if needed.

5.4 Interim conclusions

The power sector is rapidly changing, and regulatory frameworks should not hinder innovation that may bring system-wide benefits. At the same time, one regulatory principle is regulatory stability to keep attracting investment into this critical sector and maintain the quality of supply of this essential service. Therefore, it is unsurprising that regulatory experimentation, offering a framework for testing innovative solutions in a controlled environment for a limited time, has become a popular tool many NRAs have adopted during the last few years.

Experiences in different countries and some recent studies allow us to give recommendations for NRAs about implementing a regulatory experimentation framework.

First, innovators need regulatory advice, as it is sometimes difficult for them to navigate through regulation, and experience has shown that a significant portion of innovators who were looking for regulatory experiments to test their business models end up only needing regulatory advice because the current regulatory framework already permitted their business model. Some regulatory agencies noted this first lesson and implemented the regulatory advisory service to foster innovation.

Second, the regulatory learning mechanism (top-down/policy-oriented vs. bottom-up/innovator-oriented) affects the potential scope of the experimentation framework. The top-down approach favours regulatory learning, as experiments are aligned with the objectives of the regulatory agency, and it is easier for experiment results to lead to permanent, well-functioning regulatory changes. On the other hand, it presents a more rigid structure for experimentation. The bottom-up approach allows the regulator to keep pace with innovators' needs while hindering regulatory learning from experiment results. Combining a top-down approach with the regulatory advisory service may check all the boxes regarding regulatory learning and keeping pace with the needs of innovators.

Supporting innovation should be an agile service requiring specialized human resources. Therefore, adequate staffing of the framework administrator is key to success in this task. The staffing needs tend to reduce as experience is gained. Thus, a step-by-step implementation of the framework as planned by the Swedish NRA may bring good results. Collaboration of different regulatory bodies is recommended as it can broaden the scope for testing regulatory changes.

A regulatory experiment should aim to solve a real problem and not be a theoretical exercise. The proposed regulatory change must be aligned with the principles of good regulation such as improving general welfare, correct market failure, protect investors from a potential opportunistic action from the State, and correct externalities. Additionally, regulatory changes should aim for simplicity and clarity.

When planning a regulatory experiment, a well-crafted evaluation and exit strategy is key to success. A cost-benefit analysis and a scalability and replicability analysis are recommended for evaluation. Periodic reporting and evaluation during execution and not only at the end of the experiment is also a recommended practice.

Finally, collaboration between NRAs of different countries is recommended as a complementary learning experience that may help avoid unnecessary errors and duplication efforts.

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6 Conclusions

The BeFlexible project, through its Task 1.1 and Task 1.2 efforts, has embarked on a critical mission to address and navigate through the current regulatory challenges hindering the widespread deployment of flexibility within the European electricity markets. By examining and proposing a framework that encompasses regulatory experimentation insights from pilot projects, remuneration schemes for flexibility usage, rules for system operator ownership of flexible resources, and the aggregation of such resources, the project sets a solid foundation for the evolution of regulatory frameworks. This endeavour aims to not only define the roles and responsibilities of both existing and new market participants but also to tackle various challenges such as contracts with Flexibility Service Providers (SPs), retailer arrangements, baseline methodologies, and balance responsibilities, thereby paving the way for a more integrated and flexible electricity system.

The conclusions drawn from analysing DSO remuneration across six European countries underscore the pressing need for regulatory evolution to foster flexibility solutions. The shift towards flexible planning, as opposed to fixed investment decisions, emerges as a viable strategy to accommodate the growing penetration of renewable generation and electrification of energy uses. This approach reveals the potential economic value of flexibility in long-term system services procurement, advocating for a transition from traditional CAPEX-biased frameworks to more neutral incentives that promote cost-efficiency.

The comprehensive analysis of the European legal framework for energy communities, as detailed in the report, sheds light on the nuanced regulatory landscape that shapes their operation across the continent. It meticulously examines the existing legal definitions, characteristics, and requirements of energy communities, identifying five distinct legal entities recognized under European legislation. This analysis not only highlights the diversity of regulatory approaches taken by various European countries but also underscores the common challenges and gaps within these frameworks. The report emphasizes the necessity for specific, measurable requirements to ensure compliance with European regulations and suggests considering a broader spectrum of energy carriers to enhance the viability and scope of energy communities. Furthermore, the introduction of dynamic allocation coefficients is proposed as a means to foster innovative business models, such as local electricity markets. The report concludes that a tailored approach, considering local factors like population density and network characteristics, is crucial for effectively implementing energy communities in different contexts. This detailed examination and the resulting insights are pivotal for policymakers and stakeholders aiming to promote and integrate energy communities within the European energy landscape effectively.

The analysis focusing on the role of aggregators in the electricity market underscores the pivotal importance of their integration for enhancing grid resilience, sustainability, and efficiency. Aggregators, by pooling distributed energy resources, stand at the cusp of revolutionizing energy systems through the delivery of flexibility services. However, the realization of their full potential is contingent upon establishing clear roles, responsibilities, and a supportive regulatory environment. The document delineates existing regulatory landscapes across Europe, identifying both synergies and disparities, and proposes a series of regulatory recommendations aimed at creating an enabling environment for aggregators. Key suggestions include the need for balanced and penalization mechanisms for imbalances, the division of imbalance responsibilities, addressing the rebound effect, considering aggregators' bargaining power, establishing the role of independent aggregators, and ensuring transparency through independent market operators. These recommendations are poised to mitigate existing barriers and unlock the transformative potential of aggregation for the energy sector, facilitating a more dynamic, efficient, and sustainable electricity grid.

The BeFlexible project's exploration of diverse baselining methodologies and the adoption of submetering technologies underscore the potential to enhance energy market efficiency and facilitate broader participation. The comparative evaluation of various baselining solutions through the project's demonstrators is expected to illuminate their

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effectiveness, addressing barriers and requirements while highlighting the practical benefits of accuracy, simplicity, and integrity in measuring energy usage. Particularly, the project illuminates the significant role of submetering in enabling participation from smaller-scale energy resources, which is crucial for evolving electricity markets towards more dynamic and inclusive frameworks. Submeters, serving as pivotal tools for detailed energy measurement, support numerous market phases, from prequalification to activation monitoring. Their adoption, especially in contexts lacking widespread smart meter infrastructure, offers a pathway to capture the granular energy data essential for efficient market operation and participant engagement. This analysis, grounded in the experiences and data from the BeFlexible project, aims to inform and guide policymakers and regulators in crafting strategies that leverage these technologies for maximizing the utility and inclusivity of electricity markets.

The conclusions drawn from the BeFlexible project's analysis of regulatory experimentation frameworks underscore their pivotal role in nurturing innovation within the energy sector. These frameworks, designed to test innovative solutions within a controlled environment for a limited duration, have emerged as a vital tool for regulatory authorities seeking to adapt to the rapidly evolving landscape of energy systems. The insights gleaned from various countries' experiences highlight the necessity for regulatory bodies to offer clear guidance and support to innovators, facilitating their navigation through complex regulatory landscapes. Moreover, the distinction between top-down and bottom-up approaches to regulatory experimentation reveals a nuanced balance between fostering regulatory learning and accommodating the dynamic needs of innovators. The emphasis on crafting a well-defined evaluation and exit strategy for each experimental initiative, coupled with the importance of ensuring adequate staffing and inter-regulatory collaboration, points towards a structured yet flexible approach to regulatory experimentation. This approach not only encourages the development of groundbreaking energy solutions but also ensures that regulatory frameworks remain responsive and conducive to systemic innovation and sustainability.

The analysis focused on proposal for flexibility mechanisms designs, from standalone mechanisms to efficient combination, presents a comprehensive methodology for evaluating the feasibility of combining several mechanisms to acquire distribution system operator services, aimed at meeting network requirements. Key mechanisms identified for impact and maturity in the BeFlexible initiative include network tariffs, connection agreements, and local markets. The methodology emphasizes understanding the dimensions and options of each mechanism, particularly those influencing economic efficiency when combined. The approach involves comparative analyses of different acquisition mechanisms, such as network tariffs with local markets, network tariffs with connection agreements, and connection agreements with local markets, to understand their interplay and alignment. The methodology also incorporates a survey conducted in two stages, gathering insights from DSOs and SPs. This survey focused on technical parameters, need attributes, evaluation criteria, and customer engagement aspects. Information from this survey was instrumental in developing case studies to assess different scenarios of application. The decision framework, a pivotal part of the methodology, evaluates the feasibility of combining different mechanisms under various conditions, aiming for effective solutions and addressing inefficiencies. While single mechanisms can address network problems, combining them may offer more economically and technically efficient solutions. The methodology presented lays the groundwork for future quantitative analyses, as part of the BeFlexible Project's Work Package 7, to address and improve identified inefficiencies.

In conclusion, the BeFlexible project's comprehensive analysis and proposed solutions described in this document contribute significantly to the ongoing discourse on electricity market design and flexibility integration. The findings and recommendations serve as a vital resource for TSOs, DSOs, market operators, regulatory bodies, and policymakers, guiding them towards creating a more resilient, efficient, and sustainable electricity system. The path forward involves further research to deeply understand market integration, harmonization, and the efficiency of proposed market designs. The upcoming endeavours within the BeFlexible project, building upon the analyses presented in this report, are poised to significantly influence the reshaping of Europe's electricity markets for the future with the aim of fostering the flexibility deployment.

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8 Annex

8.1 Glossary

- Active Customer: Final customer who consumes, stores, or sells self-generated electricity, or participates in flexibility or energy efficiency schemes (Directive 2019/944).
- Aggregation: Combining multiple consumer loads or generated electricity for market transactions (Directive 2019/944).
- Ancillary Services: Services necessary for the operation of transmission, distribution systems, and/or storage facilities (Directive 2019/944, Directive 2009/73/EC).
- Authorization: Instrument issued by authorities granting the right to conduct business (Directive 2013/575).
- Balance Responsible Party: Market participant responsible for imbalances in the electricity market (Regulation 2019/943).
- Balancing: Actions and processes through which transmission system operators maintain system frequency and reserve quality (Regulation 2019/943).
- Baseline: Counterfactual reference about a service provider's allocated volume in the absence of activation (Framework Guidelines on Demand Response).
- Capital Requirements: Characteristics and conditions on own funds (Directive 575/2013).
- Citizen Energy Community (CEC): Legal entity providing environmental, economic, or social community benefits, engaging in various energy activities (Directive 2019/944).
- Closed Distribution System: System distributing electricity within a confined industrial, commercial, or shared services site (Directive 2019/944).
- Contract: Agreement between parties creating mutual obligations enforceable by law.
- Customer: Wholesale or final customer of energy or related services (Directive 2019/944).
- Demand Response: Change of electricity load by final customers in response to market signals (Directive 2018/2001).
- Distribution System Operator (DSO): Responsible for operating, maintaining, and developing the distribution system (Directive 2019/944, Directive 2009/73).
- Emissions Trading System (ETS): System for greenhouse gas emission allowance trading within the EU (Directive 2003/87/CE).
- Energy Efficiency: Ratio of output to input of energy (Directive 2012/27).
- Energy Service: Benefit derived from a combination of energy with energy-efficient technology or action (Directive 2012/27).
- Energy Supply Contract: Contract for the supply of energy, excluding energy derivatives (Directive 2019/944, Directive 2012/73/EC).
- Final Consumers: Customers purchasing electricity for their own use (Directive 2019/944).
- Financial Instrument: Financial support measure provided from the budget for specific policy objectives (Directive 2018/1046).

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- Generation: Production of energy, including usage and ownership of generation assets (Directive 2019/944).
- Grant: Subsidy supporting individual or company investments.
- Household Consumer: Customer purchasing electricity for household consumption, excluding commercial activities (Directive 2019/944).
- Legal Person: Legal entity with rights and obligations under the law.
- Loan: Subsidy allowing borrowing of financial resources from future income.
- Metering: Measuring energy fed or consumed from the grid (Directive 2019/944).
- Micro, Small or Medium-sized Enterprise (SME): Enterprise employing fewer than 250 persons with specific turnover and balance sheet limits (Commission Recommendation 2003/361/EC).
- Municipality: Governing body of a town or local district.
- National Energy and Climate Plan (NECP): Plan covering a ten-year period, specifying aspects related to energy and climate (Directive 2018/1999).
- Non-Discrimination: Equal and fair chance for all individuals to access opportunities (European Union definition).
- Peer-to-Peer Trading (P2P): Sale of energy between market participants under predetermined conditions (Directive 2018/2001).
- Power Purchase Agreement (PPA): Contract for purchasing renewable electricity directly from a producer (Directive 2018/2001).
- Renewable Energy Community (REC): Legal entity providing environmental, economic, or social benefits, primarily engaging in renewable energy activities (Directive 2018/2001).
- Storage: Deferring final use of energy to a later time (Directive 2019/944).
- Supply: Sale or resale of energy, including natural gas, electricity, LNG, heat, etc. (Directive 2019/944, Directive 2009/73/EC).
- Support Scheme: Instrument promoting the use of energy from renewable sources (Directive 2018/2001).
- Transmission System Operator (TSO): Responsible for operating, maintaining, and developing the transmission system (Directive 2019/944, Directive 2012/73/EC).
- Transposition: Incorporating EU directives into national laws of EU Member States (European Union definition).
- Unbundling: Separation of competitive energy activities from non-competitive ones (Directive 2009/73, Directive 2019/944).
- Balance Responsible Party: A market participant or its chosen representative responsible for its imbalances in the electricity market (Regulation 2019/943).
- Balancing Service Provider: A market participant providing either or both balancing energy and balancing capacity to transmission system operators (Regulation 2019/943).
- Dispatch Limitation: A congestion management product whereby a service provider offers to limit the use of the firm connection capacity of a service providing unit or group prior to the determination of its dispatch, i.e., prior to closure of the day-ahead market.
- Dynamic Tariffs: Tariff where the price changes hour by hour without any predefined schedule.
- Flat Tariffs: Tariff where the prices remain constant during a long period of time, no matter the moment when the customer consumes the electricity.

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- Independent Meter Service Provider: Responsible for meter data collection and meter data management.
- Last Resort Aggregator: Refers to an aggregator that accepts any client and/or energy community which has not been accepted by other aggregators.
- Local Service Provider: A service provider of product(s) for supplying local System Operator (SO) services.
- Local SO Services: Market-based procurement of congestion management or voltage control.
- Metering Point: A physical location where the withdrawal and/or injection of active power is measured.
- Redispatch Products: A congestion management product which can be activated after closure of the day-ahead market.
- Service Provider: A market participant with a legal or contractual obligation to supply System Operator (SO) services from at least one service providing unit or service providing group.
- Service Providing Group: An aggregation of units and/or service providing units connected to more than one connection point where they inject and/or withdraw electricity fulfilling the requirements to provide SO services either at connection point or aggregated level.
- Service Providing Unit: A single unit or ensemble of units connected to a single connection point of a SO network where they inject and/or withdraw electricity fulfilling the requirements to provide SO services.
- Smart Metering System: An electronic system capable of measuring electricity fed into the grid or consumed from the grid, providing more information than a conventional meter, and capable of transmitting and receiving data for information, monitoring, and control purposes, using a form of electronic communication (Directive 2019/944).
- SO Coordination Area: The area affected by an existing or forecasted congestion or voltage control issue, particularly with recurrent incidence.
- SO Coordination Group: The group of the requesting SO and affected SOs, linked to one or several congestions or voltage control issues.
- SO Services: Market-based procurement of balancing, voltage control, and congestion management.
- Standardized Device: Equipment that meets all technical requirements set by the SO for the provision of SO product according to the Original Equipment Manufacturer or other official certification authority.
- Submetering: Measurement of energy behind the meter of the final client.
- Time-based Tariffs: Tariff where there is a certain number of time intervals during the day (usually 2 or 3) with fixed prices that remain constant during a long period of time.

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8.2 Questionnaire on DSO remuneration schemes regulation

8.2.1 Scope, purpose, and instructions for filling

This survey is intended to gather information on the main regulatory aspects of DSO remuneration schemes to assess the readiness of the current regulatory framework for the provision of flexibility services.

Please specify in the following table the perspective from which you are answering.

Role	Indicate with "X" and specify if needed
Transmission System Operator	
Distribution System Operator	
Independent Aggregator	
Supplier	
Flexibility resource owner (specify the technology)	
Other, please specify	

When filling out the survey, please consider the following:

1. Be as clear and specific as possible.
2. Provide further detailed insights to clarify and/or nuanced answers.
3. Please complete the answers with references where appropriate and possible (even if the document's language is not English). **Including the section or page of the referred document if possible.**
4. In case of doubt about the questions, contact the responsible people indicated below.
5. Be complete: your answers will be used to assess the framework within your country. In case your answer is incomplete, also indicate and specify potential weaknesses.
6. To ease the interpretation of the question, examples and/or additional explanations can be added in italics.
7. Please consider both current regulations and any potential legislation change that may take place in the near future.
8. When presented with a question, feel free to add rows so that relevant information is included as much as possible.

Thank you for your cooperation

8.2.2 Questions

1. TOTEX or OPEX/CAPEX regulation?

OPEX/CAPEX: Under the OPEX/CAPEX approach, capital expenditures (CAPEX) are included in the regulatory asset base (RAB, see definition in bullet 4 question a), thus being recovered overtime as depreciation and return on capital. While operational expenditures (OPEX) are directly recovered and not included in the RAB.

TOTEX approach: Under the TOTEX approach, an expenditure (or a portion of the expenditure) is included in the RAB whether that expenditure is OPEX or CAPEX.

2. Length of regulatory period/Investment plans frequency:

-

3. Allowed revenue baseline calculation:

a. **How the allowed revenue baseline is calculated?**
   ○

b. **How the revenue is affected by decisions deriving from the approval of business plan?**
   ○

c. **Is it possible to present business plans including flexibility mechanisms as an alternative to traditional grid upgrades?**
   Flexibility mechanisms such as flexibility markets, bilateral contracts, or connection agreements, necessary to take advantage of flexible demand, generation, and storage.
   ○

d. **How is the WACC calculated?**
   WACC: weighted average cost of capital.
   ○

e. **Additional comments**
   ○

4. **Allowed revenue ex-post calculation or adjustment. Profit sharing mechanism and cost reduction incentives. CAPEX/OPEX. RAB ex-post:**

   a. **How the RAB is updated?**
      "The regulatory asset base (RAB) is an accumulation of the value of investments that a service provider has made in its network. It includes assets of various useful lives. Most of these assets depreciate in value, although a small number (such as easements and land) do not."
      (Reference: Why do we index the regulated asset base?, Australian energy regulator, p. 1 https://www.aer.gov.au/system/files/Fact%20sheet%20-%20Indexation%20of%20the%20regulatory%20asset%20base.pdf)

      ○

   b. **How the non-capitalized costs are recovered?**
      ○

   c. **How the flexibility mechanisms costs are recovered?**
      ○

   d. **Is there a total investment limit or total expenditure limit?**
      ○

   e. **Is there any incentive to reduce investment costs (e.g. profit-sharing mechanisms)? (Please specify the penalty and reward)**
      ○

   f. **Is there a rate of return ex-post assessment? Does this assessment influence the following regulatory period?**
      ○

   g. **Additional comments**
      ○

5. **What is the asset depreciation period?**
   -

6. **Quality Incentive**

   a. **Metric**
      ○

   b. **Performance evaluation**
      ○

7. **Incentive to reduce losses**
    a. **Metric**
        ○
    b. **Performance evaluation**
        ○
8. **Innovation incentives**
    -
9. **Additional incentives**
    -
10. **Dynamic/Traditional planning (uncertainty mechanisms). Do the investment plans include the possibility of increasing/decreasing investment based on future information?**

8.2.3 Additional information

Please include any additional information related with remuneration schemes and flexibility in your country or general comments on the topic.

8.3 Questionnaire on energy communities' regulation

For each of the following questions, if there are any differences between the different entities, please, specify which are those differences. In addition, if in your country there is another kind of entity that may be considered as an energy community, please, add it together with the characteristics of that entity.

8.3.1 General questions

The purpose of this section is to have a general understanding of how energy communities are managed in your country, and whether or not there is a legal framework for this type of project.

a. **Do you currently have energy communities in your country (yes/no)?**

[Please answer here]

b. **Have the following directives of the European Union already been transposed[80] to the national legislation? Please provide the references to the relevant documents.**

	Yes / Not completely / No	Legal acts
Directive 2018/1999		
Directive 2018/2001		
Directive 2019/944		

c. **Have sandboxes for energy communities been implemented in your country? If so, may you specify where they are being done, what is the name of the program or specify the corresponding regulation, and what are the main objectives? Please provide the references to the relevant documents.**

[Please answer here]

If the regulation for Energy Communities has been developed in your country, or sandboxes are ongoing, please answer the questions in the following sections.

8.3.2 Enabling framework

This section focuses on the different measures that member states have adopted to encourage energy communities in their country.

a. **Has the government performed an analysis of the barriers that energy communities might have in your country? What were the main conclusions? Please provide the references to the relevant documents. [D2018/2001§22.6]**

[Please answer here]

b. **Is there any dedicated procedure for the creation of an energy community? Is there any public program that provides special financing or support schemes for energy communities? How do they work? Please provide the references to the relevant documents. [D2018/2001§21.2.a, 21.2.d, 21.3, 21.6, 22.1, and 22.4, and D2019/944§15.1, 15.4, 15.5.a, 15.5.c, 16.1.e, and 16.3.b]**

[80] the process of incorporating EU directives into the national laws of EU Member States.

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[Please answer here]

c. **Is there any special rule to favor the participation of low-income households in energy communities? May you explain which are those measures? Please provide the references to the relevant documents [D2018/2001§22.4.f, and D2018/2001§21.6.a].**

[Please answer here]

d. **Does your country provide capacity-building[81] support? Please provide the references to the relevant documents [D2018/2001§22.4.h].**

[Please answer here]

8.3.3 Purposes

The following questions refer to which, and how different criteria are considered in the national regulation regarding the goals of energy communities.

a. **What are the criteria used to measure whether an energy community complies with those objectives? Please, provide the references to the relevant documents. [D2018/2001§2.16.c, and D2019/944§2.11.b]**

	Criteria	Limits
Environmental		
Social		
Economic		
To the grid		
Other, please specify		

8.3.4 Legal entity

This section focuses on the type of legal form that an energy community might adopt (cooperatives, societies…) or if it can just be an agreement or contract among all the members.

[81] Process of developing, and strengthening the skills, instincts, abilities, processes, and resources that organizations, and communities need to survive, adapt, and thrive in a fast-changing world.

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a. **What are the possible legal forms of an energy community? Include any other types of legal forms that you consider necessary.**

	JARSC	REC	CEC	JAAC	CDN
Association					
Contract among members					
Cooperative					
General partnership					
Private company limited by shares (Ltd.)					
Foundation					
Public limited company (PLC)					
Physical person					
Municipalities					
Regional authorities					
National authorities					
Other, please specify					

8.3.5 Participation

The following questions refer to the specifics, in the national regulation, of who can be a member of energy communities in the national regulation:

a. **Which types of legal persons[82] can be part of an energy community? Please, indicate which of those are allowed to be a part of the energy community.**

	JARSC	REC	CEC	JAAC	CDN
Association					
Contract among members					
Cooperative					
General partnership					
Private company limited by shares (Ltd.)					
Foundation					
Public limited company (PLC)					
Physical person					
Municipalities					
Regional authorities					
National authorities					
Other, please specify					

b. **Can energy communities be the primary activity for private undertakings? If not, how does the legislation ensure that energy communities are not the primary activity for private undertakings? [D2018/2001§22.1]**

[Please answer here]

8.3.6 Membership

This section focuses on the different boundaries that indicate what members of the community might be a part of it. Those boundaries might be of many different kinds, such as distance, city…

a. **Are there any limits to the membership of the community based on the rated power of the energy generation system of each of the members? If so, may you specify which?**

[Please answer here]

b. **Do energy communities have limits in terms of total generation capacity? If so, may you specify which?**

[Please answer here]

c. **Are there any limits to the membership of the community based on geographical properties (the same municipality, the maximum distance among the members, the same property code…)? If so, may you specify which?**

[Please answer here]

d. **Are there any limits to the membership of the community based on the structure of the grid (the same distributor, the same substation…)? If so, may you specify which?**

[Please answer here]

[82] Legal entity that has rights, and obligations according to the law, as if it was a physical person.

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e. **Has your country included special provisions for cross-border participation in energy communities? Is it possible? Do the same boundaries (stated in pervious questions) apply? Are there any special rules to specify which country must authorize the energy community? Are there any particular provisions? [D2018/2001§22.6]**

[Please answer here]

f. **Is there any other boundary to participate in energy communities that has not already been considered in the survey?**

[Please answer here]

8.3.7 Techno-economic (general section)

This section focuses on the different services that might be provided by energy communities, considering both the economic, and the technical aspect, and how they are remunerated.

a. **Which activities may the energy communities provide (mark where necessary)? Are you aware of any other service they may provide (add them to the list, and write a cross)? [D2018/2001§22.2, and 21.2.a, and D2019/944§15.2, 16.2, 16.3.e, and 2.11.c]**

Activities	JARSC	REC	JAAC	CEC	CDN
Storage[83]					
Sharing of energy among its members					
Aggregation[84]					
Distribution[85]					
Supply[86] to members					
Supply to third parties					
Sale of energy efficiency[87] services					
EV charging services					
Other (please specify)					

b. **In which markets the energy communities can participate? Please, mark the markets where they can participate (those limits may be defined as minimum capital requirements[88], the kind of legal person[89] it has to be, the necessary guarantees, …). [D2018/2001§22.2.c, and D2019/944§16.3.a]**

i. **Electricity:**

Market	JARSC	REC	JAAC	CEC	CDN
Day ahead wholesale energy market					
Intraday wholesale energy market					
Frequency Control Reserve (FCR)					
Frequency Restoration Reserve (FRR)					

[83] Deferring the final use of energy to a moment later than when it was generated.
[84] Function performed by a natural or legal person who combines multiple consumer loads of generated electricity for sale, purchase, or auction in any electricity market.
[85] Transport of energy (gas, electricity, …) with a view to its delivery to customers.
[86] Sale or resale of energy, e.g. natural gas, electricity, LNG, heat…
[87] The ratio of the output of performance, service, goods, or energy, to the input of energy.
[88] Characteristics, and conditions on the own funds.
[89] Legal entity that has rights, and obligations according to the law, as if it was a physical person.

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Market	JARSC	REC	JAAC	CEC	CDN
Replacement Reserve (RR)					
Fast Frequency Response (FFR)					
Network congestion management [90]					
Voltage control [91]					
Rotor angle stability (inertia) [92]					
System adequacy [93]					
System restoration [94]					
Islanded operation					
Local energy markets					
Capacity market					
Long-term (derivatives, options…)					
Other, please indicate					

ii. Gas:

Market	JARSC	REC	JAAC	CEC	CDN
Day ahead					
Intraday					
Balancing					
Other ancillary services					
Other, please indicate					

iii. Others (please, specify):

If they are not allowed to participate in any of those markets, please, specify the reasons:

8.3.8 Techno-economic (electricity section)

This section focuses on the different techno-economic aspects of energy communities, which are too specific for the power sector.

a. **Which framework[95] does the national legislation establish for the relationships with other parties? Are there any specific rules for those frameworks? If so, please specify it in the table. [D2018/2001§21.2.a, and 22.2.a, and D2019/944§15.2.b]**

Relationship type	JARSC	REC	JAAC	CEC	CDN
Power-purchase agreements					
Peer-to-peer agreements					
Contracts with suppliers					
Other (please specify)					

[90] need occurs when the thermal limits of at least one network element are violated or expected to be violated.
[91] occurs when the voltage magnitude limits of at least one network element are violated or expected to be violated.
[92] relates to the need for damping of power system oscillations to avoid low-frequency oscillations affecting the power system stability, and efficiency.
[93] Concerns ensuring a sufficient capacity to meet system demand by looking for an equilibrium between generation, and demand.
[94] Concerns ensuring the capability to restore the power supply during main system reconnection after a blackout.
[95] A system of rules, ideas, or beliefs used to plan or decide something.

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b. For electricity, does the national legislation allow the usage of dynamic network coefficients[96]? If it is the case, is there a methodology that establishes how they are calculated?

[Please answer here]

Energy communities without grid ownership, and management responsibility:

c. Are they subject to double network charges[97] on storage of energy? If so, please, specify which are those. [D2018/2001§15.5.b, and D2019/944§21.2.b]

[Please answer here]

d. If the energy community is not the grid owner, in the European legislation, it is specified that the DSO must facilitate energy transfers among the members of the energy community. How is this assured somehow in the national legislation? [D2018/2001§, and D2018/2001§22.4.c]

[Please answer here]

Energy communities without grid ownership, and management responsibility:

e. Is there any special provision regarding the management of the grid, and the establishment of grid procedures? If so, please, specify which are those. [D2019/944§16.4]

[Please answer here]

f. In case the energy communities owns the network, is there any special provision regarding the conclusion of agreements with the DSO/TSO regarding the management of their grid? If so, please, specify which are those. [D2019/944§16.4.a]

[Please answer here]

g. Are there any special provisions in the national legislation that ensure that energy communities are going to provide non-discriminatory access to their power grid[98]? If so, may you specify how? [D2019/944§16.4.c]

[Please answer here]

h. Are there any special limits[99] on the sharing of energy among the members of the community through DSO's grid? If so, may you specify which?

[Please answer here]

8.3.9 Miscellaneous

a. Is there any salient aspect in the national regulation that has not been considered in this survey? May you develop how it is managed in your country?

[Please answer here]

[96] Variable coefficient for the distribution of the energy generated by the members of the community, that is adjusted based on the total available generation as well as, the consumption needs of the rest of the final consumers or self-consumers of the community.

[97] One for the energy withdrawn, and energy feed-in.

[98] Until now, the European regulation tried to unbundle de different business both in the electricity, and in the gas sectors. Nevertheless, now we have an entity that may have, at the same time, the grid, and generation or the supply of electricity.

[99] Those limits might be limits like the distance among the members or of other kinds.

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8.3.10 Additional information

Please include any additional information related to energy communities, and flexibility in your country or general comments on the topic.

8.4 Questionnaire on aggregators' role regulation

8.4.1 Scope, purpose, and instructions for filling

This survey is intended to gather information on the main regulatory aspects of the implementation and experiences of aggregators in different European countries.

When filling out the survey, please consider the following:

1. Be as clear and specific as possible.
2. Provide further detailed insights to clarify and/or nuanced answers.
3. Please complete the answers with references where appropriate and possible (even if the document's language is not English). **Including the section or page of the referred document if possible.**
4. In case of doubt about the questions, contact the responsible people indicated below.
5. Be complete: your answers will be used to assess the framework within your country. In case your answer is incomplete, also indicate and specify potential weaknesses.
6. To ease the interpretation of the question, examples and/or additional explanations can be added in italics.
7. Please consider both current regulations and any potential legislation change that may take place in the near future.
8. When presented with a question, feel free to add rows so that relevant information is included as much as possible.
9. For clarity reasons, please be aware that there is a list of terms defined in the glossary.

Thank you for your cooperation

Abbreviations

aFRR	Automatic Frequency Restoration Reserve
BRP	Balance Responsible Party
BSP	Balancing Service Provider
DER	Distributed Energy Resource
DSO	Distribution System Operator
FCR	Frequency Containment Reserves
FFR	Fast Frequency Reserves
FSP	Flexibility Service Provider
MDC	Meter Data Company
mFRR	Manual Frequency Restoration Reserve
MO	Market Operator
TSO	Transmission System Operator

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8.4.2 Framework of the aggregators

8.4.2.1 Relationship between the aggregator, the supplier and the BRP

Table 8.1 describes the different types of relationships between the aggregator and the BRP, depending on whether there are multiple BRPs and whether the aggregator and the supplier have a contract for the provision of flexibility between them (de Heer, y otros, 2017).

Table 8.1: Types of relationships between the aggregator and the BRP (de Heer, y otros, 2017).

	An existing contract between the aggregator and supplier	**No existing contract between the aggregator and supplier**
Single BRP	Integrated Broker	Uncorrected
Dual BRP	Contractual	Corrected Central settlement

Specifically, each of those relationships means that (de Heer, y otros, 2017):

- **Integrated**: both the aggregator and the supplier act as a single market party and there is a single BRP for both of them.
- **Broker**: the aggregator sells its flexibility to the BRP, but it is not held responsible for the imbalances generated by the resources.
- **Uncorrected**: there is no relationship between the supplier and the aggregator, and there is no special BRP for the aggregator.
- **Central settlement**: a central agent coordinates and corrects the parameters of the BRP of the supplier and the aggregator.
- **Corrected**: the aggregator has its own BRP, and the retribution of the prosumer is made through the modification of its consumption profile.
- **Contractual**: there are two BRPs, one for the aggregator and another for the supplier, and there is an ex-post correction between the BRPs.

8.4.2.2 Baseline methodologies

The baseline profile refers to the value or profile used as a reference to verify the service provision. Some of these methodologies are presented in what follows (Energy Networks Association - DNV GL Ltd., 2020), (Valentini, y otros, 2022):

- **Baseline submitted by the FSP**: the DSO uses a consumption or generation profile provided by the FSP before activation.
- **High X of Y**: the baseline profile is calculated by averaging just come of the metered data of the last days. To select those days, various criteria might be applied (use only or exclude holidays, take only the days with the highest consumption…).

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- **Meter before/Meter after**: it uses the metered value just before the activation and then, to measure the provision of the service, uses the value after.
- **Regression methods**: multiple data sources allow for calculating a baseline profile for each aggregator.
- **Rolling average**: the baseline profile is calculated by averaging the consumption metered during a certain number of days before. A window might be applied to increase the relative importance of the most recent days.

8.4.3 Questions

Please, **refer to the glossary at the end of the document if you have any doubt** about the vocabulary used in the questions.

8.4.3.1 General questions

The purpose of this section is to have a general understanding of how independent aggregators are managed in your country and whether or not there is a legal framework for this type of legal entities.

a. Do you currently have independent aggregators in your country (yes/no)? If so, when has the activity first started in your country? Could you please specify how many aggregators are now?

[Please answer here]

b. Could you please specify the national laws and regulations for aggregators in your country?

[Please answer here]

c. Is there a last resort independent aggregator[100]? Please provide the references to the relevant documents.

[Please answer here]

d. Have sandboxes[101] for aggregators been implemented in your country? If so, may you specify where they are being done, what is the name of the program or specify the corresponding regulation, and what are the main objectives? Please provide the references to the relevant documents.

[Please answer here]

e. Could you please specify how many DSO, BRP and retailers are there in your country?

[100] It refers to an aggregator that accepts any client and/or energy community which has not accepted by other aggregators.

[101] Testing environment.

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Actor	Number
DSO	
BSP	
Suppliers (retailers)	

f. What types of electricity tariffs for household consumers are available in your country?

Tariff	Yes / No
Dynamic tariffs[102]	
Time-based tariffs[103]	
Flat tariffs[104]	

8.4.3.2 Baselining, measurement, and validation

a. Are there smart metering systems[105] in your country? What is the deployment percentage? What kind of resolution do they have (hourly, 15-minutes…)?

[Please answer here]

b. Who gathers and who stores the measures? Is there a validation[106] of that measure? If so, who is in charge of that validation?

[Please answer here]

c. Who has the metering data manager[107] role? Who grants the rights to the eligible parties?

[Please answer here]

d. How is the measurement done if there is no smart meter?

[Please answer here]

[102] Tariff where the price changes hour by hour without any predefined schedule.
[103] Tariff where there is a certain number of time intervals during the day (usually 2 or 3) with fixed prices that remains. Those prices remain constant during a long period of time.
[104] Tariff where the prices remain constant during a long period of time, no matter the moment when the customer consumes the electricity.
[105] An electronic system that is capable of measuring electricity fed into the grid or electricity consumed from the grid, providing more information than a conventional meter, and that is capable of transmitting and receiving data for information, monitoring and control purposes, using a form of electronic communication.
[106] Another entity check that the measure provided by the aggregator is correct.
[107] Refer to independent meter service provider in the glossary.

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8.4.3.3 Information exchange and confidentiality

a. **Do the transmission and/or distribution grid operator implement a specific method to send demand response orders?**

[Please answer here]

b. **How is the confidentiality of the distributed energy resource ensured so that the BRP and the supplier will never know whether a consumer has a contract with an independent aggregator?**

[Please answer here]

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8.4.3.4 Market access

a. Can aggregators participate in electricity markets? If so, might you fill the table explaining the relationship with the BRP and the supplier, if the supplier and the DER must be legally compensated by the aggregator (specific formula), if the rebound effect is taken into consideration in the law and how it is done, whether the law considers submetering, whether there are specific products in the market for demand-side flexibility, how the pre-qualification of the DER is done and who installs the submetering equipment.

Market	Is participation allowed in these markets? [Y/ N]	Which are the possible relationships with the BRP and the supplier?	Remuneration scheme defined in the law for changes in the consumption of the DER caused by the aggregator [Y/N and methodology]		Is rebound [108] effect considered in the law? [Y/N and methodology]	Is baselining methodology is considered by the law? [Y/N and methodology]	Is submetering covered by the law? [Y/N and methodology]	Are there specific products for demand side flexibility in the market? [Y/N and description]	Who sends and how are the orders sent to the distributed energy resource (DER)?	Is there a pre-qualification process for the DER? [Y/N and methodology]	Who installs the submetering[109] equipment? May it be used by different aggregators?
			Supplier	Distributed energy resource							
Wholesale services (Day-ahead, intraday markets…)	☐										
Frequency control (FCR, mFRR, aFRR and RR)	☐										
TSO Constraint management (Voltage control, grid management, congestion management…)											
DSO Constraint management (Voltage control, grid management, congestion management…)	☐										
Adequacy markets (Capacity markets, strategic reserves, hedging…)	☐										
Islanded operation	☐										
Local energy markets	☐										
Other, please indicate											

[Please answer here]

[108] The rebound effect refers to the delay in consumption caused by the activation of the demand response. In other words, the usage of the demand response might have effects in other time frames.

[109] It refers to the specific metering equipment inside the house that monitors and controls certain home appliances. Those appliances are the ones being used by the aggregator.

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8.4.3.5 Barriers

a. Are you aware of any of the following barriers for independent aggregators?

i. Legal:

[Please answer here]

ii. Technical:

[Please answer here]

iii. Economic:

[Please answer here]

iv. Administrative:

[Please answer here]

8.4.3.6 Aspects not addressed in the questionnaire

a. Is there any salient aspect in the national regulation that has not been considered in this survey? May you develop how it is managed in your country?

[Please answer here]

b. Please include any additional information related to aggregators and demand flexibility in your country or general comments on the topic.

[Please answer here]

8.5 Questionnaire on the adoption of the baselining methodologies

Several methodologies exist for baseline definition (Energy Networks Association - DNV GL Ltd. 2020; Valentini et al. 2022). Some aim at estimating what would have been the user's profile had the activation not taken place. Examples are the *High X of Y* (and variations), *rolling average*, *regression* and *machine learning* models. Others are simpler counterfactuals, such as *meter before/meter after* and the *capacity limitation* (e.g. max. power allowed during the activation period). Alternatively, flexibility providers may be required to *self-declare* a baseline.

High X of Y: From an original pool of the last Z calendar days, the last Y days are selected after applying the exclusion rules (e.g. exclude weekend days if flexibility is needed on a weekday; exclude days in which flexibility was provided). The Y days are ranked according to their daily load from the highest to the lowest, then the highest X days are selected. The estimated load of the event day is the average of the load of the same hour for the X days. There are also several variations possible for this type, such as the Mid X of Y, or the Last Y days (all Y days are used).

Rolling average: The Rolling Average baseline uses historical meter data from many days (e.g. 30 past days) in a moving average fashion, but gives greater weight to the most recent days.

Baseline submitted by the Service Providers (SP): instead of calculating the baseline based on metered data, the DSO requests the SP to submit a consumption/generation profile before activation. To avoid gaming, the DSO can set mechanisms to check how representative the baseline submitted is.

Meter before/Meter after: Considered a simple baseline method, it uses the metered value instants before the activation of the flexibility and the metered data during the activation period.

Regression methods: uses past consumption data together with other relevant characteristics (e.g. type of consumer, temperature, season, day of the week) to generate a baseline function for every SP. This function is estimated by the use of regression techniques and is used to generate the baseline for every flexibility activation.

Others: other types of baseline methods might include the use of machine learning techniques, different types of products that do not require a baseline for SPs (e.g. capacity limitation products) or SP-specific baselines (e.g. a "zero baseline" for backup generators).

8.5.1 General Question

Q. 1. Methodology used to assess the system service provision delivery by service providers

How do you asses the system service provision delivery by service providers? Multiple answers allowed			
By defining a baseline for the electricity exchange	By using a product that limits the energy exchange with the grid	By using a mechanism that apply monetary penalties in case of imbalances	Other
☐ Yes	☐ Yes	☐ Yes	Please explain
Please explain here the rationale of the choice			

Q. 2. Service providers' assets measuring

How do you measure the service provision by service providers?		
By using the meter used for energy billing (main meter)	By using behind the main meter submetering	other
☐ Yes	☐ Yes	Please explain
Please explain here the rationale of the choice		

8.5.2 Questions for Baselining methodologies use

Please answer to the following questions if in Q. 1, the use of baselining methodologies has been selected

Q. 3. Baselining methodologies adoptions status

Baselining methodologies	Deployment status	Deployment approach
	☐ Developed or decided	☐ It is part of demonstration activities
	☐In development	☐ It is part of simulation activities
	☐ Not defined yet	☐ It is conceptually addressed only ☐ Not yet decided
	☐ Out of the scope	
Please explain here the rationale of the choice		

Q. 4. Baselining calculation responsibility

Who is responsible for the calculation of the baseline?						
System service	**TSO**	**DSO**	**Single SP**	**Aggregator**	**Market Operator**	**Other**
Balancing	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
TSO congestion management	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
DSO congestion management	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
TSO voltage control	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
DSO voltage control	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
other	☐ Yes	☐ Yes	☐ Yes	☐ Yes	☐ Yes	Please explain
Please explain here the rationale of the choice						

Q. 5. Baselining calculation approach for each SP entity (single of aggregated SPs): portfolio or resource level?

Which approach is used for calculating the baseline approach?			
System service	**Portfolio of resources**	**Single resource**	**Other**
Balancing	☐ Yes	☐ Yes	Please explain
TSO congestion management	☐ Yes	☐ Yes	Please explain
DSO congestion management	☐ Yes	☐ Yes	Please explain
TSO voltage control	☐ Yes	☐ Yes	Please explain
DSO voltage control	☐ Yes	☐ Yes	Please explain
other	☐ Yes	☐ Yes	Please explain
Please explain here the rationale of the choice			

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Q. 6. How are baselining methodologies demonstrated or defined?

How are baselining methodologies demonstrated or defined? Please indicate them and provide us with a description of the relevant demonstration activities.				
Baselining methodologies	**System service**	**Demonstrated?**	**How? Using which procedure?**	**Motivation and link to project goals**
High X of Y	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐Yes	[Please describe here]	[Please describe here]
Rolling average	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐ Yes	[Please describe here]	[Please describe here]
Baseline submitted by the SP	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐ Yes	[Please describe here]	[Please describe here]
Meter before/Meter after	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐ Yes	[Please describe here]	[Please describe here]
Regression methods	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐ Yes	[Please describe here]	[Please describe here]
Other, specify	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	☐ Yes	[Please describe here]	[Please describe here]
References or description of the methodology used/to be used				

Q. 7. Barriers related to the methodologies and resources characteristics of the resources

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Q. 3	Do you encounter any regulatory barriers related to the methodologies presented? Have you identified some barriers related to resources' characteristics? Can you specify data requirements and the availability for computing the baseline in your demonstrator? If so, please provide references to them.			
	Baselining methodologies	**System service**	**Regulatory & resources barriers**	**Data requirements and availability**
	High X of Y	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	Rolling average	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	Baseline submitted by the SP	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	Meter before/Meter after	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	Regression methods	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	Other, specify	☐ Balancing ☐ TSO congestion management ☐ DSO congestion management ☐ TSO voltage control ☐ DSO voltage control ☐ other	[Please describe here]	[Please describe here]
	References			

8.5.3 References

Energy Networks Association - DNV GL Ltd. 2020. 'Baseline Methodology Assessment'. https://www.energynetworks.org/industry-hub/resource-library/open-networks-2020-ws1a-p7-baselining-assessment-report.pdf.

Valentini, Ottavia, Nikoleta Andreadou, Paolo Bertoldi, Alexandre Lucas, Iolanda Saviuc, and Evangelos Kotsakis. 2022. 'Demand Response Impact Evaluation: A Review of Methods for Estimating the Customer Baseline Load'. *Energies* 15 (14): 5259. https://doi.org/10.3390/en15145259.

8.6 Survey on metering and submetering solutions

8.6.1 Background

In general, the standard electrical configuration of a consumer or generator consists of several assets connected behind a point of connection with the grid, and a main meter to record all the flows exchanged between the assets and the grid (Figure 1). These assets can be made of a consumption device, a generation, or a storage device.

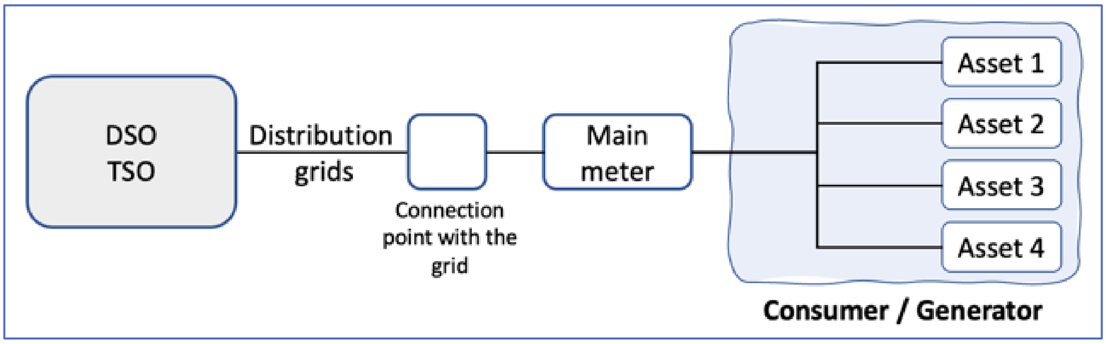

Figure 1. Consumer and generator standard configuration.

When the same consumer or generator participates in the flexibility services, an additional meter could be installed behind the main meter at the point of connection with the grid to monitor and control their flexible assets (i.e. Electric Vehicle charging point, water heater device, etc). This new device is known as submeter (Figure 2).

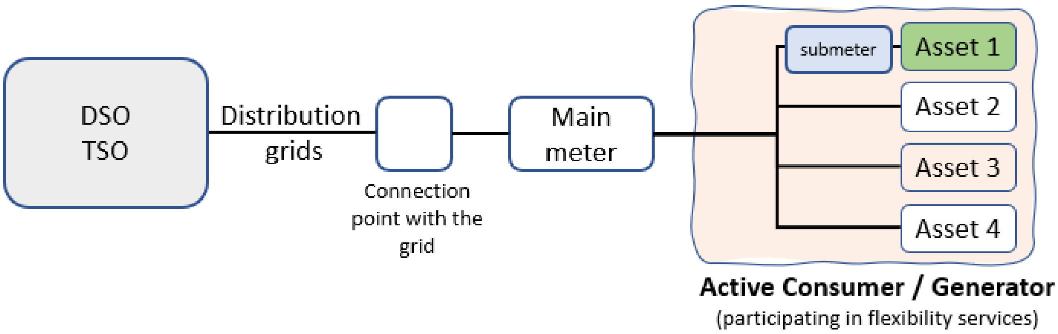

Figure 2. Consumer and generator standard configuration when provide some flexibility service

There is not a wide consensus on all the potential uses of the submetering records between all the involved stakeholders in the electricity system (TSO, DSO, aggregators, etc). On one side, some[110] defend the validity of this data for all uses, such as monitoring the assets, defining the baselines and all the settlement processes. On the opposite, others highlight

[110] https://smarten.eu/wp-content/uploads/2021/11/smartEn-DSF-NC-position-paper-FINAL.pdf

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that submeters are not explicitly regulated in the current regulation, which could constrain using the submeter records for all[111].

Recently, the Framework Guideline on Demand Response published[112] by ACER (December 2022) might be a turning point as states the following:

(19) *It is important to note that this FG considers the deployment of smart meters as a key for enabling the full potential of the participation of these resources in all electricity wholesale markets. At least where the deployment of the smart meters is delayed, the new rules shall specify the conditions for the usage of sub-meters, in order for the new rules to become effective. This does not mean that the use of sub-meters should only be restricted to the cases where smart meters have not been installed. Moreover, in order to ensure non-discriminatory access to the markets, the new rules shall specify the different models under which these resources may participate, and clarify the roles and responsibilities under each context. These general requirements, which are considered relevant for ensuring equal access of these resources to all electricity wholesale markets, are included in this Chapter.*

(33) *If the control of the provision of an SO service is based on measurement, the granularity of the meter needs to be at least equal to 15 min, which is the harmonised imbalance settlement period. The new rules shall describe the conditions for the use of sub-metering for the measurement of the provision of the service. The new rules shall define sub-meters, shall set up principles for the use of the data in order to avoid manipulation, shall include provisions i) for the respective roles, ii) for the collection of the data, iii) for the verification of the accuracy of the measurements, and iv) for the compliance with relevant standards, ensuring the coherence with the interoperability rules for access to data for demand response.*

[111] *"Roadmap on the Evolution of the Regulatory Framework for Distributed Flexibility"* (2021) https://www.edsoforsmartgrids.eu/wp-content/uploads/210722_TSO-DSO-Task-Force-on-Distributed-Flexibility_proofread-FINAL-2.pdf

[112] https://www.acer.europa.eu/news-and-events/news/acer-submitted-framework-guideline-demand-response-european-commission-first-step-towards-binding-eu-rules

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8.6.2 Scope, purpose, and instructions for filling

This survey is intended to gather inputs in your country about:

- The current implementation of smart meters
- The additional metering requirements for the providers of flexibility services
- The current implementation of submeters.
- If submeters are not already allowed, in which processes could they play a role and which technical requirements should fulfil

Please specify in the following table the perspective from which you are answering.

Role	Indicate with "X" and specify if needed
Transmission System Operator	
Distribution System Operator	X
Independent Aggregator	
Supplier	
Flexibility resource owner (specify the technology)	
Other, please specify	
Country, please specify	

When filling out the survey, please consider the following:

1. Be as clear and specific as possible.
2. Provide further detailed insights to clarify and/or nuanced answers.
3. Complete the answers with references where appropriate and possible (even if the document's language is not English).
4. In case of doubt about the questions, contact the responsible people indicated below.
5. Be complete: your answers will be used to assess the framework within your country. In case your answer is incomplete, also indicate and specify potential weaknesses.
6. To ease the interpretation of the question, examples and/or additional explanations can be added in italics.
7. Please consider both current regulations and any potential legislation change that may take place in the near future.
8. When presented with a table, feel free to add rows so that relevant information is included as much as possible.

Thank you for your cooperation.

8.6.3 Regulatory assessment

In your country, to which users the **smart meters** (understood as a meter able to record hourly or quarterly energy applies and they communicate remotely) **are mandatory**?

1. All the grid users (consumers, generators, storage, etc.) connected to the transmission and distribution network?

2. If the answer is "No" in the question 1, explain briefly:

3. Are there different requirements for consumers, generators, and storage?

4. List of the technical rules about smart meters in your country:

Requirement	**Regulation reference and link**
Accuracy	
Time granularity	
Cybersecurity	
Data protection	
Interoperability: standard communications links with customer	
Interoperability: standard communications links with external agents	
Actions to prevent the risk of manipulation	
What is the process for third-party aggregators to access smart meter	
Other relevant, please indicate	

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Please specify the **additional metering requirements for the providers of each flexibility service** compared to the non-flexibility providers.

				Balancing services					
Requirement	**Congestion management (TSO)**	**Local Congestion management (DSO)**	**Other non-frequency ancillary services, i.e. Voltage control**	**FCR**	**aFRR**	**mFRR**	**RR**	**Emergency Demand Reduction Measures**[113]	**Other services** (please, specify)
Accuracy									
Latency									
Time granularity									
Cybersecurity									
Standard communications link with customer									
Standard communications links with third parties									
Actions to prevent the risk of manipulation									
Another relevant requirement/s, specify									

Note: N/A means "No Applicable" as the service is not implemented.

[113] Council Regulation on An Emergency Intervention to Address High Energy Prices

Please specify if **submeters are already allowed for the following services and roles in your country** (Allowed/ Not allowed). In case they are allowed, please specify who is responsible for installing the submeter in each case:

Role	Congestion management (TSO)	Local Congestion management (DSO)	Other non-frequency ancillary services, i.e. Voltage control	Balancing services				Emergency Demand Reduction Measures[114]	Other services (please, specify)
				FCR	aFRR	mFRR	RR		
Prequalification									
Forecast of needs									
Bid collection									
Monitoring									
Activation									
Settlement*									
Other functions, specify									

Note: N/A means "No Applies" as the service is not implemented.

8.6.4 Submetering survey

Please specify in which processes[115] the **submeters could play a role in the future for the following services and roles** according to your role (Yes / Neutral / No):

[114] Council Regulation on An Emergency Intervention to Address High Energy Prices

[115] https://eepublicdownloads.entsoe.eu/clean-documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf

Role	Congestion management (TSO)	Local Congestion management (DSO)	Other non-frequency ancillary services, i.e. Voltage control	Balancing services				Emergency Demand Reduction Measures[116]	Other services (please, specify)
				FCR	aFRR	mFRR	RR		
Prequalification									
Forecast of needs									
Bid collection									
Monitoring									
Activation									
Settlement*									
Other functions, specify									

Note*: includes the quantification of the delivered flexibility

For the previous affirmative answers, please specify (X) **who should install the corresponding submeter**:

Agent responsible to install the submeter	Congestion management (TSO)	Local Congestion management (DSO)	Other non-frequency ancillary services, i.e. Voltage control	Balancing services				Emergency Demand Reduction Measures[117]	Other services (please, specify)
				FCR	aFRR	mFRR	RR		
TSO									
DSO									
Independent aggregator									
Meter operator (if different from TSO/DSO)									
Market operator									
Consumer									

[116] Council Regulation on An Emergency Intervention to Address High Energy Prices
[117] Council Regulation on An Emergency Intervention to Address High Energy Prices

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Manufacturer (embedded in a device)									
Others									

Please specify **which requirement should fulfill submeters to be implemented for the following services** (Yes / Neutral / No):

Submeter devices must...	**Congestion management (TSO)**	**Local Congestion management (DSO)**	**Other non-frequency ancillary services, i.e. Voltage control**	**Balancing services**				**Emergency Demand Reduction Measures**[118]	**Other services** (please, specify)
				FCR	**aFRR**	**mFRR**	**RR**		
Be the same than used for smartmeters or fulfill the same requirements									
Be certified by third parties									
Be certified by grid operators									
Be specified in a list by grid operators									
Be installed by grid operators									
Be embedded in devices, i.e. EV charging points									
Communicate through the current smartmeter data infrastructure									

Additionally, please specify **which additional requirement should fulfill submeters (compared to the current smartmeters) to be implemented for the following services** (please, specify in the text). If no additional requirement should be required, specify "No":

Compared to the current smartmeters, submeter must fulfill some additional requirements about	**Congestion management (TSO)**	**Local Congestion management (DSO)**	**Other non-frequency ancillary services, i.e. Voltage control**	**Balancing services**				**Emergency Demand Reduction Measures**[119]	**Other services** (please, specify)
				FCR	**aFRR**	**mFRR**	**RR**		

[118] Council Regulation on An Emergency Intervention to Address High Energy Prices
[119] Council Regulation on An Emergency Intervention to Address High Energy Prices

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Functionalities									
Metrology									
Interoperability									
Cybersecurity									

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8.6.5 Additional information

Please describe any experience with submetering in your country or general comments on the topic.

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8.7 Survey on Combined Mechanisms for acquiring DSO Services

This section aims to gather relevant information from the Demonstrators involved in BeFlex Project. This information will serve as the basis for developing study cases that incorporate the methodology designed for employing a combination of mechanisms to acquire DSO services.

The System Services examined have been aligned with the SO Services detailed in [120]. However, since the scope of this work is focused on distribution level, only the services described in Figure 8.1 will be considered, and they are specifically defined in the present analysis as Distribution System Operator (DSO) Services.

Congestion Management

- *Service to avoid or relieve congestion problems (physical limitations) in network components*
- *Required for mitigate high energy flows: demand or generation*
- *Predictive (pre-fault), Corrective (post-fault)*

Voltage Control

- *Service to keep tension levels in appropriate ranges in buses*
- *Required to minimize reactive power flows and reduce technical losses*
- *Predictive (pre-fault), Corrective (post-fault)*

Figure 8.1 Distribution System Operator Services

This section is divided into four stages:

- **Sub-section 4.1** aims to obtain **general information** from the **demos**.
- **Sub-section 4.2** proposes questions to obtain information on the different **mechanisms for acquiring DSO services** for this task.
- **Sub-section 4.3** involves questions related to the identified **Need Attributes** that will allow the establishment of the most relevant characteristics in the case studies.
- **Sub-section 4.4** proposes questions related to the **Evaluation Criteria**, which is used for assessing the subset of eligible combined mechanisms for acquiring DSO services in terms of their compliance with the general design principles.

8.7.1 Information from Demonstrators

1. Please fill in the box below with the requested information:

Demonstrator:	
Contact person(s):	

[120] European Union Agency for the Cooperation of Energy Regulators, 'Framework Guideline on Demand Response'. Accessed: Sep. 17, 2023. [Online]. Available: https://acer.europa.eu/Official_documents/Acts_of_the_Agency/Framework_Guidelines/Framework%20Guidelines/FG_DemandResponse.pdf

Email(s)	

If necessary, you can provide additional information:

[please answer here]

8.7.2 Mechanisms for acquiring DSO Services

2. In regards to mechanisms for acquiring DSO services, which of the following will be considered in your demo?

	Is considered?	Comments
Network Tariffs	☐	
Connection Agreements	☐	
Local Markets	☐	

If necessary, you can provide additional information:

[please answer here]

8.7.3 Network Tariffs Information

3. Assessment of the dimensions and implementation options for Network Tariffs:

Please use the table below to specify which pilots and BUCs you are assessing:

Pilots:	*None*
BUCs:	*None*

Instructions:

- In the 'Country Level' column, select options based on the current status of this mechanism in your country.
- If you intend to assess this mechanism differently in your demo, please also fill out the 'Demo Level' column.
- If there are no differences between the country and demo assessments, you only need to complete column 3.
- If a particular dimension does not apply, you may leave it blank.

Dimension	**Description**	**Please answers here** **Options** **(Country Level)**	**Please answers here** **Options** **(Demo Level)**
Cost Allocation methods	It represents how recognized costs must be recovered and assigned to customers. One option divides cost based on forecasted demand (Average Costs), while the other (Long-term Incremental + Residual Costs) considers past and future costs, encouraging customer cost reduction.	☐ Average Costs ☐ Long-term incremental + Residual Costs	☐ Average Costs ☐ Long-term incremental + Residual Costs

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Charging variable	It can be a fixed value assigned per customer (Fixed charge), allocated as a power-based (kW) charge (Capacity charge), or set based on energy (kWh) consumption (Energy charge). For the Capacity charge, there are three possibilities: based on the maximum peak demand (Used Capacity (measured)), and is determined ex-post; or according to a predetermined value in the connection contract (Capacity (contracted)); or dependent on the installation physical availability (Capacity (physical)).	☐ Fixed ☐ Used Capacity (measured) ☐ Capacity (contracted) ☐ Capacity (physical) ☐ Energy	☐ Fixed ☐ Used Capacity (measured) ☐ Capacity (contracted) ☐ Capacity (physical) ☐ Energy
Locational granularity	It can be understood as how a location is partitioned for allocating the network charges. It can be applied uniformly across an entire country (System-wide); or can be distinguished by differentiated areas (Zonal); or based on connection points (Nodal).	☐ System-wide ☐ Zonal *(specify how is the zone delimited):* ________________ ☐ Nodal, *(specify how is the node defined):* _________________	☐ System-wide ☐ Zonal *(specify how is the zone delimited):* ________________ ☐ Nodal, *(specify how is the node defined):* _________________
Temporal granularity of charges	It can be understood as how time is partitioned for allocating network charges, resulting from generation and demand profile changes and their impact on the network. It can be uniform throughout the year (Yearly); vary between seasons in the year considering specific months (Seasonal (monthly)); or it can be divided into time blocks (Blocks (hourly)), such as hours within a day or across seasons, etc; or it can be ranged by hours (Hourly).	☐ Yearly ☐ Seasonal (Monthly) ☐ Time-Blocks (Daily) ☐ Hourly	☐ Yearly ☐ Seasonal (Monthly) ☐ Time-Blocks (Daily) ☐ Hourly
Price setting periodicity	It measures how close to delivery time network charges are re-calculated. The closer this is, better network charges will reflect the current grid state and the congestion risks, but it diminishes predictability from customers (network problems could arise because the signals sent are poorly handled). This periodicity can be set once a year (Year ahead (static)); or based on the forecast network usage for the next day (Day(s) ahead (dynamic)); or after network usage has occurred (Ex-post).	☐ Year ahead (static) ☐ Day(s) ahead (dynamic) ☐ Ex-post	☐ Year ahead (static) ☐ Day(s) ahead (dynamic) ☐ Ex-post
Temporal granularity of measurements	It pertains how time is subdivided for capturing data using suitable equipment like smart metering. Less level of granularity provides highly detailed data, allowing for precise tracking of energy usage and generation. It's crucial to ensure that the Temporal Granularity of Measurements is equal to or shorter than the Temporal Granularity of Charges.	☐ Yearly ☐ Monthly ☐ Blocks (Daily) ☐ Hourly ☐ Quarter hourly	☐ Yearly ☐ Monthly ☐ Blocks (Daily) ☐ Hourly ☐ Quarter hourly
Customer differentiation	It refers to the possibility of tailoring network tariffs based on specific technologies or equipment that customers may utilize (specific tariffs according to technologies (Generation, Storage, EVs, etc.)). Alternatively, customer differentiation could be based	☐ By Voltage levels or network areas (Technology agnostic) ☐ Specific tariffs according to	☐ By Voltage levels or network areas (Technology agnostic) ☐ Specific tariffs according to

	on voltage levels or specific grid areas (By Voltage levels or network areas (Technology agnostic)).	technologies (Generation, Storage, EVs., etc.)	technologies (Generation, Storage, EVs., etc.)
Symmetry of charges (Energy o capacity components)	It states if network charges can be symmetric for energy withdrawals and injections, i.e., the same charge but with the opposite sign (Same network and injection charges), or energy withdrawals and injections can have different network charges (Different network and injection charges).	☐ Same offtake and injection charges ☐ Different offtake and injection charges	☐ Same offtake and injection charges ☐ Different offtake and injection charges

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8.7.4 Connection Agreements Information

4. Assessment of the dimensions and implementation options of Connection Agreements:

Please use the table below to specify which pilots and BUCs for are assessing:

Pilots:	*None*
BUCs:	*None*

Instructions:

- In the 'Country Level' column, select options based on the current status of this mechanism in your country.
- If you intend to assess this mechanism differently in your demo, please also fill out the 'Demo Level' column.
- If there are no differences between the country and demo assessments, you only need to complete column 3.
- If a particular dimension does not apply, you may leave it blank.

Dimension	**Description**	**Please answers here** **Options** **(Country Level)**	**Please answers here** **Options** **(Demo Level)**
Connection costs	It can be defined as the amount of cost that should be recovered, and it is assigned to new customers or those who want to increase their current capacity. They will be determined by whether new customers can connect without added charges (Shallow connection cost), or whether network reinforcement is required for accommodating the increment due to the upgraded capacity (Deep connection costs).	☐ Deep connection costs ☐ Shallow connection costs	☐ Deep connection costs ☐ Shallow connection costs
Benefit of the DSO allowing flexible connection	Non-firm grid access allows DSOs to avoid network expansion when is not possible or unfeasible (Avoid reinforcement). Alternatively, network upgrades can be deferred (Defer reinforcement), when this solution is more economic than network expansion, for example until sufficient customers are connected to share the associated cost. Also, interruptible connections can serve as a means for connection-seekers to connect to the grid already while reinforcement is being carried out due to the long-time frames required for committed grid expansions (Preliminary connection).	☐ Avoid reinforcement (Network expansion is not possible) ☐ Defer reinforcement (More economic than network expansion) ☐ Preliminary connection (Network expansion is committed in a future year)	☐ Avoid reinforcement (Network expansion is not possible) ☐ Defer reinforcement (More economic than network expansion) ☐ Preliminary connection (Network expansion is committed in a future year)
Network connection criteria	It encompasses the grid requirements that determine the access to non-firm connections. The grid's capacity (Capacity limitation) might be restricted during specific timeframe. Another criterion depends whether the network access can be limited according tension magnitude (Voltage level limitation). Also, Utilities typically plan network expansion according to specific measures, such as N or N-1 criteria (Security criteria), which can impact access to firm capacity. Additionally, it's possible that the available capacity or voltage level meets requirements, but the short-circuit power rating may not be met (Short-circuit power rate).	☐ Capacity limitation ☐ Voltage level limitation ☐ Other security criteria (N, N-1) ☐ Short-circuit power rate	☐ Capacity limitation ☐ Voltage level limitation ☐ Other security criteria (N, N-1) ☐ Short-circuit power rate

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Activation of the energy curtailment due to flexible connection	It is not limited to specific events, and it can occur for various reasons. While the operation of electricity grids already includes that customer might be disconnected due to outages (Emergency), flexible connections allow to expand the employment of injection/withdrawal reductions such as in the case of network maintenance (Maintenance). Congestion-based reduction of grid access capacity can be triggered for meteorological reasons (e.g., high wind speeds in a network area with high participation of wind capacity) or due to variations in electricity demand (Congestion).	☐ Emergency (Grid failure risk) ☐ Maintenance ☐ Congestion	☐ Emergency (Grid failure risk) ☐ Maintenance ☐ Congestion
Pre-definition of curtailment	It identifies the potential hours of curtailment and can be indicated in the connection contract if the occurrence of congestions can be forecasted. If congestions occur due to demand variations, flexible hosting capacity might be assigned as peak/off-peak capacity (peak/off-peak). The flexible connection could be bound to seasonality of resource availability that can be for days or time periods (Seasonality).	☐ Peak/off-peak ☐ Seasonality (Days or periods)	☐ Peak/off-peak ☐ Seasonality (Days or periods)
Principle of access	It considers the methodology to assign the curtailment when several customers are eligible. All customers connected can be curtailed equally (Pro-rata), the same percentage [%] of available energy or the same amount of capacity. Also, Last non-firm customer to connect is the first to be curtailed (Last-on-first-out (LIFO)). Once this customer is curtailed entirely (or at the maximum curtailable capacity), the second last is curtailed. Alternatively, curtailment is assigned according to an auction scheme (Auction). The auction might be integrated in the process of assigning hosting capacity. Finally, when the customer with the highest participation in triggering congestion is curtailed first (Level of congestions created).	☐ Pro-rata ☐ Last Input First Output (LIFO) ☐ Auction ☐ Curtailment proportional to level of congestion created	☐ Pro-rata ☐ Last Input First Output (LIFO) ☐ Auction ☐ Curtailment proportional to level of congestion created
Compensation payments for energy curtailment	If the magnitude of compensation payment can be arranged as a flat price in the connection agreement (Fixed). Furthermore, if curtailable connections participate in Local Market (LM) as a price taker, the compensation payment is deduced from the LM price (Set by the Local Market (LM)). Also, both SO and customers are expected to prefer a variable payment amount to account for future changes of SPOT and flexibility prices (Local Market-indexed). If the customer does not participate in the LM, a coupling of the compensation value to LM prices could represent an interesting solution. In certain regions, access to flexible connections may be granted with the requirement of curtailment, if necessary, without an assigned payment (None).	☐ Fixed ☐ Set by the Local Flexibility Market where the flexible connection is participating as price taker ☐ Local Market-indexed where the flexible connection is bidding a free price ☐ None	☐ Fixed ☐ Set by the Local Flexibility Market where the flexible connection is participating as price taker ☐ Local Market-indexed where the flexible connection is bidding a free price ☐ None
Possibility to resell the expected curtailed energy	For upstream congestions, customers could be able to sell their electricity to others in the same feeder. If a congestion occurs at a transformer station connecting a distribution feeder to the wider network, customers might still trade electricity downstream of the congestion. This could be enabled via the introduction of LM (Local Markets). Another approach is allowing	☐ Bilateral Contracts ☐ Local Markets	☐ Bilateral Contracts ☐ Local Markets

	participating in negotiation process (Bilateral Contracts). Electricity could be sold downstream of the congestion at a lower price to incentive the attractiveness of this option and allow both generators and demand to benefit.		
Maximum curtailment	It offers customer certainty through various options. Setting a maximum duration (Duration (hours)) for curtailment in hours per year, aiding grid planning but exposing customers to financial risk. Imposing a maximum capacity curtailed (Capacity Limitation) either full disconnection or partial with a minimum agreed capacity, ensuring firm grid capacity. Limiting maximum energy curtailed (energy) annually (MWh or % of available energy), accounting for demand and RES variations. Introducing a maximum economic (Monetary limitation) value of curtailed energy (€ or % of potential earnings), but it may be challenging for SOs to implement independently of SPOT prices during congestion hours.	☐ Duration (hours) ☐ Capacity limitation ☐ Energy limitation ☐ Monetary limitation	☐ Duration (hours) ☐ Capacity limitation ☐ Energy limitation ☐ Monetary limitation
Duration of flexible connection	Implementing an end-date, as a Duration of connection, helps to introduce certainty to customers. In the case non-firm access is offered while reinforcement (Temporary) is being carried out, the connection then automatically converts into a firm connection when the network upgrade is finished. With flexible connections as a means to defer reinforcement, the flexible connection can be turned into a firm one once reinforcement of the grid is triggered. It may also be the case that the flexible connection arrangement is maintained in the long term (Permanent). However, if sufficient customers connect under a non-firm scheme and agree to share the reinforcement expenses.	☐ Temporary ☐ Permanent	☐ Temporary ☐ Permanent
Curtailment notification	It indicates how much advance notice customers receive regarding the curtailment. The information of customers about the realisation of curtailment is an important aspect of transparency of network operation. The timing of the communication of required reinforcement might take place coupled to markets or ex-post. The notifications can occur in several timeframes depending of the network requirements: one day before (Day-ahead), hours before on the same day (intra-day), or close to real-time (real-time), such as in time intervals less than a fraction of an hour. Real-time decisions on curtailment are likely to require LM to decide on which user to curtail. In some cases, notifications may also be made after the outage due to immediate response to unforeseen events (ex-post).	☐ Day-ahead ☐ Intra-day ☐ Real-time ☐ Ex-post	☐ Day-ahead ☐ Intra-day ☐ Real-time ☐ Ex-post
Eligible customers	It refers that depending on the state of network congestions, flexible connections might be offered to customers of different technologies. It can cover generation, considering hybrid facilities (Generation), consumption (demand) including active customers. Also, storage systems (Storage), that operates as stand-alone.	☐ Generation (Including hybrid installations) ☐ Demand (Including active customers)	☐ Generation (Including hybrid installations) ☐ Demand (Including active customers)

		☐ Storage (Stand-alone)	☐ Storage (Stand-alone)

8.7.5 Market Information

5. Assessment of the dimensions and implementation options for local markets: :

Please use the table below to specify which pilots and BUCs you are assessing:

Pilots:	
BUCs:	
Role:	☐ Distribution System Operator ☐ Transmission System Operator ☐ Other. Specify: ___________________________________

If a particular dimension does not apply, you may leave it blank.

Dimension	**Description**	**Please answers here** **Options**
Flexibility need Grid level	It relates to the specific voltage level on the electricity grid where local flexibility services are required. The most suitable solutions are those in which flexible resources are electrically located as close as possible to the congested component, prioritizing those with a greater impact from both technical and economic perspectives. Therefore, in generation and transmission (High Voltage), there is a demand for flexibility services to manage high power flows. Also, flexibility needs could be associated with sub-transmission or distribution substation levels (Medium Voltage), where flexibility services may be required for network congestion or to maintain voltage and frequency. Likewise, flexibility services can also be necessary for distribution networks serving end-users (Low Voltage), where it's necessary to manage demand variations and distributed energy resources.	☐ High Voltage ☐ Medium Voltage ☐ Low Voltage

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Negotiation time frame (Gate Opening and Closure for participation)	It refers to the specific time horizon during which bids for the provision of system services are developed. Market participants can plan and submit their flexibility offers during this window. At the gate opening the requirement objectives are released to service providers. The gate closure marks the end of the negotiation period, where the clearing process is conducted to match flexibility needs with resource offers that satisfy all technical constraints. It can occur over an extended period, typically weeks to years in advance (Long-term), depending on when the services will be required. Alternatively, it can occur on a much shorter time scale, as real-time, intraday, and day-ahead markets (Short-term), primarily for addressing immediate grid operational requirements.	☐ Long-term (Weeks-ahead to years-ahead) ☐ Shot-term (Real-time, intraday, day-ahead)
Contract length	It defines the duration for which a service contract is established with a commitment from the flexible resources to remain available. The choice of the contract duration depends on the specific requirements of the network and the capabilities of the service providers, addressing both long-term and short-term objectives. This period can be of one year (Yearly), occur on a monthly basis (Monthly), seven-day periods (Weekly), cover a single day (Daily), or even real-time availability with short-term notice (Hourly).	☐ Yearly ☐ Monthly ☐ Weekly ☐ Daily ☐ Hourly
Temporal bid granularity	It corresponds to the temporal resolution, or the smallest time interval, at which flexibility needs change, and service providers must be capable of responding uninterruptedly. Market participants can make bidding decisions based on the granularity set by system operators to meet network requirements, and considering the characteristics of available resources. It can vary from greater than hour (>1 hour) providing bids in hourly or longer time-blocks, one-hour intervals (1 hour), 30-minutes intervals (30 min), or 15-minutes intervals (15 min). These options enable participants to address a wide range of scenarios, allowing them to tailor their bidding strategies to meet specific needs and network conditions.	☐ > 1 hour ☐ 1 hour ☐ 30 min ☐ 15 min
Response Time (Activation)	It encompasses the specific temporal interval during which a flexible resource is required to reach its operational level from the moment it receives a trigger signal. In general, it corresponds to the time required for a ramping operation after an activation command, whether it involves an increase (ramp-up) or a decrease (ramp-down) in power or energy. Resources can be categorized based on their activation speed, including those with slower responses exceeding one hour (> 1 hour), those with moderate responses ranging from 30 minutes to one hour (30 min – 1 hour), those responding within 15 to 30 minutes (15 min – 30 min), and those with nearly instantaneous responses (<15 min). The latter category of resources is exceptionally well-suited for addressing rapid changes in supply and demand.	☐ > 1 hour ☐ 30 min – 1 hour ☐ 15 min – 30 min ☐ < 15 min
Transactional Object	It refers to the commodity that can be involved in transaction associated with the provision of system services through the use of flexible resources. The object can represent a commitment of the resources to be available to provide its flexibility for a predetermined duration in the form of standby capacity (Capacity (Availability)). This implementation option emphasizes the object's capability to remain in reserve and be prepared for deployment when required. Likewise, this commodity can encompass the active utilization of flexible resources to respond in real-time (Energy (Activation)), comprising the injection or absorption of energy to address fluctuations in demand or generation while mitigating network congestion.	☐ Capacity (Availability) ☐ Energy (Activation)

Power	It corresponds to the specific type of power required to address network problems according to the component congested. Typically, when congestion issues arise in power lines or transformers, active power (Active Power) is required. This is because it directly influences the ability to meet the real-time demand of consumers and serves as the primary focus of power generation. Additionally, concerning issues in buses, such as overvoltage or undervoltage, reactive power (Reactive Power) may be required as it helps manage voltage fluctuations and supports the operation of reactive elements connected to the grid. Recent EU projects such as EUniversal and Coordinet are exploring the utilization of both active and reactive powers for congestion management and voltage control applications.	☐ Active Power ☐ Reactive Power
Direction	It distinguishes the orientation in which the flexible resources are required. When additional power is needed, it can be provided by increasing generation or reducing consumption (Upwards). Upward flexibility primarily depends on the system's ramping capability. Conversely, when a reduction of excess power in the network is necessary, it can be achieved by decreasing generation or increasing consumption (downwards). Downward flexibility is closely related to the system's ability to reduce the output of conventional units and is a major contributor to wind and solar curtailment.	☐ Upwards ☐ Downwards
Symmetry Requirements (For upwards and downwards)	It addresses the need for uniformity in products and services. Symmetric (Symmetric products) are characterized by a high degree of balance, offering solutions that equally apply to both upward and downward flexibility needs. In contrast, Asymmetric (Asymmetric products) are tailored to address specific requirements that may differ between upward and downward scenarios.	☐ Symmetric products ☐ Asymmetric products
Source (Flexibility assets)	It corresponds to the specific flexibility assets employed to deliver the system services. This can encompass a range of assets, including power generation sources (Generation (Including hybrid installations)), such as renewable energy installations and hybrid power plants, capable of adjusting their output to meet grid requirements. Additionally, it can involve the utilization of demand-side management techniques and active customer participation (Demand (Including active customers)), allowing customers to adapt their electricity patterns to provide grid flexibility. Furthermore, it can consider stand-alone energy storage systems (Storage (stand-alone)) such as batteries, which can store excess energy during periods of surplus and release it when needed.	☐ Generation (Including hybrid installations) ☐ Demand (Including active customers) ☐ Storage (Stand-alone)

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8.7.6 General Need Attributes assessment

6. The table below presents definitions for the identified need attributes in this task and requests feedback in the last three columns. Please check that all rows have been evaluated.

Need Attributes	Description	Sub-categories	Please answers here In cases b) and c) please provide an explanation and alternatives if applicable	Please answers here If Sub-categories are not appropriate, please suggest new Sub-categories	Please answers here What specific subcategories should be evaluated in your demo?
Voltage level of the need	Nominal voltage at the point where the service is required.	**4. High** **5. Medium** **6. Low**	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate		☐ 1.- High ☐ 2.- Medium ☐ 3.- Low
Frequency of the need	Number of times that the service is required within a predefined time interval.	5. **Very High** (daily) 6. **High** (once or more per week) 7. **Medium** (less than once per week) 8. **Low** (less than once per month)	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate	Very High: ______________ High: ______________ Medium: _____________ Low:	☐ 1.- Very High ☐ 2.- High ☐ 3.- Medium ☐ 4.- Low

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				______________	
Volume of the need	Amount of active/reactive power required for providing a service. This characteristic is case specific; therefore, it is better to express in relative terms.	4. **High** (more than 80% of the maximum total capacity of the SPs) 5. **Medium** (around 20% to 80%) 6. **Low** (Less than 20% of the maximum total capacity of the SPs)	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate	High: ______________ Medium: ______________ Low: ______________	☐ 1.- High ☐ 2.- Medium ☐ 3.- Low
Network Type	Network Topology. A higher degree of interconnection has the potential to more effectively meet the system's needs.	**3. Radial** **4. Meshed**	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate		☐ 1.- Radial ☐ 2.- Meshed
SP size	Specific size of potential services providers.	**3. Large/Aggregation of smalls** (equal or more than 10 MVA) **4. Small/ No Aggregation** (less than 10 MVA)	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories	Large/ Aggregation of smalls: ______________	☐ 1.-Large/ Aggregation of smalls

			☐ **c)** not appropriate	Small/ No Aggregation:	☐ 2.- Small/ No Aggregation
SP nominal voltage	Nominal Voltage of the network to which SPs are connected	**4. High** **5. Medium** **6. Low**	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate		☐ 1.- High ☐ 2.- Medium ☐ 3.- Low
SP Type	Classification of resources for providing services, based on their characteristics.	**4. Generation** **5. Demand** **6. Storage**	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate		☐ 1.- Generation ☐ 2.- Demand ☐ 3.- Storage
Volume of the service provided/ Volume of the need	It quantifies the relationship between the quantity of services supplied and the level of demand, as a measure of competition and liquidity	**4. High** **5. Medium** **6. Low**	☐ **a)** appropriate need attribute and Sub-categories ☐ **b)** appropriate need attribute but not the Sub-categories ☐ **c)** not appropriate		☐ 1.- High ☐ 2.- Medium ☐ 3.- Low
Other:					

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Other:					
Other:					

If necessary, you can provide additional information regarding the evaluation made:

Voltage level of the need	
Frequency of the need	
Volume of the need	
Network Type	
SP size	
SP nominal voltage	
SP Type	
Volume of the service provided/ Volume of the need	
Other: ______________________	
Other: ______________________	

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7. In regards to Congestion Management, which of the following need attribute is most important to you?
Please rank the following attributes considering their relevance for describing the congestion management problem, focusing on addressing it through the combined acquisition mechanisms for system services.

(Rank from 1-10 with 1 being the most important and 10 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5	6	7	8	9	10
Voltage level of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Frequency of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Volume of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Network Type	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP size	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP nominal voltage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP Type	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Volume of the service provided/ Volume of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8. In regards to Voltage Control, which of the following need attribute is most important to you?
Please rank the following attributes considering their relevance for describing the voltage control problem, focusing on addressing it through the combined acquisition mechanisms for system services.

(Rank from 1-10 with 1 being the most important and 10 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5	6	7	8	9	10
Voltage level of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Frequency of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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Volume of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Network Type	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP size	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP nominal voltage	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SP Type	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Volume of the service provided/ Volume of the need	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

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8.7.7 General evaluation criteria assessment

8.7.7.1 Economic Efficiency criteria assessment

It aims to maximize social welfare by ensuring services are utilized by those who benefit most, minimizing both short-term and long-term system costs. Some sub-criteria have been identified:

- *Cost-reflectivity: It measures if the chosen solution accurately reflects the associated costs, considering time, location, and quality of the system services provided.*
- *Predictability: Efficient solutions are achieved from a degree of knowledge of the relevant factors, effectively diminishing the impact of uncertainty.*
- *Technology neutrality: It guarantees the reduction of technical barriers to providing a system service.*
- *Low entry barriers: It allows for a high level of competition, which means greater efficiency, innovation, and choice of available solutions.*
- *Low exercise of market power: It prevents specific service providers from dominating all offerings by fostering competition.*

9. In regards to Economic Efficiency, which of the following evaluation criteria are most important to you?
(Rank from 1-7 with 1 being the most important and 7 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5	6	7
Cost-reflectivity	☐	☐	☐	☐	☐	☐	☐
Predictability	☐	☐	☐	☐	☐	☐	☐
Technology neutrality	☐	☐	☐	☐	☐	☐	☐
Low entry barriers	☐	☐	☐	☐	☐	☐	☐
Low exercise of market power	☐	☐	☐	☐	☐	☐	☐
Other: ______________________	☐	☐	☐	☐	☐	☐	☐
Other: ______________________	☐	☐	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8.7.7.2 Equity criteria assessment

It aims to guarantee that all stakeholders pay or earn a fair share based on their network usage. Some sub-criteria have been identified:

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- *Allocative equity: Customers with similar locations and patterns are charged/paid equally. It can be assumed cost-reflective and increase efficiency.*
- *Distributional equity: It evaluates if the customer's burden is aligned with their economic capability.*
- *Transitional equity: It supports the gradual shift from old to new structures.*

10. In regards to Equity, which of the following evaluation criteria are most important to you?
(Rank from 1-5 with 1 being the most important and 5 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5
Allocative equity	☐	☐	☐	☐	☐
Distributional equity	☐	☐	☐	☐	☐
Transitional equity	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8.7.7.3 Implementability criteria assessment

It points to the feasibility of implementing the solutions. Some sub-criteria have been identified:

- *Minimize implementation Costs: It measures that all the costs for deploying the solutions are as economically efficient as possible.*
- *Effectiveness: It measures the capability of the solution for providing a service while avoiding potential under/over procurement*
- *Complexity: It measures how straightforward the capability of the implementation solution is.*

11. In regards to Implementability, which of the following evaluation criteria are most important to you?
(Rank from 1-5 with 1 being the most important and 5 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5
Minimize implementation Costs	☐	☐	☐	☐	☐
Effectiveness	☐	☐	☐	☐	☐
Minimize implementation complexity	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐
Other: ___________________________	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8.7.7.4 Transparency and simplicity criteria assessment

Solutions should be understandable by all stakeholders to encourage their participation. Some sub-criteria have been identified:

- *Transparency in design methodology: It measures the level of transparency considering the process design.*
- *Provision of comprehensive grid data: To be able to access the complete grid description to accurately measure its dynamics and impact of service providers.*
- *Provision of partial grid data: By using sensitivities of flexibilities towards critical V/I constraints and V/I margin in the grid.*
- *Simplicity: The solution has been designed to be easy comprehend and use, reducing unnecessary considerations.*

12. In regards to Transparency and simplicity, which of the following evaluation criteria are most important to you?

(Rank from 1-5 with 1 being the most important and 5 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5
Transparency in design methodology	☐	☐	☐	☐	☐
Provision of comprehensive grid data	☐	☐	☐	☐	☐
Provision of partial grid data (Sensitivities)	☐	☐	☐	☐	☐

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Simplicity	☐	☐	☐	☐	☐
________________________________	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8.7.7.5 Additional criteria assessment

If you added any additional criteria to the 4 initially considered (Economic efficiency, Transparency and simplicity, Equity, and Implementability) do you think an additional disaggregation is needed?

(Rank from 1-5 with 1 being the most important and 5 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

New criteria: ____________________________

Disaggregation proposed	1	2	3	4	5
________________________________	☐	☐	☐	☐	☐
________________________________	☐	☐	☐	☐	☐
________________________________	☐	☐	☐	☐	☐

New criteria: ____________________________

Disaggregation proposed	1	2	3	4	5
________________________________	☐	☐	☐	☐	☐
________________________________	☐	☐	☐	☐	☐
________________________________	☐	☐	☐	☐	☐

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8.7.7.6 Evaluation criteria assessment

13. Which of the following evaluation criteria for acquisition mechanisms are most important to you?

(Rank from 1-6 with 1 being the most important and 6 being the least important. Choose a single box for each item. Different items cannot have the same rank position. You can propose additional item in the lines below).

	1	2	3	4	5	6
Economic efficiency	☐	☐	☐	☐	☐	☐
Transparency and simplicity	☐	☐	☐	☐	☐	☐
Equity	☐	☐	☐	☐	☐	☐
Implementability	☐	☐	☐	☐	☐	☐
Other: ______________________________	☐	☐	☐	☐	☐	☐
Other: ______________________________	☐	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

8.7.7.7 Additional information

Please include any additional information related to combination of mechanisms for acquiring DSO services in your country or general comments on the topic.

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8.8 Survey on Combined Mechanisms for acquiring DSO Services – Customer's engagement

The questions below are proposed to identify those aspects, from the consumer's perspective, that encourage active participation in programs for the provision of flexibility in electrical networks.

It's important to clarify that even though there are matters concerning incentives discussed, this survey is purely informative. It does not imply any form of economic compensation.

Customer engagement criteria assessment

Customer engagement can have a significant impact on how mechanisms for acquiring flexibility services, individually or in combination, are designed and adapted to increase the performance of electrical networks.

The primary objective is to encourage and keep the active participation of customers.

Some Criteria have been identified:

1. Benefits for active participation
2. Integration of diverse customer segments
3. Customer easiness of participation
4. Installation of assets
5. Reduction of controllability

Some definitions are provided to understand the context of the questions. Similarly, a set of questions is presented. Please read the instructions provided and fill in as much information as possible.

1. ***Benefits for active participation:*** It allows to measure the effectiveness for incorporating signals in terms of tangible benefits or financial incentives for customer participation:
   Sub-criteria:
   - Monetary rewards
   - Energy cost reduction
   - Avoid penalties

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In regards to Benefits for active participation, how relevant are the sub-criteria?

Please answers here

Sub-criteria	Description	How relevant is for you?
Monetary rewards	You can receive specific payments for the service provision	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Energy cost reduction	You can reduce costs in the electrical bills for changing your behaviour of appliance usage	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Avoid penalties	You can prevent network infractions that could results in penalties	☐ highly relevant ☐ somewhat relevant ☐ not relevant

how would you rank them in terms of importance?

Note: Rank from 1-3, with 1 being the most important and 3 being the least important. Choose a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

Most important → Least important

	1	2	3
Monetary rewards	☐	☐	☐
Energy cost reduction	☐	☐	☐
Avoid penalties	☐	☐	☐

2. ***Integration of diverse customer segments:*** It refers to the process of effectively bringing together and coordinating several groups or categories of customers:
   Sub-criteria:
   - Customer's type
   - Technology agnostic
   - Equity in participation
   - Social inclusion
   - Environmental inclusion

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In regards to Integration of diverse customer segments, how relevant are the sub criteria?

Please answers here

Sub-criteria	Description	How relevant is for you?
Customer's type	Develop strategies to address the specific requirements of different customer types (residential, commercial, and industrial), for increase competition and potentially reducing costs.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Technology agnostic	Benefits should not be linked to a particular technology. For example, storage or electrical vehicles should not receive preferential treatment.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Equity in participation	Small customers and businesses should have equal opportunities to participate.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Social inclusion	Promote for the participation of disadvantaged communities.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Environmental inclusion	Promote the adoption of clean technologies.	☐ highly relevant ☐ somewhat relevant ☐ not relevant

how would you rank them in terms of importance?

Note: Rank from 1- 5, with 1 being the most important and 5 being the least important. Choose a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

Most important → Least important

	1	2	3	4	5
Customer's type	☐	☐	☐	☐	☐
Technology agnostic	☐	☐	☐	☐	☐
Equity in participation	☐	☐	☐	☐	☐
Social inclusion	☐	☐	☐	☐	☐
Environmental inclusion	☐	☐	☐	☐	☐

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3. ***Customer easiness of participation****:* It refers to how easily customers can engage with flexibility services provision.
Sub-criteria:
   - Simplicity
   - Accessibility and transparency of information
   - Customer education and training

- **In regards to Customer easiness of participation, how relevant are the sub criteria?**

Please answers here

Sub-criteria	**Description**	**How relevant is for you?**
Simplicity	Being able to participate in the different options for flexibility provision should be as understandable as possible.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Accessibility and transparency of information	The information is easily accessible, regardless of their background or abilities, and that it states all the process clearly.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Customer education and training	The processes of providing customers with information, knowledge, and skills necessary to understand, use, and maximize the benefits of the service provided. It can include about technical topics like activation frequency, notice time, available activation methods, etc.	☐ highly relevant ☐ somewhat relevant ☐ not relevant

how would you rank them in terms of importance?
Note: Rank from 1-3, with 1 being the most important and 3 being the least important. Choose a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

	Most important 1	→ 2	Least important 3
Simplicity	☐	☐	☐
Accessibility and transparency of information	☐	☐	☐
Customer education and training	☐	☐	☐

4. ***Installation of Assets:*** It involves providing customers with the means to have more control over their energy patterns in order to make informed decisions, utilizing tools like smart devices, automatization, multidevice app, etc
Sub-criteria:
   - Customers buy the devices required
   - Customers rent the devices required

- Devices are installed by third parties

In regards to Installation Assets, how relevant are the sub criteria?

Please answers here

Sub-criteria	**Description**	**How relevant is for you?**
Customers buy the devices required	Customers are responsible for acquiring the equipment and their maintenance, but receive the total benefits for the provision of services	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Customers rent the devices required	Customers must pay a fee for the installation of the equipment and their maintenance, but receive the total value of the service provided. Customer have the freedom to end the contract without additional payments	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Devices are installed by third parties	The equipment and maintenance are commissioned by third parties, but the service provision contract is discounted. The contract is long term, until the device cost is recovered.	☐ highly relevant ☐ somewhat relevant ☐ not relevant

how would you rank them in terms of importance?

Note: Rank from 1-3, with 1 being the most important and 3 being the least important. Choose a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

	Most important 1	→ 2	Least important 3
Customers buy the devices required	☐	☐	☐
Customers rent the devices required	☐	☐	☐
Devices are installed by third parties	☐	☐	☐

5. ***Reduction of controllability:*** It allows to measure to what extent customers are willing to reduce their controllability due to the provision of a service.
   Sub-criteria:
   - Customers have total control
   - Customers have control over some appliances
   - Customers have control over some time-periods
   - Notification and alerts

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In regards to Reduction of Comfort, how relevant are the sub criteria?

Please answers here

Sub-criteria	**Description**	**How relevant is for you?**
Customers have total control	Customers have the ability to opt-out of events or actions that may reduce their comfort, providing them with control over their participation, even though profits are reduced.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Customers have control over some appliances	Customers have access to offer customization options that allow you to specify comfort preferences regarding appliances, for example, heating, cooking, etc.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Customers have control over some time-periods	Customers have access to offer customization options that allow you to specify comfort preferences regarding time in the day or week.	☐ highly relevant ☐ somewhat relevant ☐ not relevant
Notification and alerts	There are effective notification and alert tools to inform customers in advance of any actions that may affect their comfort, allowing customers to prepare accordingly.	☐ highly relevant ☐ somewhat relevant ☐ not relevant

how would you rank them in terms of importance?

Note: Rank from 1- with 1 being the most important and 4 being the least important. Choose just a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

	Most important 1	2	3	Least important 4
Customers have total control	☐	☐	☐	☐
Customers have control over some appliances	☐	☐	☐	☐
Customers have control over some time-periods	☐	☐	☐	☐
Notification and alerts	☐	☐	☐	☐

In regards to Costumer engagement, which of the following evaluation criteria are most important to you?. Please rank them.

Rank from 1-5 with 1 being the most important and 5 being the least important. Choose a single box for each sub-criterion. Different sub-criteria cannot have the same rank position.

Please answers here

	Most important 1	2	3	4	Least important 5
Benefits for active participation	☐	☐	☐	☐	☐
Integration of diverse customer segments	☐	☐	☐	☐	☐
Customer easiness of participation	☐	☐	☐	☐	☐
Installation of assets	☐	☐	☐	☐	☐
Reduction of controllability	☐	☐	☐	☐	☐

If necessary, you can provide additional information regarding the ranking:

[please answer here]

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