LEONARDO

Project number: 101215528

Project Acronym: LEONARDO

D2.1 STAKEHOLDERS' FUNCTIONAL AND BUSINESS REQUIREMENTS & REGULATORY FRAMEWORK LIMITATIONS

Date: 29/05/2026

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This project has received funding from the European Union's LIFE programme under grant agreement No 101215528.

Project contractual details

Project title	fLexibility sErvices prOvision eNAbled fRom aggregated inDustrial prOsumers
Project Acronym	LEONARDO
Grant Agreement No.	101215528
Project start date	1 September 2025
Project end date	31 August 2028
Duration	36 months
Website	https://www.rina.org/en/media/projects/leonardo-life-project

Deliverable details

Number	D2.1
Title	Stakeholders functional and business requirements and regulatory framework limitations
Work Package	WP2
Dissemination level[1]	PU - Public
Due date	31-05-2026
Submission date	29-05-2026
Deliverable responsible	European Center for Renewable Energy (AT)
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[1] PU = Public
SEN = Confidential, only for members of the consortium (including Commission Services)

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Final review and quality approval	29-05-2026

DOCUMENT HISTORY

DATE	VERSION	NAME	CHANGES
07-05-2026	0.1	Andrea Moser, Daniela Hacker	Consolidation of partners input, completion of chapters
11-05-2026	0.2	Andrea Moser, Joachim Hacker	Document revision, creation of summary and conclusions
22-05-2026	0.3	Michaela Papageorgiou	Document revision, suggestions
22-05-2026	0.4	Matteo Varesco	Document revision
28-05-2026	1.0	Andrea Moser, Konstanze Schulter, Federico Mucciarelli	Updated final version following the review

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Executive summary

Deliverable D2.1 presents the main results of Tasks 2.1 and 2.2 within the LEONARDO project and provides an overview of stakeholder requirements and framework conditions related to industrial Demand-Side Flexibility (iDSF) in the pilot regions in Italy, Austria and Bulgaria/Greece.

The increasing integration of renewable energy sources, growing electrification and changing electricity market conditions are creating a growing need for flexibility within European energy systems. In this context, industrial consumers and prosumers can play an important role by adjusting electricity consumption, supporting grid stability and contributing to balancing processes. At the same time, industrial flexibility participation is still influenced by technical, organisational, regulatory and economic barriers that differ across countries and industrial sectors.

The deliverable combines stakeholder consultation activities with desk research and comparative framework analysis. Workshops, interviews, questionnaires and bilateral exchanges were carried out with industrial actors, technology providers, aggregators, system operators and other relevant stakeholders in order to better understand the conditions influencing flexibility participation in the pilot regions.

The analysis first describes the broader European context for flexibility and electricity market developments, including renewable energy integration, balancing markets and aggregation concepts. Based on this, the deliverable examines the political, economic, technological, organisational and regulatory conditions within the pilot countries using a comparative PESTLE-oriented approach.

The stakeholder consultations show that industrial flexibility participation depends not only on technical capabilities, but also on operational feasibility, organisational readiness, market conditions and interoperability between existing systems. Across the pilot regions, stakeholders highlighted the importance of reliable monitoring infrastructures, compatibility with existing EMS and SCADA environments, transparent coordination mechanisms and predictable market conditions.

The consultations also revealed clear differences between the pilot regions regarding market maturity, flexibility experience and organisational structures. While some stakeholders already have experience with balancing markets and aggregation schemes, others are still in an early exploration phase focused on operational feasibility and practical implementation aspects.

Overall, Deliverable D2.1 provides a consolidated overview of the main stakeholder perspectives, operational conditions and framework limitations influencing industrial flexibility participation across the LEONARDO pilot environments. The findings contribute to a better understanding of the enabling and limiting factors relevant for coordinated industrial flexibility activation and for the further development of the LEONARDO flexibility concepts and platform-related activities.

Abbreviations

aFRR - automatic Frequency Restoration Reserve

API - Application Programming Interface

BESS - Battery Energy Storage System

BRP - Balancing Responsible Party

BSP - Balancing Service Provider

CACM - Capacity Allocation and Congestion Management

DAM - Day-Ahead Market

DSO - Distribution System Operator

DSF - Demand-Side Flexibility

EB - Electricity Balancing

EMS - Energy Management System

ESCO - Energy Service Company

FCR - Frequency Containment Reserve

GDPR - General Data Protection Regulation

HV - High Voltage

iDSF - industrial Demand-Side Flexibility

IDM - Intraday Market

iFAAP - Industrial Flexibility Activation and Aggregation Platform

mFRR - manual Frequency Restoration Reserve

MQTT - Message Queuing Telemetry Transport

MV - Medium Voltage

NEMO - Nominated Electricity Market Operator

PV - Photovoltaic

RES - Renewable Energy Sources

SCADA - Supervisory Control and Data Acquisition

SME - Small and Medium-sized Enterprise

TSO - Transmission System Operator

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1 INTRODUCTION

The ongoing transformation of the European energy system, driven by the increasing integration of renewable energy sources, electrification processes and evolving market structures, is significantly increasing the need for flexibility across electricity systems. In this context, Demand-Side Flexibility (DSF) is increasingly recognised as an important mechanism to support grid stability, facilitate renewable energy integration and improve overall system efficiency. While flexibility strategies have traditionally focused on generation-side solutions and large-scale storage, the industrial sector is receiving growing attention as a potentially significant flexibility resource due to its considerable electricity consumption, process diversity and operational capabilities.

Despite this potential, the large-scale implementation of industrial Demand-Side Flexibility (iDSF) remains limited across Europe. Various technological, regulatory, organisational, contractual and market-related barriers continue to affect the ability of industrial actors to participate in flexibility schemes. In addition, differences in national regulatory frameworks, market maturity, digitalisation levels and industrial structures create heterogeneous conditions for flexibility activation across European regions. As highlighted in the LEONARDO project description, current progress regarding industrial flexibility deployment ranges from low to non-existent in many contexts due to economic, regulatory, technological, behavioural and informational barriers.

The LEONARDO project (“fLexibility sErvices prOvision eNAbled fRom aggregated inDustrial prOsumers”) addresses these challenges by supporting the aggregation and coordinated activation of industrial flexibility through interoperable Energy Management Systems (EMSs) and collaborative flexibility approaches. The project investigates how industrial consumers and prosumers can contribute to flexibility services while maintaining operational reliability and aligning with existing market and regulatory conditions. The project includes three pilot sites located in Italy, Austria and Bulgaria/Greece, representing different industrial and energy system contexts.

Within this framework, Work Package 2 (WP2) focuses on analysing the contextual conditions required for successful industrial flexibility activation. Particular emphasis is placed on identifying stakeholder expectations, technical and business requirements, as well as framework limitations that may influence the deployment of coordinated flexibility solutions. WP2 therefore establishes an important preparatory basis for the subsequent technical development, pilot implementation and evaluation activities within the project.

Deliverable D2.1 consolidates the main outcomes generated in Tasks 2.1 and 2.2 and provides a structured overview of stakeholder requirements and framework conditions relevant for the LEONARDO pilots and platform development. The deliverable combines stakeholder consultation activities with desk research and contextual analyses in order to identify both enabling conditions and existing barriers related to industrial flexibility participation. The assessment covers functional, technical and business requirements alongside regulatory, contractual and market-related aspects that may affect the implementation and operation of flexibility services in the targeted pilot environments.

1.1 Purpose, Scope and Relation to Project Objectives

The overall rationale of LEONARDO is closely linked to the increasing need for flexibility within European electricity systems. The rapid expansion of variable renewable energy generation, increasing electrification and changing consumption patterns require new approaches for balancing electricity demand and supply. In this context, industrial consumers are increasingly considered important flexibility actors due to their significant load profiles, operational capabilities and growing deployment of digital energy management solutions. The project therefore investigates how industrial flexibility can be activated, coordinated and aggregated in a practical and interoperable manner across different industrial and regional contexts.

WP2 contributes to this objective by establishing the knowledge base required for the subsequent pilot implementation and technical platform development activities. The work focuses on understanding the needs, expectations and limitations of relevant stakeholders involved in industrial flexibility ecosystems. These include industrial site operators, technology providers, aggregators, distribution system operators (DSOs), energy service providers, research organisations and other relevant market actors. In parallel, WP2 analyses regulatory frameworks, contractual conditions and market structures that may either enable or constrain flexibility participation.

The main objective of Deliverable D2.1 is therefore to provide a structured assessment of the stakeholder requirements and framework conditions relevant for the LEONARDO pilots and associated flexibility services. The deliverable covers:

- functional and operational stakeholder requirements related to industrial flexibility participation,
- technical and interoperability-related aspects connected to EMS integration and data exchange,
- business-related expectations, incentives and organisational considerations,
- regulatory, contractual and market-related framework conditions,
- barriers and enabling factors affecting industrial flexibility activation.

The deliverable thereby supports the definition of pilot use cases, the refinement of technical specifications and the preparation of coordinated flexibility activation approaches within the project. In addition, the findings contribute to the alignment between stakeholder expectations and the development of the LEONARDO Industrial Flexibility Activation and Aggregation Platform (iFAAP) flexibility platform and associated orchestration concepts.

1.2 Structure of the Deliverable

This deliverable is structured to progressively connect the broader European flexibility context with national framework conditions, stakeholder perspectives and the resulting implications for pilot preparation and platform development within the LEONARDO project.

Following the introductory chapter, **Chapter 2** presents the methodological approach applied within Tasks 2.1 and 2.2. The chapter describes the overall analytical framework, the applied stakeholder consultation and data collection activities, as well as the

comparative desk research approach used to assess regulatory, organisational and market-related conditions relevant for industrial flexibility participation across the pilot regions.

Chapter 3 introduces the broader European context for Demand-Side Flexibility and power system integration. The chapter outlines the increasing relevance of flexibility in the context of renewable energy integration, electricity market evolution and industrial electrification trends. In addition, it summarises the main technical, organisational and regulatory barriers affecting industrial flexibility activation at European level.

Chapter 4 focuses on transnational and national framework conditions influencing industrial flexibility participation within the pilot countries. Based on a comparative PESTLE-oriented assessment, the chapter analyses political, economic, social, technological, legislative and environmental dimensions relevant for flexibility activation. Furthermore, the chapter examines national market structures, participation conditions, contractual aspects and data governance considerations affecting the deployment of interoperable and data-driven flexibility services.

Chapter 5 presents the stakeholder functional, technical and business-related requirements collected through the pilot-level consultation activities. The chapter is structured around pilot-specific insights from Italy, Austria and Bulgaria/Greece and reflects the perspectives of industrial end-users, technology providers, aggregators, network operators and other relevant ecosystem actors. In addition, cross-pilot patterns related to operational practices, organisational readiness, digital maturity and perceived enabling or limiting conditions are identified and consolidated.

Chapter 6 provides a cross-analysis of the findings generated throughout the stakeholder consultations and contextual assessments. The chapter identifies common requirement clusters, operational constraints and implementation-relevant conditions affecting coordinated industrial flexibility activation across the pilot environments. Particular emphasis is placed on the implications for pilot preparation activities and for the further refinement of the Industrial Flexibility Activation and Aggregation Platform (iFAAP).

Finally, **Chapter 7** summarises the main conclusions of the deliverable and highlights the relevance of the identified stakeholder requirements and framework conditions for the subsequent technical development, pilot implementation and evaluation activities within the LEONARDO project.

Deliverable D2.1 provides a structured assessment of the stakeholder requirements, operational conditions and framework limitations relevant for industrial flexibility participation across the LEONARDO pilot environments. The findings establish an analytical basis for understanding how technical, organisational, contractual and regulatory factors influence the feasibility of coordinated flexibility activation and support the alignment between stakeholder perspectives, pilot-specific conditions and the further development of the LEONARDO flexibility concepts and platform-related activities

2 METHODOLOGICAL APPROACH

The analysis presented in this deliverable is based on a structured methodological approach combining stakeholder engagement activities with comparative framework assessment and desk research. The overall objective of the methodology was to establish a consistent evidence base for identifying the functional, technical, organisational and business-related conditions influencing industrial participation in Demand-Side Flexibility (DSF) strategies across the LEONARDO pilot regions.

To support a harmonised stakeholder requirement elicitation process across the consortium, several common supporting materials and guidance documents were prepared and provided to the pilot partners. These included stakeholder mapping and classification templates, predefined workshop presentations, structured questionnaires in both hardcopy and online formats, as well as supporting guidance for interviews and consultation activities. In parallel, a dedicated desk research template was developed to support the comparative assessment of regulatory, market, technological and contractual framework conditions using a PESTLE-oriented analytical perspective.

The methodological approach therefore combined bottom-up stakeholder evidence gathered within the pilot ecosystems with top-down contextual assessments addressing European and national framework conditions. This enabled the identification of both pilot-specific and cross-cutting patterns related to industrial flexibility activation, digital maturity, organisational readiness and regulatory constraints.

2.1 Overall Analytical Framework

The overall analytical framework applied within Tasks 2.1 and 2.2 integrates stakeholder analysis, structured consultation activities and comparative desk research into a multi-level assessment approach. The methodology was designed to capture practical stakeholder perspectives while simultaneously considering the broader European and national conditions shaping industrial flexibility participation.

The analytical approach combines three complementary dimensions. First, stakeholder engagement activities were carried out within the pilot ecosystems in order to identify operational realities, expectations, perceived barriers and flexibility-related requirements from industrial actors and other relevant stakeholders. Second, structured desk research was conducted to assess political, economic, social, technological, legal and environmental framework conditions influencing flexibility activation in the participating countries. Third, a cross-analysis was performed to connect stakeholder requirements with the identified contextual conditions and pilot-specific characteristics.

The analytical perspective therefore covers:

- the broader European context related to flexibility, renewable energy integration and electricity market developments,
- national and regional framework conditions affecting industrial flexibility participation,
- stakeholder evidence collected through workshops, interviews, questionnaires and bilateral exchanges within the pilot ecosystems.

This structure enabled the identification of common requirement patterns as well as contextual differences between pilot regions. The analytical logic of the deliverable is based on the assumption that industrial flexibility activation is not solely determined by technical feasibility, but rather by the interaction between operational conditions, organisational readiness, market incentives, regulatory frameworks and digital capabilities.

The resulting cross-analysis links stakeholder requirements, regulatory constraints and pilot-specific conditions in order to derive implications for pilot preparation activities and the further development of coordinated flexibility activation approaches within the LEONARDO project.

2.2 Data collection and Validation

The data collection process combined multiple qualitative and semi-structured approaches in order to capture both practical stakeholder perspectives and contextual framework conditions relevant for industrial flexibility participation.

For the stakeholder requirement elicitation activities within Task 2.1, the consortium developed a common questionnaire framework covering technical, operational, organisational, business and regulatory aspects related to industrial flexibility. The questionnaire was structured into a core section applicable to all stakeholders and several dedicated modules addressing industrial end-users, technology providers, regulatory actors, business actors and distribution system operators. The questionnaire was made available in different formats, including online surveys and printable hardcopy versions, in order to support flexible application across the pilot regions.

In addition to the questionnaires, pilot partners conducted stakeholder workshops, bilateral meetings, semi-structured interviews and consultation exchanges with relevant ecosystem actors. To support consistency across pilots, predefined workshop presentations and supporting consultation materials were prepared and shared among consortium partners.

These activities aimed to collect indicative insights regarding:

- operational conditions and industrial process characteristics,
- current energy management and monitoring practices,
- digitalisation and interoperability aspects,
- organisational readiness and decision-making structures,
- perceived barriers and enabling conditions for flexibility participation,
- expectations regarding platform functionalities and flexibility services.

The stakeholder-related activities were complemented by a comparative desk research process carried out within Task 2.2. For this purpose, a dedicated Desk Research Template was developed by EEE and RINA-C in order to support harmonised data collection across pilot countries. The template followed a PESTLE-oriented structure and addressed political, economic, social, technological, legal and environmental dimensions influencing industrial flexibility participation.

The template included sections related to:

- national industrial and energy system contexts,

- technological maturity and interoperability conditions,
- economic and organisational framework conditions,
- regulatory and legal aspects,
- contractual and data governance considerations,
- pilot-relevant implications and cross-cutting barriers.

The desk research relied primarily on publicly available sources, including legislation, regulatory authority publications, national policy documents, market reports, standardisation documents and previous EU or national projects.

2.3 Stakeholder Identification and Classification

A structured stakeholder mapping and classification process was carried out within Task 2.1 in order to identify the most relevant actors involved in industrial flexibility ecosystems across the LEONARDO pilot regions. The objective was to ensure a balanced representation of operational, technical, market-related and regulatory perspectives within the consultation activities.
To support a harmonised approach across the consortium, a common stakeholder mapping template was developed and shared with all pilot partners. The template enabled the systematic identification and categorisation of stakeholders according to their role within industrial flexibility ecosystems, their involvement in energy management and market participation processes, and their relevance for the LEONARDO pilot activities.
The stakeholder mapping considered both pilot-specific ecosystem conditions and broader flexibility-related value chains. Particular attention was given to stakeholders directly involved in industrial energy consumption, monitoring and control systems, flexibility aggregation, network operation and electricity market participation.

Based on the common classification structure, stakeholders were grouped into the following main categories:

- Industries,
- EMS providers,
- EDM providers,
- Aggregators,
- DSOs,
- TSOs,
- Technology Providers,
- Energy Market Operators.

The stakeholder mapping activities provided the basis for the consultation and engagement process carried out within Task 2.1, including workshops, bilateral exchanges, interviews and questionnaire dissemination activities across the pilot regions.

3 European Context for Demand-Side Flexibility and Power System Integration

At European level, regulatory developments, electricity market reforms and the progressive digitalisation of the energy system are reshaping the conditions under which industrial electricity consumers can participate in demand-side flexibility mechanisms. The evolution of aggregation models, the emergence of new market roles, and the growing requirements for data access and interoperability concretely influence the ways in which industrial flexibility can be activated. The ongoing policy and market developments in this area provide an essential reference context for interpreting stakeholder expectations and assessing the relevance of the requirements identified across the different regional contexts covered by the LEONARDO project. This chapter sets out the European reference context within which the national and transnational frameworks examined in Chapter 4 are situated.

3.1 Integration of Renewable Energy Sources and System Operation Challenges

The rapid expansion of renewable energy generation across Europe is fundamentally altering the operational characteristics of electricity systems. Installed renewable energy capacity in the European Union exceeded 1,000 GW in 2024, with solar photovoltaic alone recording net additions of over 60 GW during the year. According to the projections of ENTSO-E's European Resource Adequacy Assessment (ERAA 2024), the share of variable renewable generation is set to reach structurally dominant levels in most Member States by 2030, with significant implications for system balancing and network congestion management.

The intermittency and non-programmability of wind and photovoltaic generation introduce growing imbalances between production and consumption at very short time scales, increasing the need for flexibility resources capable of responding rapidly to deviations in frequency, voltage levels, and power flows across transmission and distribution networks. Network operators - at both transmission (TSO) and distribution (DSO) level - face the challenge of integrating growing volumes of variable energy while maintaining system quality and security parameters, including during periods of excess generation that give rise to increasingly frequent curtailment events.

A study commissioned by the European Parliament (ECTI, 2025) estimates that the need for additional flexibility in the EU could reach 100–200 GW by 2030, considering both generation-side and demand-side flexibility. In this context, industrial demand-side flexibility (DSF) is identified as one of the structurally most relevant options, given its scalability and the relative speed of activation compared to other infrastructure investments.

The need for flexibility manifests across three distinct operational scales, each with its own technical and institutional characteristics. At local level, the growing penetration of distributed generation and flexible loads in distribution networks generates congestion and voltage problems that traditional TSO-level dispatching cannot resolve with sufficient

geographic granularity: in this context, the flexibility of industrial clusters connected to urban or rural distribution networks can provide local ancillary services for congestion and voltage profile management. At regional level, national TSOs require balancing reserves - FCR, aFRR, and mFRR - to compensate for deviations between scheduled and actual renewable generation: large industrial consumers, given their controllability characteristics and consumption volumes, represent a potentially significant resource for these markets. At transnational level, the growing interdependence of European electricity systems through interconnections makes the question of cross-border flexibility increasingly relevant: the possibility of aggregating industrial resources located in different countries to participate simultaneously in multiple national balancing markets represents a frontier that is still largely unexplored but of growing regulatory interest - as evidenced by the progressive integration of the European PICASSO and MARI platforms and the development of the Network Code on Demand Response.

3.2 Evolution of Flexibility Concepts in European Energy Policy and Market Design

The European regulatory framework for demand-side flexibility has evolved over approximately twenty years through a progressive affirmation of the principle of non-discriminatory access of demand-side resources to energy and ancillary service markets. Primary legislation adopted by EU institutions is complemented by the Network Codes and implementation guidelines developed by ENTSO-E and ACER, which define the technical and operational requirements for access to balancing markets at European and cross-border level.

From the Third Package to the Clean Energy Package: historical evolution

The liberalisation of the European electricity market began with the first Directives of the 1990s, culminating in the Third Energy Package of 2009 (Directive 2009/72/EC and Regulation 2009/714/EC), which introduced ownership unbundling of transmission operators, established ENTSO-E as the European coordination body for TSOs, and laid the groundwork for the creation of the Agency for the Cooperation of Energy Regulators (ACER). In this context, the concept of demand response was mentioned explicitly for the first time among the instruments available to Member States for the functioning of the internal market, though without a binding obligation of access.

A further step was taken with the Energy Efficiency Directive of 2012 (2012/27/EU), which introduced the obligation for TSOs and DSOs to consider demand response as a technical and economic alternative to network infrastructure investment. This provision represented the first structural recognition of DSF as a system resource, opening the way for a more systematic integration into balancing markets.

The fundamental regulatory turning point came with the Clean Energy Package of 2019, comprising Directive (EU) 2019/944 and Regulation (EU) 2019/943. These two acts enshrined the right of final customers and independent aggregators to participate in all electricity markets on an equal footing with generators, and obliged Member States to

remove unjustified barriers to their activity. The Clean Energy Package also laid the foundations for the development of local DSO-level flexibility markets and strengthened the role of ACER and ENTSO-E in elaborating technical network codes for balancing and flexibility.

Subsequent years saw a further strengthening of the framework, with the recast of the Energy Efficiency Directive in 2023 (EU/2023/1791) - which introduced the 'energy efficiency first' principle and expanded energy management system obligations for large enterprises - and the electricity market reform of 2024 (Directive 2024/1711 and Regulation 2024/1747), which represented the legislative response to the 2021–2023 energy crisis and introduced specific provisions to accelerate the development of local flexibility markets and simplify independent aggregator access.

The current regulatory framework: Directives, Regulations and digital governance

Directive (EU) 2019/944 constitutes the main pillar of the current regulatory framework. Article 17 recognises independent aggregators as new market participants and obliges Member States to guarantee them market access without the need for a prior agreement with the aggregated customer's supplier - a provision further strengthened by the 2024 reform. Article 32 establishes that DSOs must procure the flexibility services needed for network management through transparent and non-discriminatory procedures, laying the foundations for local flexibility markets. Article 40 defines TSO obligations regarding the opening of balancing markets to demand-side resources and storage.

Regulation (EU) 2019/943 completes the framework by setting operational rules for the internal electricity market. In particular, it establishes the principle of non-discriminatory access of all resources - including demand-side resources - to balancing markets and introduces balancing product design requirements that allow the participation of resources with technical profiles different from conventional generation.

The Energy Efficiency Directive (EU) 2023/1791 reinforced the 'energy efficiency first' principle, under which demand-side solutions must be systematically considered as alternatives to network investment. It also expanded the obligations for large industrial enterprises to adopt energy management systems (EMS), creating a broader technical foundation for future flexibility market participation.

The 2024 electricity market reform - Directive 2024/1711 and Regulation 2024/1747, which entered into force in July 2024 - introduced the obligation for DSOs to develop competitive mechanisms for the procurement of local flexibility, and removed the requirement for prior agreement between the aggregator and the customer's supplier for access to balancing markets. It also introduced new instruments for managing price volatility, including contracts for difference for renewables, with indirect effects on the price signal underlying DSF.

On digital governance and cybersecurity, the framework is completed by a set of instruments that directly affect aggregation platforms and industrial EMS systems. Regulation (EU) 2016/679 (GDPR) governs the processing of personal data, including metering-related data flows. Directive (EU) 2022/2555 (NIS2) imposes enhanced cybersecurity requirements on essential entities in the energy sector, which may include aggregators and flexibility platform

operators. Regulation (EU) 2024/2847 (Cyber Resilience Act) introduces horizontal cybersecurity requirements for products with digital elements - relevant for EMS, controllers, and aggregation platform components. Regulation (EU) 2024/1689 (AI Act) governs artificial intelligence systems, potentially applicable to the forecasting and optimisation modules integrated into flexibility platforms. Both of these latter Regulations are currently in transitional implementation phase at Member State level.

Network Codes and ACER/ENTSO-E guidelines

Alongside the primary legislative framework, the European Network Codes developed by ENTSO-E and approved by the European Commission define the technical and operational requirements for access to balancing markets. These acts - adopted in the form of Commission Regulations - are directly applicable in all Member States and constitute the common technical basis upon which national specificities are layered.

Regulation (EU) 2017/2195 - the Guideline on Electricity Balancing (GL EB) - is the central technical instrument for demand-side flexibility in balancing markets. It defines the standard European balancing products: the Frequency Containment Reserve (FCR), with a mandatory response within 30 seconds and mandatory cross-border exchange among all European TSOs in the synchronous area; the automatic Frequency Restoration Reserve (aFRR), with automatic activation within 15 minutes and cross-border exchange through the PICASSO platform (operational since 2022); and the manual Frequency Restoration Reserve (mFRR), with manual activation within 12.5 minutes and cross-border exchange through the MARI platform (operational since 2024). The GL EB explicitly provides that these products must be designed to allow the participation of demand-side resources, without exclusions based on resource type.

Regulation (EU) 2017/1485 - the Guideline on System Operation (SO GL) - governs the operational rules for electricity system management, including TSO-DSO coordination. It defines the interfaces between the two network levels and the information exchange mechanisms required for the safe activation of flexibility resources, including those located on distribution networks.

Regulations (EU) 2015/1222 (CACM) and 2016/1719 (FCA) govern respectively the market coupling for day-ahead and intraday markets - through the SDAC and SIDC platforms - and the allocation of cross-border capacity in forward markets, creating the wholesale market context within which industrial consumers can participate as price-responsive actors.

On the demand response side, the technical instrument of greatest prospective relevance is the Network Code on Demand Response, whose development was initiated by ACER in March 2025 with the submission of a formal proposal to the European Commission. The Network Code, expected by 2027, will introduce harmonised technical requirements for the participation of demand-side resources in cross-border balancing markets, addressing the issues of prequalification, measurement, baseline calculation, and reporting obligations. Its adoption is expected to significantly reduce the technical fragmentation currently existing among Member States.

On system assessment, ENTSO-E annually publishes the European Resource Adequacy Assessment (ERAA), which quantifies the flexibility requirement at European and national level, and the Ten-Year Network Development Plan (TYNDP), which plans infrastructure developments of the network. ACER annually publishes the Market Monitoring Report, which documents the state of development of balancing and demand response markets across all Member States, identifying access barriers and regulatory good practices.

Table 1 below provides a consolidated overview of the main European regulatory instruments relevant to demand-side flexibility, covering both the historical evolution and the current framework.

TABLE 1: *EUROPEAN REGULATORY FRAMEWORK FOR DEMAND-SIDE FLEXIBILITY*

HISTORICAL EVOLUTION - main acts preceding the current framework				
Third Energy Package (Dir. 2009/72/EC + Reg. 2009/714/EC)	Directive / Regulation	2009	First explicit mention of demand response; establishment of ENTSO-E and ACER; TSO ownership unbundling	Repealed (replaced by 2019/944 and 2019/943)
Energy Efficiency Directive (2012/27/EU)	Directive	2012	Obligation for TSOs/DSOs to evaluate DSF as alternative to network investment	Repealed (replaced by 2023/1791)
CURRENT REGULATORY FRAMEWORK - Directives and Regulations				
Dir. (EU) 2019/944 - Internal market for electricity	Directive	2019	Art. 17: independent aggregators; Art. 32: DSO flexibility; Art. 40: TSO obligations. Removal of unjustified barriers to demand-side market access	In force
Reg. (EU) 2019/943 - Internal market for electricity	Regulation	2019	Non-discriminatory market access for all resources including demand-side; balancing product design compatible with DSF and storage	In force
Dir. (EU) 2023/1791 - Energy Efficiency (recast)	Directive	2023	'Energy efficiency first' principle; EMS obligations for large enterprises; strengthened demand response and aggregation framework	In force
Dir. (EU) 2024/1711 - Electricity Market Design Reform	Directive	2024	Mandatory DSO local flexibility markets; aggregator access without prior supplier agreement; contracts for difference for renewables	In force
Reg. (EU) 2024/1747 - Electricity Market Design Reform	Regulation	2024	DSO flexibility procurement procedures; removal of barriers to independent aggregation	In force
DIGITAL GOVERNANCE AND CYBERSECURITY				
Reg. (EU) 2016/679 - GDPR	Regulation	2018*	Personal data protection; applicable to metering data and aggregation platforms	In force
Dir. (EU) 2022/2555 - NIS2	Directive	2022	Cybersecurity for essential entities in the energy sector; applicable to aggregators and flexibility platform operators	In force
Reg. (EU) 2024/2847 - Cyber Resilience Act	Regulation	2024	Cybersecurity requirements for digital products; applicable to EMS, controllers and flexibility platform components	In force (transitional)

Reg. (EU) 2024/1689 - AI Act	Regulation	2024	Framework for AI systems; potentially applicable to forecasting and flexibility optimisation modules	In force (transitional)
NETWORK CODES AND ACER/ENTSO-E GUIDELINES				
Reg. (EU) 2015/1222 - CACM	Network Code	2015	Day-ahead (SDAC) and intraday (SIDC) market coupling; wholesale market context for price-responsive demand participation	In force
Reg. (EU) 2016/1719 - FCA	Network Code	2016	Forward capacity allocation; relevant for industrial consumer price risk management	In force
Reg. (EU) 2017/1485 - SO GL	Network Code	2017	System operation rules; TSO-DSO coordination; interfaces for safe activation of distributed flexibility resources	In force
Reg. (EU) 2017/2195 - GL EB (Electricity Balancing)	Network Code	2017	Standard balancing products (FCR, aFRR, mFRR); cross-border platforms PICASSO (aFRR, op. 2022) and MARI (mFRR, op. 2024); product design obligation compatible with demand-side resources	In force
Network Code on Demand Response (under development)	Network Code	exp. 2027	Harmonised technical requirements for DSF participation in cross-border balancing markets; prequalification, measurement, baseline calculation, reporting obligations	Under development (ACER proposal Mar. 2025)

** The GDPR entered into application in May 2018.*

Flexibility market architecture: from TSO-level to DSO local markets

The regulatory framework described in the preceding sub-sections has given rise to a multi-level market architecture that allows demand-side resources to participate in different segments of the electricity system. Understanding this architecture - and the role that aggregators play within it as intermediaries between industrial consumers and markets - is essential for contextualising the participation conditions analysed in the national frameworks of Chapter 4.

The markets in which demand-side flexibility resources can participate are structured around three main levels, each with distinct technical and temporal characteristics: wholesale energy markets, TSO-managed balancing markets, and DSO-managed local flexibility markets.

Wholesale energy markets comprise the Day-Ahead Market (DAM) and the Intraday Market (IDM). The DAM operates through the Single Day-Ahead Coupling (SDAC) mechanism, which determines zonal or nodal prices by maximising the overall economic surplus of cross-border trade. The IDM operates under continuous coupling (Single Intraday Coupling, SIDC). In both markets, large industrial consumers can participate as price-responsive actors, modulating their consumption profiles in response to price signals - a form of implicit flexibility that does not necessarily require the involvement of an aggregator.

TSO-managed balancing markets are the primary outlet for explicit demand-side flexibility at European level. Regulation (EU) 2017/2195 standardised three main products. The Frequency Containment Reserve (FCR) is a symmetric fast-response reserve, activated automatically within 30 seconds in response to frequency deviations; it is exchanged cross-border among all TSOs in the European synchronous area through the TERRE platform. The automatic Frequency Restoration Reserve (aFRR) is activated automatically within 15 minutes for frequency restoration; cross-border exchange occurs through the PICASSO platform, operational since July 2022, which allows the compensation of aFRR requirements among participating TSOs at minimum cost. The manual Frequency Restoration Reserve (mFRR) is activated manually by the TSO within 12.5 minutes; cross-border exchange occurs through the MARI platform, operational since 2024. Beyond these standardised products, TSOs can procure Replacement Reserves (RR) for the management of prolonged imbalances.

The general requirement for participation in balancing markets is obtaining Balancing Service Provider (BSP) qualification, which involves demonstrating technical response capacity - activation times, measurement precision, real-time communication - and compliance with minimum bid thresholds that vary by country and product. These requirements apply in principle to demand-side resources as well, although the practical accessibility varies significantly among Member States.

DSO-level local flexibility markets represent the most rapidly evolving segment, though still in the development phase in most Member States. These markets, whose establishment is now mandatory under Directive 2024/1711, allow DSOs to procure localised flexibility for network congestion management, voltage control, and other local ancillary services - functions that TSO-level balancing cannot perform with sufficient geographic granularity. The design of these markets is still largely heterogeneous across countries, with different models being tested in Italy, Austria, Germany, Denmark, and the Netherlands, among others.

The role of aggregators and the value chain

The participation of industrial consumers in explicit flexibility markets is mediated through a value chain involving several actors with distinct roles and responsibilities. Understanding this structure is essential for identifying the enabling conditions and friction points that influence effective market access.

The industrial consumer holds the physical resource - that is, the capacity to modulate its consumption profile in response to an external signal - and must be equipped with the technical infrastructure needed to measure, communicate, and implement the required modulations, typically through an EMS integrated with plant SCADA systems. Its decision to participate depends on the assessment of the relationship between the expected economic value of flexibility and the operational risks associated with production process modulation.

The independent aggregator is the entity that intermediates between the consumer and the market. Its role consists of pooling the flexibility of multiple industrial consumers to reach the

minimum bid thresholds required by TSOs or DSOs, submitting offers in balancing or local markets, managing the calculation of the consumption baseline needed for performance verification, and distributing revenues among participants according to pre-defined contractual mechanisms. Article 17 of Directive 2019/944 enshrined the right of independent aggregators to operate without a prior agreement with the customer's supplier - a right further strengthened by the 2024 reform, which removed the veto power that some Member States had implicitly retained during transposition.

The Balancing Responsible Party (BRP) is the entity responsible for the energy balance of its production and consumption portfolio within the settlement period. Every industrial consumer participating in markets is associated with a BRP, which is accountable for deviations from declared schedules and manages imbalance costs. In many cases, the BRP coincides with the consumer's energy supplier; however, sufficiently capitalised aggregators can directly assume BRP status, simplifying the contractual chain.

The revenue sources available to an industrial consumer participating in flexibility markets fall into three main categories. Capacity payments (availability payments) remunerate the provision of response capacity, independently of actual activation. Energy activation payments remunerate the services actually delivered during activation windows. Tariff benefits derive from reductions in peak demand, which affects the capacity components of network tariffs in many national systems. To these can be added, in a more advanced market setting, the benefits of implicit price arbitrage in wholesale markets, obtainable by modulating demand in response to DAM and IDM price signals.

This structure is implemented differently across Member States, depending on the degree of market openness to independent aggregators, the technical and minimum size prequalification thresholds, and the coordination rules between aggregators and suppliers. These variations constitute the primary subject of the analysis conducted in Chapter 4.

3.3 Electricity Demand Trends and the Role of Large Consumers

Electricity demand in Europe is expected to grow structurally over the coming decades, reversing the relative stability observed in the 2010–2020 period. According to projections from the IEA World Energy Outlook and Eurostat, European electricity demand could grow by 30–60% by 2050 relative to current levels, driven primarily by the electrification of transport, heating, and industrial processes. The REPowerEU and Fit for 55 projections foresee an acceleration of industrial electrification as a central lever for the decarbonisation of energy-intensive sectors.

In this context, large industrial consumers - including steelworks, refineries, chemical plants, aluminium producers, cement manufacturers, and high-consumption manufacturing industries - represent a significant share of overall electricity demand. At European level, industry absorbs approximately 25–30% of final electricity consumption, with significant concentrations in energy-intensive sectors. These consumers possess characteristics that make them potentially well suited to provide flexibility services: high consumption volumes,

processes with load modulation margins, and monitoring and control infrastructure that is already, at least partially, in place.

The progressive electrification of production processes - including the introduction of electrolysers for green hydrogen production, industrial heat pumps, and thermal storage systems - will further expand the flexibility profile available on the demand side, making these actors increasingly central interlocutors in the functioning of energy and ancillary service markets. As electrification deepens, the temporal flexibility embedded in new industrial loads - which can shift consumption across hours or days without compromising the end product - adds to the traditional load shedding and modulation capacity of conventional energy-intensive processes, broadening the range of balancing services that large industrial consumers can credibly offer.

3.4 Barriers to Flexibility Activation Identified at European Level

Despite the progressive strengthening of the European regulatory framework and the growing availability of cross-border market platforms, the activation of industrial flexibility continues to encounter significant structural obstacles. These obstacles are not attributable to a single cause, but are organised around four distinct clusters which combine in varying ways across different national and sectoral contexts: technical-digital, measurement-informational, institutional-operational, and financial-strategic. The first cluster concerns the fragmentation of technical standards and the lack of interoperability between industrial EMS systems and aggregation platforms. Industrial consumers operate with heterogeneous energy management systems - developed by different vendors, with proprietary communication protocols, and with very different digitalisation levels between large enterprises and SMEs. The absence of shared semantic standards for data exchange between industrial EMS, aggregators, and network operators makes every integration a bespoke project, with high onboarding costs that discourage the participation of smaller or less digitally mature resources. This barrier cannot be overcome by regulation alone: it requires technical interoperability solutions that allow heterogeneous systems to communicate with aggregation platforms and markets without custom integrations.

The second cluster concerns uncertainty in the measurement of available flexibility and in the calculation of the consumption baseline. Participation in balancing markets requires the flexibility provider to demonstrate, ex ante, its response capacity, and to verify, ex post, the service actually delivered relative to a reference consumption profile - the so-called baseline. For continuous industrial processes - refineries, steelworks, chemical plants - the determination of a reliable baseline is technically complex, since the consumption profile depends on production variables that are not directly observable from the outside. The absence of standardised methodologies and of sufficiently accurate forecasting tools for real-time estimation of available flexibility constitutes one of the main practical barriers to balancing market entry, documented across the European literature (ACER Market Monitoring Report 2023; ScienceDirect, 2024).

The third cluster concerns the complexity of TSO-DSO coordination and the operational difficulties of multi-market participation. The current electricity market architecture is designed around a centralised dispatching model at TSO level, which struggles to efficiently integrate resources located on distribution networks. When an industrial consumer connected to the distribution network wishes to participate simultaneously in a TSO balancing market and a local DSO market, problems arise of double use of the same capacity, conflicts between activation signals, and responsibility for impacts on the distribution network. These problems are even more acute in the cross-border dimension, where simultaneous participation in the balancing markets of two different national TSOs through an interconnection requires coordination mechanisms - commercial, technical, and regulatory - that the current regulatory framework only partially addresses. The smartEn and LCP Delta Market Monitor on Demand-Side Flexibility (2024) documents how only a minority of the 30 European markets analysed allow advanced forms of multi-market participation by independent aggregators.

The fourth cluster concerns long-term economic risk and the lack of adequate tools for flexibility investment planning. The revenues expected from balancing market participation are inherently volatile - they depend on activation frequency, market prices, and settlement rules, all variables subject to regulatory change. In this context, an industrial consumer or aggregator evaluating an investment in flexibility infrastructure - advanced telemetry, automated control systems, storage capacity - must estimate uncertain future revenues over a 5–10 year horizon, without analytical tools for regulatory scenario assessment and investment portfolio optimisation that are accessible and calibrated to the specific profile of the industrial actor. This information asymmetry between the complexity of the investment decision and the availability of adequate decision-support tools structurally depresses investment propensity, particularly among medium-sized actors.

These four dimensions of constraint are reflected, with country- and sector-specific variations, in the national and transnational frameworks examined in Chapter 4.

4 Transnational and National Framework Conditions

Industrial participation in Demand-Side Flexibility strategies is influenced by a range of contextual factors that extend beyond purely technical considerations. To capture these influences in a structured way, a comparative assessment across pilot countries is carried out using a PESTLE perspective. This includes examining political priorities, economic conditions, social and organisational aspects, technological readiness, legislative provisions and environmental drivers relevant for flexibility participation. Understanding these dimensions helps to identify enabling and limiting conditions shaping the feasibility of industrial flexibility activation in different regional contexts.

4.1 Comparative PESTLE Analysis across Pilot Countries

This section presents a comparative analysis of the political, economic, social, technological, legislative, and environmental (PESTLE) framework conditions that influence industrial demand-side flexibility (DSF) activation across the four national contexts covered by the LEONARDO pilot sites: Italy (IT), Austria (AT), Greece (GR), and Bulgaria (BG). The analysis draws on desk research carried out by the pilot partners - covering publicly available regulatory sources, national and EU policy documents, legislation, and regulatory authority publications - and consolidates the main findings by PESTLE dimension in order to identify shared patterns, divergences, and cross-national implications relevant for the deployment of the iFAAP platform and the broader project objectives.

The BG/GR pilot site (Pilot Site #3) is organised around a cross-border use case involving two distinct national regulatory and market contexts: Greece, where HELLENiQ ENERGY a leading Energy Group operates, and Bulgaria, where the Stomana industrial cluster operates in the Sofia balancing area. The cross-border use case (UC#2) envisions the implicit participation of Bulgarian industrial flexibility in the Greek balancing market through a certified Greek aggregator, exploiting the capacity margin of the 400 kV Greece–Bulgaria transmission interconnection (Nea Santa–Maritsa East line). Given their regulatory and institutional distinctiveness, Greece and Bulgaria are treated separately throughout the analysis, where required by differences in their national frameworks.

4.2 Political Framework Conditions

Political framework conditions encompass the national and supranational policy priorities, governmental strategies, and institutional mandates that shape the enabling environment for industrial flexibility participation. Across all four pilot countries, the overarching political context is defined by EU-level obligations: the Governance Regulation (EU 2018/1999) requires Member States to submit and implement updated National Energy and Climate Plans (NECPs), while the Clean Energy Package (Directive 2019/944 and Regulation 2019/943) establishes non-discriminatory market access for demand-side resources as a binding legislative baseline. The 2024 Electricity Market Design Reform (Directive 2024/1711 and Regulation 2024/1747) has further strengthened these obligations, most notably by making the establishment of DSO-level local flexibility markets mandatory in all Member States and by reinforcing the rights of independent aggregators. These EU-level

instruments provide the common political and legal floor upon which the national frameworks analysed below are built.

In Italy, industrial flexibility is embedded within the Piano Nazionale Integrato per l'Energia e il Clima (PNIEC), updated in 2023, which identifies demand response and aggregation as key enabling instruments for the integration of variable renewable energy sources and the decarbonisation of energy-intensive industry. The PNIEC is adopted pursuant to the EU Governance Regulation and sets national trajectories for renewable energy, energy efficiency, and greenhouse gas reductions that are directly relevant to the conditions under which industrial flexibility is expected to operate. Regulatory oversight is exercised by ARERA (Autorità di Regolazione per Energia Reti e Ambiente), while transmission system operation, dispatching, and the management of ancillary service markets are assigned to Terna under the Codice di Rete. Electricity wholesale markets are operated by the Gestore dei Mercati Energetici (GME), which also manages the Mercato dei Servizi di Dispacciamento (MSD) under Terna's governance.

A significant political development for the Italian pilot context is the entry into force in January 2025 of the new Testo Integrato del Dispacciamento Elettrico (TIDE), which represents a comprehensive reform of the dispatching framework with the objective of improving ancillary service procurement efficiency by extending access to distributed, virtual, and aggregated resources - including industrial loads. The TIDE reform absorbs and consolidates the previous UVAM (Unità Virtuali Abilitate Miste) framework and the interruptibility service, signalling a clear political direction toward more open and competitive access to balancing markets.

At the DSO level, ARERA has progressively instituted a framework for local flexibility market procurement through Resolution 352/2021/R/eel (further specified by Resolutions 484/2023 and 372/2023), which establishes the Mercato Locale della Flessibilità (MLF), managed by GME and structured into forward (MLT-FLEX) and spot (MLP-FLEX) segments. Three authorised pilot projects - EDGE (E-Distribuzione/Enel Group), RomeFlex (Areti/ACEA Group), and MiNDFlex (Unareti/A2A Group) - are actively testing these mechanisms across different regions and voltage levels, with their outcomes expected to inform ARERA's decisions on the permanent institutionalisation of local flexibility markets, as required by Directive 2024/1711. Italy's political trajectory in this area is therefore one of active regulatory construction, albeit at a pace constrained by the inherent complexity of multi-level coordination between TSO and DSO.

In Austria, the political framework for industrial flexibility is anchored in the #mission2030 climate and energy strategy and the Erneuerbaren-Ausbau-Gesetz (EAG, Renewable Energy Expansion Act, 2021), which establishes the target of 100% renewable electricity production on a national balance basis by 2030. The EAG is accompanied by a set of related legislative frameworks - including the Gaswirtschaftsgesetz (Gas Economy Act), the Elektrizitätswirtschaftsgesetz (ElWOG) and the recently adopted Elektrizitätswirtschaftsgesetz (ElWG) - which collectively strengthen the enabling framework for market participation, aggregation and flexibility-oriented energy services for consumers and prosumers. National energy policy is overseen by the Federal Ministry for Climate

Action, Environment, Energy, Mobility, Innovation and Technology (BMK), while market regulation and consumer rights are the responsibility of E-Control, the independent national regulatory authority.

The Austrian political context reflects a high degree of engagement with EU-level energy transition policy, including early transposition of the Clean Energy Package and active participation in EU platform processes for cross-border balancing (FCR cooperation, PICASSO, MARI). Political attention to demand-side flexibility has increased in recent years, driven by the growing share of variable renewables and by the recognition that transmission-level balancing markets alone are insufficient to manage distributed flexibility needs. However, the regulatory framework for DSO-level flexibility markets has not yet been enacted; Austria's transposition of Directive 2024/1711 will require the establishment of such mechanisms, and this represents a significant forthcoming development for the Austrian pilot context, particularly given the role of Kiendler - the local DSO in the Southeastern Styria pilot region - as a key institutional actor in the LEONARDO pilot.

In Greece, the political framework is shaped by one of the most ambitious energy transition agendas in the EU. The updated NECP, submitted to the European Commission in 2024, sets a target of 76.8% renewable electricity by 2030 - significantly above the EU average - and explicitly identifies demand response, energy storage, and grid flexibility as critical enabling elements for achieving this target. The National Climate Law (Law 4936/2022) establishes binding targets for a 55% reduction in greenhouse gas emissions by 2030 relative to 1990 levels and climate neutrality by 2050, creating a legally anchored long-term policy signal for investments in the energy transition, including demand-side flexibility.

Institutional oversight of the electricity market is distributed among several authorities: RAAEY (formerly RAE) as the national energy regulator, IPTO/ADMIE as the independent transmission system operator and balancing market manager, HEDNO as the distribution system operator, and HEnEx as the market operator for the Day-Ahead and Intraday Markets. Greece is a participant in the EU Single Day-Ahead Coupling (SDAC) and Single Intraday Coupling (SIDC) platforms, which positions it within the integrated European electricity market. The urgency of flexibility policy has been heightened by the extraordinary pace of RES deployment: installed RES capacity surpassed 16 GW in early 2025, well ahead of the original NECP trajectory, generating significant and increasing curtailment of renewable production and creating systemic pressure for additional flexibility resources. Law 5106/2024 on RES curtailment and battery energy storage systems signals a political recognition of this challenge, as does the Ministerial Decision 28255/1143/2025 on standalone BESS grid connections. The cross-border dimension of the BG/GR pilot is embedded in this context of rapid RES-driven system transformation.

In Bulgaria, the political framework reflects a country in a transitional phase of energy market reform, characterised by the co-existence of a legacy coal-based generation system and a progressive regulatory alignment with EU requirements. The updated NECP, submitted to the European Commission in January 2025, significantly raises renewable energy targets relative to the previous version - setting a goal of 35% renewable energy in gross final consumption by 2030 (49.3% for the electricity sector) - and includes provisions for the

gradual phase-down of coal-based electricity production at the Maritsa East complex, Bulgaria's main thermal generation cluster.

Regulatory oversight is exercised by the Energy and Water Regulatory Commission (EWRC), which is responsible for adopting the Electricity Trading Rules (ETR), setting network tariffs, and issuing licences for electricity trading and balancing group coordination. The transmission system is operated by ESO EAD (Electricity System Operator), a subsidiary of the state-owned Bulgarian Energy Holding. Wholesale market organisation is provided by the Independent Bulgarian Energy Exchange (IBEX), which operates the Day-Ahead Market (DAM), Intraday Market (IDM), and a bilateral contracts segment. A distinctive feature of the Bulgarian political framework is the mandatory exchange trading requirement: since 2021, all RES and co-generation plants with installed capacity of 500 kW or more are required to sell electricity through IBEX platforms, making Bulgaria one of only two EU countries - alongside Romania - with this requirement. This political choice has significant implications for market structure and the conditions under which industrial demand-side flexibility operates. The pace of reform has been more measured than in the other pilot countries, but the June 2025 ETR amendments - which introduced a new balancing price methodology and new contract types, mandated by EU Regulation 2019/943 - signal continuing political commitment to market modernisation.

4.3 Economic Factors and Market Incentives

Economic conditions and market incentive structures determine the financial attractiveness of flexibility participation for industrial actors and shape the investment decisions of flexibility service providers, aggregators, and platform operators. Across the four national contexts, the economic rationale for industrial flexibility participation is primarily driven by exposure to wholesale market price volatility, the availability and design of remuneration mechanisms in balancing and ancillary service markets, and the structure of network tariff components. Public funding instruments specifically targeting industrial flexibility remain limited across all pilot countries, expect for the Italian MLF pilot projects; the economic case depends predominantly on market revenues and cost avoidance.

In Italy, the industrial sector is substantially exposed to wholesale electricity price volatility: industrial electricity consumption accounts for approximately 124.8 TWh out of a national total of 292.7 TWh (42.6%, according to Terna's 2024 statistical data), and a significant share of this consumption is procured at market-indexed prices in the GME-operated day-ahead market. The 2021–2023 energy crisis dramatically amplified price volatility and accelerated industrial interest in flexibility as a hedging and optimisation strategy. While prices moderated in 2024, the structural exposure of energy-intensive industries in Northern Italy - particularly in the manufacturing clusters of Lombardy, Veneto, Emilia-Romagna, and Trentino-Alto Adige - to intraday and day-ahead price signals remains a persistent driver of demand management activity.

The Italian flexibility market landscape is relatively articulated. The MSD (Mercato dei Servizi di Dispacciamento), operated by Terna, provides access to balancing revenues through aFRR, mFRR, and Replacement Reserve (RR) products, principally through the UVAM scheme (now absorbed into TIDE). The Capacity Market, established by the Ministerial Decree of 28 June 2019, provides availability-based capacity payments to qualifying

resources committed to provide dispatchable capacity during scarcity periods, and represents an additional revenue stream for flexible industrial assets with sufficient controllability. The interruptibility service - which provided guaranteed, contracted revenues to large industrial consumers in exchange for rapid load reduction upon TSO request - has been progressively reformed and integrated into the TIDE framework from January 2025.

Beyond TSO-level mechanisms, the Italian regulatory framework provides access to additional economic instruments for industrial energy consumers: the imprese elettrivore and gasivore tariff relief schemes offer reduced network charges to highly energy-intensive industries meeting specific consumption thresholds; White Certificates (Titoli di Efficienza Energetica, TEE) reward certified energy savings; the Energy Release mechanism provides below-market access to energy from the strategic reserve; and the Iperammortamento 2026 provision enables accelerated depreciation for qualifying investments in energy management systems. These mechanisms supplement flexibility revenues but do not substitute for them. Stakeholder evidence from Italian industrial consumers indicates that availability-based capacity payments - as opposed to activation-only payment structures in the balancing market - are perceived as the most financially attractive component, given that they provide predictable income regardless of activation frequency and reduce the revenue uncertainty that is otherwise the principal financial disincentive for flexibility infrastructure investment.

At DSO level, the MLF pilot markets (EDGE, RomeFlex, MiNDFlex) operate through dual-component remuneration systems combining availability payments (EUR/MW/h) and activation payments (EUR/MWh), with forward procurement through monthly auctions and price caps on both components. These markets are not yet financially self-sustaining - they are currently funded by ARERA - but their design points toward the long-term economic model that is expected to emerge from the permanent institutionalisation of local flexibility markets in Italy. For the Storo pilot cluster, which operates within the specific DSO context of CEDIS - an electricity cooperative that simultaneously acts as a DSO and as a BSP - the local DSO-level market represents an additional and complementary revenue pathway alongside national MSD potential participation.

In Austria, the economic framework for industrial flexibility is characterised by an early-stage market development in which the financial case for flexibility participation exists in principle but is difficult to quantify in advance for most industrial actors. No dedicated national funding scheme exists specifically for industrial flexibility participation. Flexibility-related investments and activities may attract indirect support through broader programmes managed by the Klima- und Energiefonds (Climate and Energy Fund), the Austrian Research Promotion Agency (FFG), and Austria Wirtschaftsservice (aws), primarily in the context of research, innovation, or energy efficiency projects. In practice, the economic case for industrial flexibility in Austria rests primarily on market-based revenues from APG-operated balancing markets.

APG (Austrian Power Grid), as the national TSO, procures FCR, aFRR, and mFRR balancing capacity and energy through competitive tenders. Remuneration for balancing services combines capacity payments (for prequalified availability) and energy payments (for actual activation), with prices determined through competitive bidding. The financial attractiveness of balancing market participation varies significantly depending on the plant load profile, the controllability of industrial processes, and the ability to maintain performance

across multiple activations without disruption to production quality and safety. For medium-sized industrial companies with less specialised energy management functions, the economic uncertainty of balancing market revenues - which depend on volatile market prices and unpredictable activation frequencies - is a significant barrier.

Network tariff structures in Austria do not include explicit bonus payments for demand-side flexibility, but they provide indirect economic incentives through peak demand and capacity-related tariff components: industrial consumers that can reduce their peak demand through load shifting or peak shaving can reduce their network charge liabilities, which creates a cost-avoidance incentive for flexible consumption behaviour. Several business and contractual models for flexibility have emerged in the Austrian market, including aggregator–industrial client arrangements (where aggregators pool flexibility from multiple industrial customers and market it through APG's platforms), utility-mediated demand response services, and ESCO-based contracting models in which an external provider finances and operates energy optimisation solutions with remuneration linked to savings or shared revenues.

In Greece, the economic landscape for industrial flexibility is defined by substantial wholesale market price volatility - particularly pronounced during the 2021–2023 energy crisis, when gas price shocks drove Greek day-ahead market prices to levels substantially exceeding the EU average - and by an increasing frequency of intraday price differentials generated by excess midday solar generation. RES curtailment events have become more frequent as installed solar capacity has grown, creating periods in which electricity prices approach zero or turn negative and amplifying the economic opportunity for demand-side resources that can absorb surplus renewable generation.

Greece is one of only four EU countries (alongside Belgium, France, and Great Britain) where explicit demand-side flexibility participation in wholesale markets through an independent aggregator framework is operationally established. IPTO procures balancing reserves through a structured mechanism that combines pay-as-bid capacity payments and marginal pricing for activation energy. Daily procurement volumes amount to approximately 300 MW of aFRR (in six 4-hour blocks) and approximately 600 MW of mFRR. Prequalification for balancing services requires technical demonstration of response capability (including a 24-hour baseline test), compliance with metering requirements (at least 50% of declared capacity must be verifiable through real-time telemetry during testing), and formal registration with IPTO as a Balancing Service Entity (BSE). Remuneration for balancing services includes both capacity availability payments and energy activation payments, with pricing determined through competitive tenders.

The cost of flexibility activation in energy-intensive continuous-process industries is a critical economic parameter. For aluminium smelting processes, the cost of production interruptions has been estimated at approximately €900/MWh including production losses, efficiency degradation, and equipment recovery costs - a figure that illustrates the high economic threshold above which balancing market revenues must exceed in order for participation to be commercially viable. For HELLENiQ ENERGY, continuity, safety of operation and asset integrity impose strict constraints on the timing, duration, and magnitude of load adjustments, making the business case for flexibility dependent on the availability of intelligent dispatch algorithms that can optimise the trade-off between balancing revenue and process safety risk. The Greek capacity mechanism, restructured through competitive

tenders in 2023–2025 with 10-year availability-based contracts, represents an additional potential revenue pathway for industrial demand-side resources, though its current eligibility framework primarily targets BESS and generation assets.

In Bulgaria, the economic conditions for industrial flexibility are structured differently from the other pilot countries, reflecting the specific institutional position of the Stomana industrial cluster as a direct market participant. Stomana Industry acts as a Balancing Responsible Party (BRP) and Balancing Service Provider (BSP) with direct participation in IBEX's Day-Ahead and Intraday Markets. This BRP/BSP status means that the economic framework for flexibility at the cluster level is primarily one of portfolio optimisation - managing the combined consumption and production of Stomana, Etem Gestamp, and Sofia Med to minimise imbalance costs and optimise market positions - rather than one of explicit remuneration for flexibility services sold to the TSO.

Balancing energy prices in the Bulgarian market follow marginal pricing with regulatory price caps determined by EWRC. Historically, the Bulgarian balancing energy market has suffered from limited competition, with a small number of providers and instances of price convergence at the cap - conditions that undermine the economic attractiveness of flexibility participation for new entrants. The June 2025 ETR amendments introduced a new balancing price methodology, moving the price-setting rules out of the ETR itself into a separate regulatory instrument, with the objective of increasing transparency and market-based price formation.

The aggregate flexibility potential of the Bulgarian cluster has been estimated at approximately 26 GWh/year from the Stomana-led cluster alone (Stomana Industry, Etem Gestamp, Sofia Med), representing a substantial commercially exploitable resource. The cross-border UC#2 scenario - in which Bulgarian flexibility participates implicitly in IPTO's Greek balancing market through a certified Greek aggregator (PPC) - offers the prospect of accessing a more economically developed and competitively priced market environment than the current Bulgarian balancing framework provides. From a stakeholder perspective, the Bulgarian pilot actors have identified direct investment subsidies for infrastructure (BESS, advanced EMS), reduced network charges for verified flexibility providers, and capacity payments rewarding availability as the most important additional economic mechanisms that would improve the business case for industrial flexibility participation. The RESTORE programme - a €590 million EU Recovery and Resilience Facility allocation for 3,000 MWh of energy storage capacity - represents a significant public investment signal in this direction.

4.4 Social and Organisational Aspects

Social and organisational dimensions capture the degree of awareness, internal readiness, and workforce capabilities within industrial enterprises, as well as the broader social and institutional context within which flexibility decisions are taken. Across all four national contexts, a consistent pattern emerges from the evidence gathered: large energy-intensive industrial consumers with established energy management functions tend to exhibit higher organisational readiness for flexibility market participation, while medium-sized enterprises face structural barriers related to internal skill gaps, absence of dedicated energy flexibility roles, and the complexity of simultaneously managing production processes and market

participation obligations. Risk aversion with respect to production disruption is a pervasive constraint across all countries, particularly in continuous-process industries.

In Italy, the stakeholder consultation carried out within the LEONARDO project reveals a significant spectrum of organisational readiness across the industrial actors engaged. At one end, the most experienced industrial respondents - notably a paper and energy company with direct participation in electrical interruptibility, gas interruptibility, the Capacity Market, and the UVAM balancing market - have developed mature internal flexibility management capabilities exploiting existing industrial assets at minimal CAPEX. At the other end, discrete manufacturers and smaller batch-process industries report limited familiarity with flexibility market mechanisms and identify process continuity and production planning constraints as the primary barriers to market participation.

The Italian industrial landscape engaged in flexibility markets spans a diverse range of process types: continuous-process industries (paper, petrochemicals, fermentation) exhibit minimal intrinsic process flexibility but may offer significant controllable loads through auxiliary systems and co-generation assets; discrete and batch manufacturers can engage primarily through load shifting and peak shaving; and energy asset owners combining on-site PV generation with BESS or electrolysers represent an emerging category of flexibility providers with a different risk profile. ISO 50001:2018 energy management system certification is relatively widespread among medium-to-large energy-intensive industries and provides a structured operational baseline for energy monitoring and internal optimisation, but does not by itself confer the market-facing capabilities required for balancing market participation.

Organisational barriers identified by Italian stakeholders include the high administrative burden of onboarding resources into flexibility mechanisms - covering sensitive data management, asset qualification procedures, and the fiscal and invoicing complexity of distributing revenues across multiple assets or sub-entities - which is disproportionately burdensome for smaller actors (small BSPs, Comunità Energetiche Rinnovabili, Autoconsumatori in forma associata) relative to large, established players. For aggregators, the need to estimate the verifiable aggregate power before offering in auctions, with a safety margin to minimise non-delivery risk, requires high-quality asset data, reliable forecasting tools, and operational discipline that not all industrial actors currently possess. The Storo pilot cluster, managed by CEDIS as both a DSO and a BSP, presents a distinctive organisational configuration: the integration of DSO and market-participation roles within a single cooperative entity creates both specific opportunities - greater information symmetry between grid management and flexibility activation - and specific challenges, including the need to manage potential conflicts of interest between the regulatory DSO function and the commercial BSP function.

In Austria, the social and organisational landscape for industrial flexibility is characterised by a moderate baseline awareness among larger industrial companies. Many Austrian industrial enterprises are already familiar with the concept of balancing market participation through intermediaries or through existing utility relationships, and a number have direct or indirect experience with TSO-level flexibility markets. However, the translation of awareness

into active participation is constrained by organisational factors: energy management decisions in Austrian industry are typically taken by small in-house energy teams or, in some cases, delegated to external energy consultants, and the functions of production planning, energy management, and market participation are rarely integrated within a single organisational unit.

The Austrian pilot region in Southeastern Styria presents specific social characteristics that are relevant for the LEONARDO pilot. The pilot involves two industrial actors - Fleischhof (a food industry facility with flexible refrigeration and ventilation loads) and Gsellmann (a biomass processing facility with flexible mill and press loads) - whose flexibility profiles differ significantly from large energy-intensive process industries. Both companies operate within a local value chain coordinated by Kiendler (the local DSO and grid operator for the area) and EVON (the EMS provider), supported by ENES as the service provider for billing, metering, and market access. This constellation reflects a social model of flexibility participation that is more cooperative and locally embedded than the large-industrial model prevalent in Italy or Greece, and in which the organisational integration of flexibility functions depends critically on the coordination capacity of the DSO as a local intermediary.

EMS solution providers active in the Austrian industrial market - including AIT Austrian Institute of Technology, Siemens, ABB, Schneider Electric, and domestic specialists - play a significant social and organisational role in enabling flexibility participation, since they provide the interface between the physical process and the market, and often substitute for in-house technical capabilities that industrial SMEs do not possess. Lessons from Austrian research projects (NEFI - New Energy for Industry, Green Energy Lab, and AIT programmes) consistently indicate that technical readiness is necessary but not sufficient for flexibility activation: well-defined market interfaces, clear liability and contract frameworks, and organisational processes for handling dispatch signals without disrupting production are equally critical preconditions.

In Greece, the social dimension of flexibility participation is predominantly shaped by the risk profile of the energy-intensive industries involved. HELLENiQ ENERGY's Thessaloniki refinery is a continuous hydro-skimming refining facility where load adjustments follow strict protocols to ensure operational safety. The company has prior experience with a national load-shedding programme (2015) and operates under the ISO 50001 framework, which represents a meaningful organisational baseline.while the awareness levels and familiarity with flexibility concepts or demand-response participation is enhanced by its aggregator’s experience. Enerwave, a subsidiary company of HELLENiQ ENERGy, reported the highest level of familiarity on a self-assessed scale from one (limited knowledge) to five (expert level), consistent with its operational role as a certified demand-response provider in the Greek market.

The aggregator (in the BG/GR pilot, Public Power Corporation (PPC) is the one for the Greek market side) plays a critical social and organisational intermediation function: it translates market signals into actionable dispatch instructions, manages prequalification and performance monitoring, and shields the industrial client from direct exposure to the operational complexity of TSO interaction. The risk aversion specific to continuous-process industries - where the cost of unplanned production interruption can reach approximately

€900/MWh including production losses, quality degradation, and equipment recovery costs - creates a structural social reluctance to engage with real-time activation signals that is only partially addressable through improved technology and automation.

In Bulgaria, the Stomana industrial cluster presents a comparatively structured organisational approach to energy management. Within the cluster, Stomana Industry acts as the internal aggregator and Balancing Responsible Party, coordinating the energy nominations and market positions of the three affiliated companies (Stomana, Etem Gestamp, Sofia Med). The cluster's BRP/BSP status implies that market-facing organisational capabilities - including the daily alignment of production schedules with energy nominations, peak-load management through the avoidance of simultaneous start-ups of high-power equipment, and intra-group financial optimisation - are already institutionalised to a meaningful degree at the cluster coordinator level.

However, the cluster's organisational readiness for external flexibility market participation - particularly in the context of explicit balancing market products or cross-border aggregation - is more limited. Within the affiliated companies (Etem Gestamp, Sofia Med), energy management responsibilities are not specifically oriented toward flexibility provision for third-party markets, and the decision-making logic is primarily focused on minimising energy costs within the corporate balancing arrangement. The production-continuity imperative is particularly acute in steel and metallurgy - Stomana's Electric Arc Furnaces and Ladle Furnaces represent high-power, safety-critical equipment where interruption carries significant process risk - and creates organisational resistance to flexibility commitments that would constrain production scheduling autonomy. Limited awareness of demand-side flexibility business models and market mechanisms among industrial management, and the absence of dedicated flexibility management roles, are identified as structural social barriers that would need to be addressed through capacity building and institutional engagement to unlock the full potential of the cluster's flexibility resources.

4.5 Technological Readiness

Technological readiness encompasses the maturity of energy management systems (EMS), metering infrastructure, automation and control capabilities, communication protocols, and digital integration tools present at industrial sites and across the national industrial base. The level of technological readiness directly determines the feasibility and implementation cost of the monitoring, control, and communication functions required for flexibility market participation. Crucially, evidence across all four pilot countries indicates that the primary technological barrier to flexibility activation is typically not the absence of physical load modulation capacity - most energy-intensive industrial processes possess latent flexibility in their consumption patterns - but rather the insufficiency of the digital infrastructure required to make that capacity measurable, verifiable, and market-ready in real time.

In Italy, large and medium-sized industrial enterprises widely deploy SCADA systems, PLC-based automation, and Energy Management Systems, with ISO 50001:2018 certification providing a structured operational baseline for energy monitoring in a significant share of energy-intensive sites. Communication standards commonly used at equipment level

include Modbus and OPC-UA; MQTT and REST APIs are increasingly adopted for integration with cloud platforms, aggregation systems, and market interfaces. Interoperability frameworks are shaped by IEC standards - particularly IEC 61850 for power system communication and IEC 62351 for cybersecurity in energy systems - as well as emerging EU data infrastructure requirements under the Energy Data Act and the Data Act.

Lessons drawn from the UVAM framework and Terna's MSD operational experience consistently indicate that the principal technological barriers relate to telemetry requirements, minimum performance standards, response latency constraints, and the integration costs associated with legacy monitoring and control systems, rather than to the absence of load modulation capability per se. Industrial actors with legacy SCADA systems that lack open API interfaces or real-time communication capabilities face significant - and potentially prohibitive - upgrade costs to achieve the telemetry standard required for balancing market prequalification. This creates a technological stratification: large, capital-intensive industrial facilities with modern EMS can participate directly or through aggregators at relatively low marginal technological cost, while medium-sized enterprises with heterogeneous digitalisation levels face barriers that require dedicated technology investment and technical support to overcome. The iFAAP platform's role as an integration layer between heterogeneous EMS environments and market interfaces is directly relevant to addressing this structural technological gap.

Cybersecurity obligations under GDPR and the NIS2 Directive (EU 2022/2555) impose additional technological requirements on industrial actors participating in digitalised flexibility schemes, as the connectivity between industrial control systems and external platforms creates potential attack surfaces that must be managed in accordance with sector-specific cybersecurity standards. For industrial actors in the energy sector, NIS2 substantially strengthens risk management, incident reporting, and supply chain security obligations, with direct implications for the architecture of flexibility platforms and the contractual allocation of cybersecurity responsibilities between industrial clients, aggregators, and platform operators.

For the Storo cluster, the integration of different EMS providers within the CEDIS DSO ecosystem will represent the main challenge that the iFAAP should address throughout the project. In parallel, the iFAAP is expected to support and facilitate the activities of local stakeholders, many of whom will be engaging with flexibility services and market activities for the first time.

In Austria, the technological landscape for industrial flexibility is characterised by a solid EMS infrastructure base among larger industrial consumers, with widespread deployment of solutions from established providers including Siemens, ABB, Schneider Electric, and domestic providers such as Moon Power and Weidmüller. Communication protocols include Modbus, OPC-UA, and BACnet at field level, with REST API and MQTT for cloud and market integration. The Austrian Institute of Technology (AIT) has developed dedicated EMS tools for industrial applications and has been involved in research programmes exploring the integration of industrial EMS with flexibility market interfaces.

The main technological challenges in the Austrian pilot context concern interoperability across heterogeneous EMS and SCADA environments, real-time communication capabilities for dispatch signal transmission and performance monitoring, and secure data exchange with external platforms - particularly in the context of the NIS2 Directive's requirements for energy sector entities. Several national research and demonstration projects have generated relevant technological lessons: the Green Energy Lab project, which develops digital solutions for connecting market actors and enabling flexibility services; the NEFI - New Energy for Industry programme, which applies data-driven approaches for the optimisation of industrial energy systems; and GAIA-X Austria, which supports the development of secure and interoperable data spaces with potential energy-sector applications. These programmes collectively indicate that Austria possesses a strong technological innovation capacity in the DSF domain, even if translating this capacity into routine commercial deployment at industrial scale remains a work in progress.

For the specific pilot context of Southeastern Styria, the technological integration challenge is compounded by the involvement of multiple actors with different system architectures: EVON as the EMS provider for the industrial actors, ENES as the data management and market interface platform, Kiendler as the DSO with its own grid management systems, and the LEONARDO iFAAP platform as the overarching flexibility optimisation and market interface layer. Achieving real-time, secure, and standards-compliant data flows across this multi-actor technical architecture is a key technological challenge for the Austrian pilot.

In Greece, technological readiness is heterogeneous across the industrial sector, with a significant gap between the technology infrastructure of large energy-intensive consumers and the broader industrial base. HELLENiQ ENERGY's Thessaloniki refinery operates a Protasis Zenon EMS system connected to IPTO's grid, supported by an extensive array of telemetry equipment and real-time data collection systems spanning the refinery's major energy-consuming processes. This infrastructure places HELLENiQ ENERGY at the higher end of technological readiness within the Greek industrial landscape, and is a significant enabling condition for the BG/GR pilot's Greek component.

More broadly, Greek industrial facilities deploy a range of EMS and process control solutions, with significant heterogeneity depending on firm size and sector. Common communication standards follow international norms (OPC-UA, Modbus at equipment level; MQTT and REST APIs for external interfaces), while cybersecurity requirements for energy sector entities follow ISO/IEC 27001:2022 and NIS2 frameworks, with additional specific guidance expected from RAAEY as the national regulatory authority. Greece has been a participant in several EU research and demonstration projects addressing cross-border flexibility trading in Southeast Europe - including CROSSBOW, FLEXITRANSTOREand OneNet - which have generated technological and operational experience relevant to the BG/GR pilot's cross-border use case, particularly with respect to the technical mechanisms for cross-border balancing capacity exchange and the interoperability requirements for cross-border market participation.

In Bulgaria, the Stomana industrial cluster operates Schneider Electric EMS platforms for energy monitoring and process control across all three cluster facilities (Stomana Industry,

Etem Gestamp, Sofia Med). The facilities are connected to the 110/150/220 kV transmission grid with the metering infrastructure required for Stomana's role as BRP and BSP in IBEX markets already in place and compliant with ESO's technical requirements. All three companies deploy extensive submetering and process automation systems, providing a solid technological foundation for real-time flexibility monitoring and dispatch.

Communication protocols follow standard industrial norms (Modbus TCP/IP, OPC, EtherNet/IP), and cybersecurity compliance follows ISO/IEC 27001:2022 and NIS2 requirements, with secure communication protocols mandatory for data exchange between industrial EMS platforms and external aggregation and market systems. A significant technological gap relevant to the cross-border UC#2 scenario is the absence of an operational national energy data space in Bulgaria: digital energy data infrastructure development is at an earlier stage compared to Western European countries, and clear contractual definitions of data governance responsibilities - particularly for cross-border data exchange - will need to be established before the cross-border aggregation model can be operationally implemented. The forthcoming RESTORE programme investments in 3,000 MWh of energy storage capacity are expected to drive significant technological upgrades in the Bulgarian electricity system, with potential positive spillover effects for the data and communication infrastructure required for industrial flexibility participation.

4.6 Legislative and Regulatory Framework

The legislative dimension covers the specific laws, regulatory decisions, market rules, technical codes, and grid codes that define the formal conditions for industrial flexibility participation at national level. Across all four pilot countries, the legislative framework is built on the transposition obligations of the Clean Energy Package (Directive 2019/944 and Regulation 2019/943), which mandate non-discriminatory market access for demand response and establish the legal status of independent aggregators. The 2024 Electricity Market Design Reform (Directive 2024/1711 and Regulation 2024/1747) has introduced additional legislative obligations - including the mandatory establishment of DSO-level flexibility markets and the reinforcement of independent aggregator rights - whose transposition is ongoing and will significantly shape the national frameworks over the coming years.

In Italy, the legislative framework for industrial flexibility is built on the transposition of Directive 2019/944 through Legislative Decree 210/2021 and the direct applicability of Regulation 2019/943. At the regulatory level, ARERA's Resolution 300/2017/R/eel and its subsequent amendments established and progressively refined the UVAM (Unità Virtuali Abilitate Miste) scheme, enabling aggregated distributed resources - including industrial loads - to provide ancillary services within the MSD operated by Terna. The TIDE reform (2025) absorbs and supersedes the UVAM framework, extending market access for aggregated and virtual units and introducing updated rules for baseline calculation, performance verification, and settlement.

At the DSO level, the key regulatory instruments are ARERA Resolution 352/2021/R/eel (as further specified by Resolution 484/2023), which established the general framework for

DSO-level local ancillary service procurement and TSO–DSO coordination, and Resolution 372/2023 (amended by Resolution 118/2024), which instituted the Mercato Locale della Flessibilità (MLF) managed by GME. The MLF is structured into a forward segment (MLT-FLEX, typically one month ahead) and a spot segment (MLP-FLEX, comprising a day-ahead component, MGP-Flex, and an intraday component, MI-Flex, the latter not yet fully operational). Remuneration across all MLF segments follows a pay-as-bid mechanism. The three authorised pilot initiatives - EDGE, RomeFlex, and MiNDFlex - are implementing these frameworks in different regional contexts and are expected to generate the regulatory evidence base for the permanent institutionalisation of local flexibility markets under Directive 2024/1711.

Independent aggregators are formally recognised under Article 17 of Directive 2019/944 as transposed into Italian law, with the right to operate without mandatory agreement with the customer's electricity supplier. However, Italian implementation requires aggregators to coordinate with the relevant electricity supplier for the purposes of preventing double-charging and ensuring the integrity of baseline calculation methodologies - an obligation that, while necessary from a market design perspective, adds contractual and operational complexity to aggregation arrangements and may discourage entry by smaller or less experienced aggregators. Data protection and cybersecurity obligations applicable to flexibility platforms and energy service providers are governed by GDPR, NIS2, and the applicable IEC technical standards. The forthcoming transposition of the Data Act is expected to further shape data access and portability frameworks in ways that are relevant for platform-based flexibility services.

In Austria, the legislative framework is structured around the Elektrizitätswirtschaftsgesetz (ElWOG 2010, as amended through subsequent legislative reforms), which transposed the EU electricity market directives and regulates market organisation, grid access, consumer rights, and the obligations of market participants. In parallel, Austria recently adopted the new Elektrizitätswirtschaftsgesetz (ElWG), which further strengthens the regulatory framework for active customers, aggregation and flexibility-oriented market participation, while several implementation-related and operational details are still evolving. The E-Control Act defines the competences of E-Control as the national regulatory authority. Technical and operational requirements for grid users - including prequalification criteria, communication standards, and performance verification obligations for balancing market participants - are specified through the Technical and Organisational Rules for Operators and Users of Networks (TOR, Technische und Organisatorische Regeln für Betreiber und Benutzer von Netzen), issued by APG under E-Control oversight.

A distinctive feature of the Austrian legislative framework is that it does not establish a standalone legal category exclusively for aggregators. Entities performing aggregation functions must comply with existing electricity market rules and operate through recognised market roles - supplier, trader, balancing responsible party, or energy service provider - while also satisfying the technical requirements applicable to balancing market participation. This embedded model creates a workable legal basis for aggregation but reduces regulatory clarity compared to countries that have established dedicated aggregator licensing frameworks. Network tariffs do not include explicit incentive components for demand-side

flexibility, but peak demand and capacity-related tariff elements provide indirect cost-reduction incentives for load-shifting and peak-shaving behaviour.

Austria has not yet enacted the regulatory instruments required by Directive 2024/1711 for the mandatory establishment of DSO-level local flexibility markets. The transposition of this directive represents a significant forthcoming legislative development, and the specific design of Austrian DSO flexibility market rules - including the definition of eligible resources, procurement mechanisms, and TSO–DSO coordination frameworks - will be a critical determinant of the long-term regulatory environment for the Austrian pilot context. Additional legislative developments relevant to flexibility include the progressive implementation of smart metering obligations, the transposition of the NIS2 Directive's cybersecurity requirements for energy sector entities, and the expected application of the EU Data Act to industrial flexibility platforms and connected devices.

In Greece, the overarching electricity market framework is established by Law 4001/2011 (as extensively amended), which provides the general framework for electricity market organisation and the roles of market participants, supplemented by Law 4512/2018 (which introduced the Target Model and established HEnEx as the market operator) and Law 4643/2019 (which facilitated HEnEx operations and further promoted market liberalisation). RAAEY (formerly RAE) exercises regulatory oversight and issues licences for market participants, including aggregators.

Greece has implemented one of the most developed independent aggregator frameworks in the EU. The concept of aggregation entities - referred to as Φορείς Ολοκληρωμένης Συνάθροισης Ευέλικτης Ζήτησης (FOSE, Aggregation Representative Entities) - was introduced under Greek energy law and progressively extended from RES aggregation to demand-side resources. Under this framework, industrial consumers can participate in balancing markets either directly as Balancing Service Providers (BSPs) or through certified independent aggregators, without the mandatory agreement with the incumbent electricity supplier that characterises less advanced implementations in other Member States. Greece is identified by the JRC and smartEn monitoring as one of only four EU countries where explicit demand-side flexibility through an independent aggregator is operationally established.

Balancing market participation is governed by the IPTO Balancing Market Rulebook and the HETS (Hellenic Electricity Transmission System) Grid Code, which define eligibility criteria, prequalification requirements (including a 24-hour baseline test demonstrating response capability and real-time telemetry covering at least 50% of declared capacity), baseline methodologies, performance verification mechanisms, and settlement procedures. No formal DSO-level local flexibility market currently exists in Greece, though this will be required under Directive 2024/1711. The cross-border dimension of UC#2 is governed by ENTSO-E cross-border balancing platform rules (PICASSO for aFRR, MARI for mFRR) and by the interconnection capacity allocation mechanisms applicable to the Greece–Bulgaria 400 kV transmission line (Nea Santa–Maritsa East), as well as by the forthcoming Network Code on Demand Response (expected 2027, ACER proposal March 2025), which will

establish harmonised technical requirements for cross-border demand-side flexibility participation.

In Bulgaria, the legislative framework is built on the Energy Act (Zakon za energetikata, last significantly amended in May 2025), which establishes the general rules for electricity market organisation, licensing, tariff regulation, and market participants' obligations. EWRC is the national regulator and is responsible for adopting the Electricity Trading Rules (ETR), setting network tariffs, and issuing licences. ESO EAD, a subsidiary of the state-owned Bulgarian Energy Holding, operates the transmission system and the balancing market.

A significant legislative development is the June 2025 revision of the ETR, which introduced a new balancing price methodology (removed from the ETR itself into a separate regulatory instrument for greater flexibility), abolished the combined balancing groups previously used for RES producers and co-generation plants, created new contract types including contracts for clearing services, and implemented several other provisions mandated by EU Regulation 2019/943 and Directive 2019/944. These amendments represent a meaningful step in the alignment of Bulgarian market rules with EU requirements, but important gaps remain: explicit demand response products at TSO or DSO level have not yet been established, the independent aggregator framework introduced following Directive 2019/944 transposition is recognised in law but practically underdeveloped, and no DSO-level local flexibility market framework exists.

The JRC's 2022 assessment identified Bulgaria as a country where independent aggregation has only recently been introduced, with barriers including the absence of a fully functional compensation mechanism between aggregators and incumbent suppliers, limited smart meter deployment, and an unconvincing business case for aggregation of smaller resources. For large industrial consumers such as Stomana - which participates directly in IBEX as a BRP and BSP and does not require an external aggregator for its own market participation - the aggregator model is most relevant for cross-border transactions and for the optimisation of intra-cluster flexibility across multiple legally distinct industrial entities. The forthcoming Network Code on Demand Response (ACER proposal, March 2025, expected 2027) will introduce harmonised EU-level requirements for demand-side flexibility prequalification, baseline calculation, and cross-border participation, with significant implications for Bulgaria's market design and ESO's operational requirements.

4.7 Environmental Drivers

Environmental drivers reflect the decarbonisation objectives, renewable energy integration pressures, and climate policy commitments that create structural demand for demand-side flexibility as a system-level resource. Across all four pilot countries, the growth of variable renewable generation capacity is the primary environmental factor driving the need for industrial flexibility: as wind and solar capacity expands, the temporal mismatch between supply and demand increases, balancing reserve requirements grow, and curtailment events - wasteful from both an economic and an environmental perspective - become more frequent. Industrial flexibility, by providing adjustable demand that can absorb surplus renewable generation or reduce consumption during periods of scarcity, contributes directly

to the efficient integration of variable renewables and to the achievement of national decarbonisation targets.

In Italy, decarbonisation targets embedded in the PNIEC set a trajectory toward 65% renewable electricity by 2030 and net-zero greenhouse gas emissions by 2050. The rapid growth of solar PV capacity - particularly in Southern Italy and in the islands - is already generating localised curtailment events and intraday price volatility that create direct economic and operational incentives for demand-side flexibility. In Northern Italy, where the LEONARDO pilot cluster is located (Storo, Trentino-Alto Adige), the environmental context is shaped by the significant existing share of hydropower in the regional generation mix and by the growing penetration of distributed PV generation, which creates specific local congestion and voltage management challenges at the DSO level.

The Italian pilot's distinctive feature from an environmental standpoint is the integration of DSO and BSP functions within CEDIS, which positions the Storo cooperative at the nexus of local renewable generation management and industrial flexibility activation. The potential for islanded or microgrid-compatible operation - enabling the local energy system to operate autonomously during grid emergencies - represents an emerging environmental and resilience co-benefit that is not yet formally explored within the current market framework but is of considerable strategic relevance for industrial clusters in areas with significant hydropower and distributed renewable resources. The PNIEC's decarbonisation objectives for energy-intensive industry, combined with the national framework for White Certificates (TEE) and the evolving regulatory framework for renewable energy communities, provide additional environmental policy anchors for flexibility investment decisions.

In Austria, the 100% renewable electricity target by 2030 under the EAG represents the dominant environmental driver for flexibility deployment. Achieving this target requires a substantial increase in variable renewable capacity - primarily wind and solar PV - which in turn demands a corresponding expansion of balancing resources and grid management capabilities. The Austrian pilot region in Southeastern Styria is characterised by significant and growing PV penetration at distribution level, with Gsellmann operating 3 MWp of on-site PV capacity and Fleischhof planning additional PV installations within the project. This local renewable generation creates specific congestion and voltage management challenges in Kiendler's distribution network - precisely the type of local grid constraint that DSO-level flexibility markets are designed to address.

The Climate and Energy Fund (Klima- und Energiefonds) provides financial support for energy transition projects, including those combining renewable generation with flexible demand management, and has funded a number of demonstration projects relevant to the Austrian pilot context. The environmental co-benefit of industrial flexibility in Austria is therefore twofold: it supports the integration of increasing renewable generation at both transmission and distribution level, and it contributes to the decarbonisation of energy-intensive industrial processes by enabling more efficient use of renewable electricity and reducing the need for fossil-fuel-based balancing resources. The intersection of local renewable generation and industrial flexibility is a defining characteristic of the Austrian pilot design and is directly reflected in the use case architecture developed within LEONARDO.

In Greece, the environmental dimension of flexibility is exceptionally salient, given the combination of an extraordinarily ambitious RES expansion trajectory and the associated increase in curtailment events. Greece's updated NECP sets a 76.8% renewable electricity target for 2030, but actual installed RES capacity is projected to reach 34 GW by 2030 - significantly exceeding the NECP target of 24.7 GW - driven by an accelerated solar PV rollout that reflects both declining technology costs and favourable solar irradiation conditions. Curtailment of renewable generation has become an increasingly frequent operational reality in the Greek system, particularly during midday hours with high solar output and low demand, generating both economic waste (curtailed renewable energy that could displace fossil generation) and grid stability challenges for IPTO.

Industrial demand-side flexibility is directly relevant to addressing this curtailment problem: flexible industrial loads that can absorb surplus renewable generation during high-RES periods reduce the need for curtailment, improve the economic utilisation of renewable capacity, and contribute to system balancing at reduced cost. Law 5106/2024 on RES curtailment and BESS specifically addresses this challenge at the legislative level, and the Ministerial Decision 28255/1143/2025 on standalone BESS grid connections signals the policy priority attached to storage and demand-side resources as instruments for managing the integration challenges associated with rapid RES expansion. Greece's climate neutrality target for 2050 (Law 4936/2022) provides the long-term environmental horizon within which investments in industrial flexibility are evaluated and justified.

For the BG/GR pilot, the environmental rationale for cross-border flexibility is particularly compelling: by enabling implicit participation of Bulgarian industrial flexibility in the Greek balancing market through the Nea Santa–Maritsa East interconnection, UC#2 promotes the more efficient allocation of flexibility resources across the two national systems, reduces curtailment in the Greek system, and contributes to the decarbonisation of both grids through more efficient renewable energy utilisation.

In Bulgaria, environmental drivers are shaped by a structural energy transition that requires progressive coal phase-out and substantial renewable expansion, embedded in a challenging political and economic context characterised by significant legacy investments in coal infrastructure. The updated NECP (2025) sets a 35% renewable energy target in gross final consumption and 49.3% for the electricity sector by 2030, representing a significant increase from historical levels and implying a major transformation of the generation mix. Installed solar PV capacity doubled to 2.2 GW by 2024 and continues to grow rapidly, generating new system integration challenges that demand-side flexibility is well positioned to address.

The Stomana industrial cluster's environmental profile is double-edged: as a large energy-intensive manufacturing facility, it is one of Bulgaria's top five electricity consumers and a significant contributor to national industrial energy demand. At the same time, the cluster's participation in demand-side flexibility markets contributes to the decarbonisation of the Bulgarian electricity system by enabling a more efficient and flexible integration of renewable generation capacity. The RESTORE programme - a €590 million EU Recovery and Resilience Facility investment in 3,000 MWh of energy storage capacity - represents a major

environmental policy signal, directed at enabling the Bulgarian electricity system to accommodate higher shares of variable renewables by providing additional balancing resources.

ESO's Ten-Year Network Development Plan projects over 23 GW of new generation capacity (predominantly renewables) for the 2025–2034 period, which would more than double the current installed capacity and create a substantially more flexibility-intensive system operation environment. In this context, the development of industrial demand-side flexibility through mechanisms such as those explored in the LEONARDO BG/GR pilot represents not only a business opportunity for the Stomana cluster, but a strategic contribution to the environmental and grid stability objectives of Bulgaria's energy transition.

4.8 National Market Structures and Flexibility Participation Conditions

4.8.1 Italy - Pilot Site #1 (Storo Industrial Cluster, Trentino-Alto Adige)

Market structure and institutional actors

The Italian electricity market is one of the most liquid and institutionally developed in the EU. The wholesale market is operated by the Gestore dei Mercati Energetici (GME) and comprises a Day-Ahead Market (Mercato del Giorno Prima, MGP), an Intraday Market (Mercato Infragiornaliero, MI, with seven sessions), and a forward market segment. Italy participates in the EU Single Day-Ahead Coupling (SDAC) and Single Intraday Coupling (SIDC) platforms. The transmission system is operated by Terna S.p.A., which also manages the Mercato dei Servizi di Dispacciamento (MSD) - the national ancillary services market - and is responsible for system balancing and dispatching. Distribution network management is fragmented among multiple DSOs, of which E-Distribuzione (Enel Group) is by far the largest nationally. In the Storo pilot region, the DSO role is held by CEDIS (Consorzio Elettrico di Storo), a local electricity cooperative that simultaneously acts as DSO, electricity supplier, BRP, and BSP - an institutional configuration shared with a few other historical electric cooperatives in the country and one that creates specific opportunities for integrated local flexibility management. The national energy regulator is ARERA, which defines tariff structures, market rules, and consumer rights, while GME manages both the wholesale market and, since 2023, the Mercato Locale della Flessibilità (MLF) for DSO-level procurement.

Flexibility mechanisms and participation conditions

Since January 2025, the Italian flexibility market framework has been consolidated under the new Testo Integrato del Dispacciamento Elettrico (TIDE), which superseded the previous UVAM scheme and the interruptibility service and represents the primary access pathway for industrial demand-side resources to TSO-level balancing products. Under TIDE, aggregated industrial resources can participate in three standard balancing products: aFRR (automatic Frequency Restoration Reserve), mFRR (manual Frequency Restoration Reserve), and Replacement Reserve (RR). These products are procured by Terna through competitive tenders within the MSD, with eligibility conditional on satisfying technical prequalification requirements including a minimum aggregated bid size of 1 MW, real-time telemetry integration compliant with Terna's technical specifications, a validated baseline

calculation methodology, and demonstrated response capability through performance testing.

Beyond standard balancing products, TIDE has absorbed the former interruptibility service as an extraordinary upward modulation mechanism, which provides contracted availability for fast industrial load reduction in exchange for a fixed availability fee supplemented by activation payments - making it particularly relevant for large continuous-process industries capable of rapid and significant load reduction. The Italian Capacity Market, established by the Ministerial Decree of 28 June 2019, provides an additional revenue stream through availability-based capacity payments under 1-year or 3-year contracts, and is open to demand-side resources with sufficient controllability and response speed. The Capacity Market is notable for providing more predictable revenue than activation-only balancing market products, and is accordingly identified by Italian industrial stakeholders as one of the most financially attractive flexibility mechanisms.

At the DSO level, the Mercato Locale della Flessibilità (MLF), governed by ARERA Resolution 372/2023 and managed by GME, provides a framework for local flexibility procurement by DSOs. The MLF is structured into a forward segment (MLT-FLEX, with monthly procurement auctions) and a spot segment (MLF-FLEX, comprising a day-ahead component, MGP-Flex, and an as yet not fully operational intraday component, MI-Flex). Remuneration in all MLF segments follows a pay-as-bid mechanism with dual-component availability and activation payments. As of 2025, the MLF is operational only in three pilot areas - EDGE (E-Distribuzione), RomeFlex (Areti/ACEA), and MiNDFlex (Unareti/A2A) - with their experience expected to inform ARERA's decisions on permanent national rollout under Directive 2024/1711. For the Storo pilot, the CEDIS configuration as combined DSO and BSP places the cluster at the intersection of TSO-level and DSO-level flexibility markets, creating a test case for multi-level simultaneous participation that is directly relevant to the LEONARDO project's research objectives.

Industrial consumers can participate in TSO-level balancing markets either directly or through an independent aggregator. Independent aggregators are legally recognised in Italy under the transposition of Directive 2019/944, but must coordinate with the industrial customer's electricity supplier to prevent double-counting of imbalance positions and ensure baseline integrity - a coordination obligation that adds contractual complexity to aggregation arrangements but does not preclude independent operation. Complementary economic instruments available to Italian industrial flexibility actors include White Certificates (Titoli di Efficienza Energetica) for certified energy savings, reduced network charges for qualifying highly energy-intensive consumers (imprese elettrivore and gasivore schemes), the Energy Release mechanism for below-market energy access, and the Iperammortamento 2026 provision for accelerated depreciation of qualifying energy management investments.

Country-specific conditions affecting engagement of large electricity consumers

Several national conditions specifically shape the engagement of large industrial consumers with flexibility markets in Italy. The 1 MW minimum bid threshold for TSO-level balancing products under TIDE requires either sufficient individual load controllability or effective aggregation by a third party, which in practice makes direct participation accessible only to

the largest industrial consumers and constrains smaller industrial sites to aggregated pathways. The coordination obligation between the independent aggregator and the electricity supplier - necessary for baseline and imbalance management purposes - adds a contractual layer that increases transaction costs and can discourage aggregator entry, particularly for smaller players seeking to serve fragmented industrial portfolios. Revenue predictability is a further structural condition: activation-only payment structures in balancing markets create income uncertainty that discourages upfront investment in flexibility-enabling infrastructure, while the dual-component availability plus activation model of the Capacity Market and MLF pilot schemes is identified by industrial stakeholders as significantly more attractive for long-term investment planning.

The institutional configuration of CEDIS in the Storo pilot context is a country-specific condition with no direct equivalent in the other pilot countries. By internalising within a single cooperative entity the DSO, supplier, BRP, and BSP functions, CEDIS substantially reduces the multi-party coordination friction that characterises flexibility market engagement for most Italian industrial clusters. This configuration gives the pilot direct access to both TSO-level MSD and DSO-level MLF, positions it to explore simultaneous multi-level market participation, and allows grid-level and market-level optimisation to be coordinated within a single institutional actor. Additional country-specific conditions relevant to large consumer engagement include the availability of complementary economic instruments - White Certificates, imprese elettrivore tariff relief, Energy Release, and Iperammortamento - that supplement market revenues and improve the overall economics of flexibility infrastructure investment, and the relatively high exposure of Northern Italian industry to wholesale market price volatility, which creates a structural economic motivation for active demand-side management.

4.8.2 Austria - Pilot Site #2 (Southeastern Styria)

Market structure and institutional actors

The Austrian electricity market is fully integrated into the Central Western European (CWE) price zone and participates in the EU SDAC and SIDC coupling platforms. Wholesale market trading is accessible through the EXAA exchange and EPEX SPOT for day-ahead and intraday transactions. The transmission system is managed by Austrian Power Grid (APG), a subsidiary of Verbund AG and the sole national TSO, which is also responsible for the procurement and operation of all TSO-level balancing markets. Distribution grids are managed by regional DSOs; in the Southeastern Styria pilot region, the relevant local DSO is Kiendler, which manages the distribution network in the pilot area and plays an active coordination role within the LEONARDO pilot value chain. The national energy regulator is E-Control, which oversees market rules, network tariff regulation, consumer rights, and the licensing of market participants. ENES, an energy service company active in the pilot region, provides billing, metering management, and market trading services that function as a key interface between the pilot industries and the wholesale and balancing markets.

Flexibility mechanisms and participation conditions

APG procures three standard balancing products through competitive tenders, all of which are in principle accessible to demand-side resources meeting the applicable prequalification

criteria. Frequency Containment Reserve (FCR) is a symmetric product requiring automatic activation within 30 seconds of a frequency deviation; it is tendered weekly and procured at European level through the FCR Cooperation platform. FCR is technically the most demanding product for industrial demand-side resources, given the need for continuous automatic response to frequency signals. The automatic Frequency Restoration Reserve (aFRR), procured daily, requires automatic activation within 15 minutes and real-time integration with APG's Automatic Generation Control (AGC) system; it is exchanged cross-border through the PICASSO platform. The manual Frequency Restoration Reserve (mFRR), also procured daily, is activated manually upon APG's dispatch instruction within 12.5 minutes and exchanged cross-border through the MARI platform. Of these three products, mFRR is the most accessible for industrial demand-side participation, given its less stringent automation requirements and the greater compatibility of manual activation with industrial process management constraints.

Austria does not maintain a standalone legal category for aggregators: entities performing aggregation functions must comply with existing electricity market rules and operate through recognised roles - supplier, trader, or BRP - while satisfying the applicable technical prequalification requirements for balancing market participation. In practice, medium-sized industrial consumers typically access balancing markets through intermediaries - utilities, energy trading companies, or specialised flexibility platform operators - that aggregate their load modulation capacity alongside other resources, manage the market interface, and distribute revenues according to contractual arrangements. The business models currently observed in the Austrian market include aggregator–industrial client arrangements, utility-mediated demand response services, and ESCO-based contracting where an external provider finances and operates the enabling infrastructure.

Austria currently has no established regulatory framework for DSO-level local flexibility markets. The transposition of Directive 2024/1711, which makes such markets mandatory, represents a significant forthcoming development for the Austrian pilot context. In the absence of a DSO-level market, grid congestion in Kiendler's distribution network - increasingly driven by the high penetration of distributed PV generation in the Southeastern Styria region - is currently managed through network planning and reinforcement rather than through market-based flexibility procurement. The LEONARDO pilot is positioned to generate evidence on the potential for DSO-level industrial flexibility as an alternative congestion management instrument in this specific local context, contributing to the evidence base that will inform Austria's eventual DSO flexibility market design. Network tariffs do not include explicit bonus payments for demand-side flexibility, but peak demand and capacity-related tariff components provide indirect cost-reduction incentives for load-shifting and peak-shaving behaviour that supplement the revenue case for balancing market participation.

Country-specific conditions affecting engagement of large electricity consumers

The absence of a dedicated aggregator licence category is a country-specific condition with direct practical implications for large industrial consumers in Austria. Without a clearly defined aggregator role in national regulation, industrial actors seeking market access

through intermediaries face a less transparent contractual landscape in which the capabilities, obligations, and market roles of potential aggregation partners are not standardised. In practice, this means that the identification of a suitable intermediary - one combining technical EMS integration capability, market access infrastructure, and risk management capacity - requires individual due diligence that adds to the transaction cost of market entry. The Austrian pilot's specific institutional architecture, in which EVON provides EMS integration, ENES provides market access and billing, and Kiendler coordinates grid-level management, represents a cooperative solution to this structural condition that is relevant for the broader question of how SME-scale industrial flexibility can be organised in the absence of a dedicated aggregator framework.

The network tariff structure provides an important country-specific indirect incentive for large consumer engagement. Although no explicit bonus payments for demand-side flexibility exist in Austrian tariff regulation, peak demand and capacity-related components mean that industrial consumers capable of load shifting or peak shaving can reduce their network charge liabilities - a cost-avoidance motivation that supplements balancing market revenues and may lower the minimum revenue threshold at which flexibility infrastructure investment becomes commercially viable. The high PV penetration in the Southeastern Styria region creates an additional local condition: distribution-level congestion driven by midday PV generation creates a practical need for local demand-side flexibility management that the current regulatory framework does not yet address through market mechanisms, but which the LEONARDO pilot is designed to demonstrate and which Directive 2024/1711 will eventually require to be formalised. Economic uncertainty remains the most frequently cited structural barrier for large Austrian industrial consumers: the difficulty of estimating flexibility revenues in advance - given the variability of activation frequency, market prices, and prequalification outcomes - makes investment decisions in flexibility infrastructure contingent on a degree of risk tolerance that not all industrial actors are willing or able to accept.

4.8.3 Greece - Pilot Site #3, Part I (HELLENiQ ENERGY, Thessaloniki)

Market structure and institutional actors

The Greek electricity market is structured around a multi-segment architecture that integrates EU-level coupling platforms with national market institutions. The Day-Ahead Market (DAM) and Intraday Market (IDM) are operated by the Hellenic Energy Exchange (HEnEx) within the EU SDAC and SIDC frameworks. The Balancing Market (BM) is operated by the Independent Power Transmission Operator (IPTO/ADMIE) on a central dispatch basis with 15-minute Imbalance Settlement Periods (ISPs). The Hellenic Electricity Distribution Network Operator (HEDNO) manages the distribution grid nationally. Regulatory oversight is exercised by RAAEY (Regulatory Authority for Energy, Waste and Water, formerly RAE). Greece participates in the EU cross-border balancing platforms PICASSO for aFRR and MARI for mFRR, through which IPTO exchanges balancing capacity and energy with other European TSOs. PPC (Public Power Corporation), Greece's largest electricity company and a certified aggregator, plays a central institutional role in the BG/GR pilot as the designated aggregator for the cross-border UC#2 use case.

Flexibility mechanisms and participation conditions

The Greek balancing market provides access to three standard reserve products. FCR is procured through the EU FCR Cooperation platform under terms broadly equivalent to those of other participating TSOs. The aFRR is procured daily in six 4-hour blocks totalling approximately 300 MW; remuneration combines pay-as-bid capacity payments and marginal pricing for activation energy, with settlement on a 15-minute ISP basis. aFRR requires real-time AGC-compatible telemetry and automatic activation capability. The mFRR is procured daily in volumes of approximately 600 MW; it is manually activated upon IPTO's dispatch instruction and exchanged cross-border through MARI. Of the three reserve products, mFRR is the most accessible for industrial demand-side resources, given its compatibility with manual activation procedures and the longer notice period it affords for process adjustment. Beyond explicit balancing products, large industrial consumers can participate in the DAM and IDM as price-responsive loads, modulating their consumption in response to day-ahead and intraday price signals without requiring BSP prequalification - a form of implicit flexibility that HELLENiQ ENERGY already practises through its current market participation arrangement with the aggregator Enerwave, a subsidiary of HELLENiQ ENERGY.

Greece is one of only four EU Member States where explicit demand-side participation in wholesale markets through an independent aggregator is operationally established without a mandatory agreement between the aggregator and the customer's incumbent supplier. This places Greece among the most advanced demand-side flexibility environments in the EU and substantially reduces the contractual and institutional friction that characterises aggregator market entry in less developed national frameworks. Prequalification for balancing market participation as a Balancing Service Entity (BSE) requires a 24-hour baseline test demonstrating response capability, with at least 50% of declared capacity verifiable through real-time telemetry integration during testing; compliance with IPTO's metering and communication standards; formal registration with IPTO; and demonstration of financial standing. These requirements are technically demanding but operationally feasible for large industrial consumers with advanced EMS infrastructure, as is the case for HELLENiQ ENERGY's Thessaloniki refinery.

The Greek capacity mechanism, restructured through competitive tenders in 2023–2025, provides 10-year availability-based contracts that currently target primarily BESS and generation assets, but whose eligibility criteria are under review in the context of broader demand response policy development. For the cross-border UC#2 scenario, the participation of Bulgarian industrial flexibility in IPTO's balancing market through PPC as the certified Greek aggregator requires alignment with ENTSO-E cross-border balancing rules under the PICASSO and MARI platforms, management of interconnection capacity allocation on the Greece–Bulgaria 400 kV line (Nea Santa–Maritsa East), and a contractual framework governing the allocation of activation instructions, telemetry obligations, settlement proceeds, and liability between the Greek aggregator, the Bulgarian industrial cluster, and the respective TSOs. No formal DSO-level local flexibility market exists in Greece; its establishment will be required under Directive 2024/1711.

Country-specific conditions affecting engagement of large electricity consumers

The open independent aggregator framework is the most significant country-specific enabling condition for large consumer engagement in Greece. By eliminating the mandatory supplier agreement requirement that characterises less advanced EU implementations, the Greek framework substantially reduces the institutional friction between industrial consumers and aggregation services, and allows the market for aggregation to develop competitively without the coordination burden imposed by supplier involvement.

The process-specific constraints of continuous refining operations are a country-specific condition of a different kind: they define the operational envelope within which the refinery's flexibility can be offered, and directly shape the competitive attractiveness of its balancing bids. The timing, duration, and magnitude of load adjustments that can be implemented without compromising process safety and product quality are constrained by the thermally sensitive nature of crude distillation and secondary processing, and must be pre-defined through intelligent dispatch algorithms that identify exploitable flexibility windows in the refinery's operational schedule. The high and growing frequency of RES curtailment events in the Greek system - driven by the rapid expansion of solar PV capacity - creates an increasingly favourable economic environment for demand-side resources that can absorb surplus generation during midday hours, amplifying the market-based incentive for large consumer engagement. The Greek capacity mechanism, currently targeting primarily BESS and generation assets, represents an additional potential revenue pathway for qualifying industrial demand-side resources if its eligibility criteria are extended in the course of ongoing market design reform.

4.8.4 Bulgaria - Pilot Site #3, Part II (Stomana Industrial Cluster, Sofia)

Market structure and institutional actors

The Bulgarian electricity market is organised around the Independent Bulgarian Energy Exchange (IBEX), which operates the Day-Ahead Market (DAM), Intraday Market (IDM), and a bilateral contracts segment, and serves as the central counterparty for DAM and IDM transactions. ESO EAD (Electricity System Operator), a subsidiary of the state-owned Bulgarian Energy Holding, manages the transmission grid and operates the balancing market. EWRC (Energy and Water Regulatory Commission) is the national regulator responsible for adopting the Electricity Trading Rules (ETR), setting network tariffs, and issuing licences for electricity trading and balancing group coordination. A distinctive structural feature of the Bulgarian market is mandatory exchange trading: since 2021, all RES and co-generation plants with installed capacity of 500 kW or more are required to sell electricity through IBEX platforms - one of only two such requirements in the EU, alongside Romania.

The Stomana industrial cluster occupies an unusual institutional position within this market. Stomana Industry acts as a Balancing Responsible Party (BRP) and Balancing Service Provider (BSP), managing the combined energy portfolio of three legally distinct but affiliated industrial companies: Stomana Industry (steel, approximately 540 GWh/year, 140 MWp peak), Etem Gestamp (aluminium extrusion, approximately 16 GWh/year, 5 MWp peak),

and Sofia Med (copper alloys, approximately 54 GWh/year, 13 MWp peak). The cluster's combined consumption of approximately 610 GWh/year and peak capacity exceeding 158 MW place it among Bulgaria's five largest electricity consumers, giving it a market presence that is significantly larger than any other LEONARDO pilot actor.

Flexibility mechanisms and participation conditions

The primary market participation channel for the Stomana cluster is direct access to IBEX's DAM and IDM as a BRP, where Stomana Industry submits buy orders representing the aggregate consumption of the three cluster facilities. Portfolio optimisation within the balancing group - coordinating production schedules, managing deviations, and minimising imbalance costs across the three companies - constitutes the main form of operational flexibility currently exercised by the cluster. Settlement occurs on 15-minute ISPs, and imbalance prices are determined by ESO's balancing market mechanism under the ETR framework.

The Bulgarian balancing market, operated by ESO, has historically been characterised by limited competition and a small number of providers, with balancing energy prices subject to regulatory caps set by EWRC. The June 2025 ETR amendments, mandated by EU Regulation 2019/943 and Directive 2019/944, introduced a new balancing price methodology - removed from the ETR itself into a separate regulatory instrument to allow greater flexibility in price-setting - and abolished the combined balancing groups previously used by RES and co-generation producers, creating new contract types including contracts for clearing services. These reforms represent meaningful progress in aligning the Bulgarian balancing market with EU market design standards, but explicit demand response products or dedicated demand-side flexibility procurement mechanisms at TSO or DSO level have not yet been established. There is no formal prohibition on demand-side flexibility participation, but the regulatory framework has historically been designed around supply-side balancing resources, and the practical pathways for industrial consumers to offer explicit controllable flexibility to ESO in exchange for direct remuneration are not yet defined.

The concept of independent aggregators is legally recognised following transposition of Directive 2019/944, but practical implementation remains limited. The cross-border use case - in which Bulgarian cluster flexibility participates implicitly in IPTO's Greek balancing market through a certified Greek aggregator, using capacity on the 400 kV Greece–Bulgaria interconnection - represents the project's primary mechanism for accessing explicit flexibility remuneration in a more developed market environment.

Country-specific conditions affecting engagement of large electricity consumers

The Stomana cluster's BRP and BSP status is the defining country-specific enabling condition for large consumer engagement in Bulgaria. Direct IBEX market participation - without the need for an external aggregator or intermediary - gives the cluster an unusual degree of market autonomy relative to industrial consumers in other pilot countries, and provides the institutional and technical infrastructure through which intra-cluster portfolio optimisation already generates commercial value from load flexibility. This status also positions Stomana as the natural intra-cluster aggregator for the LEONARDO pilot,

coordinating the flexibility contributions of Etem Gestamp and Sofia Med within the corporate balancing framework.

The principal country-specific barrier to engagement is structural rather than technical: the absence of explicit DSF products at TSO or DSO level means that there is currently no formal mechanism through which the cluster can offer controllable demand reduction to ESO in exchange for direct remuneration as a balancing service. Flexibility value is captured indirectly through imbalance cost minimisation within the balancing group, but this mechanism does not reward the provision of explicit, contracted balancing capacity to the system operator. The historically limited competition in the Bulgarian balancing energy market - with prices frequently converging toward the regulatory cap - further reduces the economic attractiveness of explicit market participation even where it would be technically feasible. Ongoing regulatory reforms (ETR June 2025, forthcoming Network Code on Demand Response) may progressively address these gaps, but in the short-to-medium term the cross-border use case linking the Bulgarian cluster to the Greek balancing market through PPC as the certified aggregator represents the most viable pathway for the cluster to access explicit flexibility remuneration. This makes the Bulgarian pilot's engagement conditions uniquely dependent on cross-border regulatory interoperability - a dimension with no equivalent in the Italian or Austrian pilot contexts.

4.9 Contractual and Data Governance Aspects

Starting at European level, contractual relationships between industrial customers and energy service providers, which include ESCOs (Energy Service Companies) and aggregators, have evolved from traditional supply agreements towards more complex, service-oriented and performance-based arrangements. These contracts are led by the digitalisation strategies of the energy systems, the integration of distributed energy resources and the growing role of the data in the decision-making processes, such as optimisation, flexibility and advanced data-driven services.

Particularly, the case of the ESCOs, the most well-established Energy Performance Contracting (EPC) schema is the most widely adopted. Under this model, the service provider commits to delivering energy efficiency improvements, typically with remuneration linked to the achieved performance. Although two variants are observed across EU Member States. First, in the guaranteed savings model, the industrial customer finances the investment, while the ESCO guarantees certain level of energy savings, assuming the performance risk. Second, the shared savings model, where the ESCO assumes both the technical and financial risk by financing the intervention and recovering its costs through a share of the achieved savings.

About the aggregators, they usually operate under contractual frameworks that enable industrial customers to participate in flexibility markets, including demand response and ancillary services. Contracts between aggregators and industrial customers are typically structured as flexibility service agreements, under which the customer commits to provide load flexibility (e.g. curtailment or shifting) in exchange for financial remuneration. Following the provisions of Directive (EU) 2019/944, independent aggregators can operate without requiring direct contractual linkage with the customer’s energy supplier, which in practice

may lead to multi-party contractual arrangements involving aggregators, suppliers and balance responsible entities.

In any case, regardless of whether ESCO or aggregator models are applied, contracts are increasingly dependent on the availability and quality of data. Measurement and verification of performance, real-time monitoring of consumption and participation in flexibility markets require continuous access to high-resolution operational data and reliable data flows. Measurement and verification of energy savings are typically based on internationally recognised protocols such as IPMVP, which entail real data for validation.

That is the reason why EPC-based contractual frameworks systematically incorporate provisions governing data access, processing and validation. In many cases, the industrial customer retains ownership of the primary consumption data, while granting the ESCO rights to access and process such data for the purpose of service delivery. However, digital solutions advance day-by-day, including additional analytics; in consequence, increasing the complexity. Data governance therefore becomes particularly critical, as consumption data, baseline calculations and activation signals must be exchanged securely and reliably among different actors. Within the contracts, it is crucial the definition of the data exchange responsibilities, access rights and confidentiality obligations, especially given the commercial sensitivity of industrial load profiles.

There exist other emerging models, as happening with the Energy-as-a-Service (EaaS) approach. This model integrates energy efficiency, on-site generation, storage and flexibility services into a single contractual framework, which is supported by digital platforms and advanced data analytics. In this context, service providers require continuous access to operational data, with special rights to use such data for optimisation algorithms or even for improving their own services (e.g., algorithm training). This raises new contractual challenges, particularly regarding the ownership and permitted use of derived data, as well as issues of data portability and vendor lock-in. It derives in the growing emphasis on interoperability and data portability, in line with broader EU policy developments such as the Data Act. Industrial customers are increasingly seeking contractual safeguards to ensure that their data can be accessed and transferred if they change service providers, thereby avoiding dependency on proprietary platforms.

Overall, these contractual structures reflect a broader transition towards data-driven energy services, where value creation increasingly depends on the ability to collect, process, and exchange data across multiple actors. Given the sensitivity of industrial data, confidentiality provisions and non-disclosure obligations are systematically included. Consequently, data governance considerations, for instance, ownership models, confidentiality, regulatory compliance, cybersecurity and interoperability, are becoming a core component of contractual design.

4.9.1 Data ownership, confidentiality and GDPR issues

From the industrial energy services perspective, data ownership constitutes a central element, particularly given the increasing reliance on data-driven optimisation, monitoring and control. At European level, there is no single harmonised legal definition of data ownership. Nevertheless, contractual arrangements typically distinguish between different categories of data and allocate rights and responsibilities / roles accordingly. Normally, industrial customers retain ownership or control over raw data, that include smart

meter data, processes-related data and operational parameters. On the contrary, service providers (ESCOs or aggregators) are usually granted access rights to this data for the sole purpose of delivering the contracted service.

As stated before, beyond raw data, aggregated or pre-processed data are gaining importance in order to implement performance indicators, forecasts, flexibility baselines or outputs from AI-based optimisation algorithms. In this way, contracts should assign usage rights over such data to service providers. In this respect, recent EU policy developments, mainly the Data Act, are expected to strengthen the position of data owners by facilitating access, sharing and portability through connected devices and services, while also clarifying conditions for third-party access.

Moreover, roles in the data lifecycle must be set up. Responsibilities for data collection, storage, processing, quality assurance and security must be clearly established. Service providers usually act as data processors, while industrial partners remain the data controller. However, when involving multi-stakeholder scenarios (involving aggregators, digital platforms or multi-party ecosystems) careful allocation of liabilities and obligations should be made to allow joint controllership or parallel responsibilities.

Apart from ownership, confidentiality is another critical dimension, given the commercially sensitive nature of industrial data. Energy consumption profiles, production schedules and operational parameters may reveal strategic information about industrial processes. As a result, contractual agreements systematically include confidentiality clauses and non-disclosure obligations, covering both raw and processed data. These clauses typically restrict the use of data to the purposes defined in the contract and prohibit unauthorised sharing with third parties. Particular attention is increasingly paid to the use of data for secondary purposes, such as benchmarking, service improvement, or AI model training, which must be explicitly regulated to avoid misuse or unintended disclosure.

In this line, the General Data Protection Regulation (GDPR) provides the overarching legal framework whenever personal data is involved. Although most industrial datasets are non-personal, situations may arise where personal data is indirectly processed, for example in relation to employee behaviour, occupancy patterns or access control systems. In such cases, contracts must explicitly define the roles of data controller and processor in accordance with GDPR Articles 4, 24, and 28. Data processing agreements (DPAs) are typically annexed to the main contract, specifying technical and organisational measures, breach notification procedures, and conditions for subcontracting.

4.9.2 Cyber-security and data sovereignty

Cybersecurity must be addresses from the perspective of the protection of data and systems across the entire data lifecycle, including data collection, transmission, storage and processing. Industrial environments are often considered critical infrastructure and therefore subject to specific regulatory frameworks at EU level. One example is the NIS2 (2022/2555) Directive, which imposes strict requirements on risk management, incident reporting and supply chain security. Service providers must demonstrate compliance with recognised cybersecurity standards (e.g., ISO/IEC 27001 for information security management or IEC 62443 for industrial control systems). In this sense, contracts increasingly include obligations related to security certification, regular audits and incident response procedures.

In terms of security, industrial partners remain responsible for cybersecurity of on-site systems and infrastructure, while service providers are responsible for securing their own platforms, communication interfaces and data processing environments. Nevertheless, it should be taken into consideration the current trend about remote monitoring, control and/or optimisation. Given these new approaches, it is important that contracts then explicitly define responsibilities for access management, authentication, encryption, vulnerability management and incident handling, as well as include clear procedures for notification and mitigation in case of a cybersecurity breach.

In parallel, data sovereignty has emerged as a central concern for industrial actors, particularly in relation to control over where data is stored and who can access it. Industrial companies are often reluctant to share detailed operational data due to risks related to loss of competitive advantage, exposure of sensitive process information or dependence on external service providers. This is especially relevant in platform-based or cloud-based service models, where data may be stored or processed outside the country or even outside the European Union.

EU-level initiatives such as GAIA-X and European Energy Data Space aim to address these concerns by promoting federated data infrastructures that ensure data sovereignty, interoperability and trust. Moreover, the implementation of the Data Act further reinforces these principles by establishing rules for fair access to and use of data generated by connected devices and services.

For industrial actors, these developments imply that cybersecurity and data sovereignty are not only technical issues but also contractual and strategic ones. Data should remain under the control of the industrial customer.

Within the project context, these aspects are closely connected to WP1 and WP3. WP1 provides the overarching data management and governance framework. WP3 contributes by enabling secure and interoperable data exchange through semantic models and standardised interfaces, which can support the implementation of controlled data sharing in line with data sovereignty principles.

4.9.3 Compatibility with FAIR principles and Data Spaces

FAIR principles (Findable, Accessible, Interoperable and Reusable) are a reference model for high-quality data governance. In practical terms:

- Findable states for standardised metadata, clear identification mechanisms and cataloguing practices that allow relevant datasets to be discovered within and across organisations
- Accessible implies that data can be retrieved under well-defined conditions, typically through secure interfaces and access control mechanisms
- Interoperable by means of the use of shared data models, ontologies and standard formats to ensure that data exchanged between different systems can be correctly interpreted
- Reusable beyond its original purpose via clear data usage conditions, sufficient data quality and documentation.

Achieving full alignment with FAIR principles presents both opportunities and challenges. On the one hand, the adoption of common data models and semantic frameworks can

significantly enhance interoperability between systems, which is particularly relevant in multi-actor environments involving ESCOs, aggregators, platform providers and industrial customers. On the other hand, the need to protect commercially sensitive information and ensure compliance with confidentiality and data protection requirements imposes constraints on data accessibility and reuse. As a result, FAIR implementation in this context is typically defined as open as possible and as closed as necessary. That is to say, requiring a balanced approach between data sharing and data protection.

Data space initiatives such as the European Energy Data Space and GAIA-X aim at facing the aforementioned challenges. Both provide a structured framework to operationalise these principles in a secure and sovereign manner. These initiatives are based on the concept of federated data infrastructures, where data remains with the data owner but can be shared under controlled conditions through standardised services. Key features include the use of federated identity management, policy-based data sharing, and trusted data exchange mechanisms. Rather than centralising data, these approaches enable interoperability and collaboration while preserving control and sovereignty for data providers.

Contractually speaking, several requirements should be met. First of all, it is crucial to define clear metadata and documentation obligations to ensure that data can be understood and reused within and beyond the project. Secondly, the conditions under which data can be accessed and shared, including the use of standardised interfaces (e.g., APIs) should be established. Last, agreements should address the governance of data usage rights, ensuring that data providers can define and enforce policies regarding how their data is used, by whom and for what purposes.

Within the project, interoperability is linked to the activities of WP3, where shared ontologies and semantic models enable consistent interpretation of data across different systems and stakeholders. WP1 also contributes by defining data management procedures, metadata standards and access policies that ensure data is properly documented, governed and aligned with regulatory requirements.

4.10 Cross-Country Synthesis

4.10.1 Convergences, gaps, and structural differences between pilot contexts

A comparative reading of the national frameworks analysed in Sections 4.1 and 4.2 reveals a set of structural conditions that are broadly shared across the four pilot countries, alongside divergences that are sufficiently deep to constitute qualitatively distinct regulatory environments for industrial flexibility activation.

The most significant point of convergence is the shared EU legislative baseline. All four pilot countries operate under the same foundational obligations: the Clean Energy Package (Directive 2019/944 and Regulation 2019/943) establishes the right of industrial consumers to participate in demand response and the right of independent aggregators to operate in wholesale and balancing markets; the 2024 Electricity Market Design Reform (Directive 2024/1711 and Regulation 2024/1747) reinforces these rights and makes the establishment of DSO-level local flexibility markets mandatory; and the cross-border balancing platforms PICASSO and MARI provide a common European infrastructure for aFRR and mFRR exchange that is accessible — at least in principle — to demand-side resources across all

participating TSO areas. This shared legislative foundation creates a common directional trajectory for all four national frameworks, even where current implementation diverges substantially.

A second convergence concerns the structural gap between the formal regulatory framework and effective market participation by industrial consumers. In all four countries, the legal eligibility of large industrial consumers to participate in balancing and flexibility markets is formally established, yet actual participation rates remain limited relative to the potential. The gap is explained by a combination of factors that appear consistently across national contexts: the technical complexity and cost of prequalification, the insufficiency or unpredictability of revenue streams — particularly where activation-only payment structures prevail over availability-based remuneration — the organisational burden of managing market participation alongside production priorities, and the absence of dedicated support structures for industrial actors that lack in-house energy market expertise. This convergent gap is directly relevant for the LEONARDO project, because it defines the common problem space that the iFAAP platform is designed to address: bridging the distance between latent industrial flexibility potential and currently lacking market-accessible flexibility provision.

A third shared condition is the near-universal absence of operational DSO-level local flexibility markets. Despite growing evidence of distribution-level congestion driven by rapid RES expansion — acute in the Italian pilot region (where ARERA pilot schemes are under way), in the Austrian Southeastern Styria area (where PV penetration is high), and in Greece (where curtailment events are increasing) — none of the four countries has yet established a permanent, nationally operative DSO flexibility market framework. Italy is furthest advanced, with three authorised pilot schemes (EDGE, RomeFlex, MiNDFlex) and a regulatory architecture (MLF under ARERA Resolution 372/2023) that anticipates permanent institutionalisation. Austria, Greece, and Bulgaria are at earlier stages, with transposition of Directive 2024/1711 pending in all three cases. This convergent gap directly conditions the LEONARDO pilot design: in the short term, market value creation for industrial flexibility must rely primarily on TSO-level balancing mechanisms, while the DSO-level dimension remains largely in the evidence-generation and policy development phase.

Against this backdrop of shared structural features, the four pilot contexts diverge along several dimensions that are material for the project. The most consequential concerns the maturity of the independent aggregator framework. Greece stands out as one of only four EU Member States where independent aggregators can operate without a mandatory agreement with the industrial customer's incumbent electricity supplier, enabling a fully open and competitive market for aggregation services. Italy formally recognises independent aggregators but imposes a coordination obligation with the relevant supplier for baseline and imbalance management purposes, adding contractual complexity that constitutes a partial barrier to aggregator entry and competition. Austria lacks a standalone legal category for aggregators altogether, requiring aggregation functions to be performed through existing market roles within the current framework. Bulgaria has transposed the formal recognition of independent aggregators but practical implementation remains limited by the absence of compensation mechanisms between aggregators and suppliers and by limited smart metering coverage. This progression — from Greece's open framework to Bulgaria's

nascent implementation — defines a regulatory gradient that directly affects the business model options available to the iFAAP platform in each national context.

A second significant divergence concerns the structure and depth of balancing market product offerings. Italy offers the broadest and most layered landscape: the TIDE framework provides access to aFRR, mFRR, and Replacement Reserve through aggregated virtual units; the Capacity Market adds availability-based long-term revenue; the extraordinary upward modulation scheme provides contracted availability for rapid load reduction; and DSO-level MLF pilots offer complementary local market access. Greece provides a structured and competitively remunerated balancing market with clearly defined daily procurement volumes (approximately 300 MW aFRR, 600 MW mFRR) and an operational independent aggregator framework, but currently lacks a DSO-level market. Austria offers access to FCR, aFRR, and mFRR through APG with technically demanding prequalification requirements and a market that, while functionally adequate, is less articulated in terms of demand-side participation pathways. Bulgaria presents the least developed framework: the balancing market has historically been characterised by limited competition, the absence of explicit demand-side flexibility products, and a structure designed primarily around supply-side resources.

A third structural difference — specific to the BG/GR pilot — is the cross-border dimension introduced by the use case in which Bulgarian industrial flexibility from the Stomana cluster in Sofia participates implicitly in the Greek balancing market operated by IPTO, through a certified Greek aggregator, exploiting the available capacity margin on the 400 kV Greece–Bulgaria interconnection (Nea Santa–Maritsa East line). No other LEONARDO pilot involves a multi-jurisdictional regulatory environment or the need to coordinate flexibility activation across two national TSOs, two market frameworks, and an international transmission line. The regulatory mechanics — covering ENTSO-E platform participation, interconnection capacity allocation, cross-border settlement, and liability allocation in two Member States — introduce a layer of institutional complexity with no equivalent in the Italian or Austrian pilot contexts, making the BG/GR pilot not only a national market access case but a cross-border market design experiment.

4.10.2 Implications for pilot implementation diversity and replication potential

The structural diversity described above has direct implications for how the LEONARDO pilots will be implemented, how their results should be interpreted, and what the project's findings can contribute to the broader policy debate on industrial demand-side flexibility in the EU.

From an implementation standpoint, the regulatory heterogeneity of the pilot set means that the iFAAP platform must function as an adaptable market interface rather than a uniform product. In Italy, iFAAP will need to manage simultaneous or sequential participation across multiple market layers — TSO-level (TIDE/MSD) and DSO-level (MLF) — and navigate the coordination requirements between the aggregation function embedded in CEDIS and the applicable market rules. The institutional peculiarity of CEDIS as a combined DSO and BSP means that the Italian pilot will generate evidence on a form of integrated local energy management with few precedents in the European regulatory literature, potentially

significant for the design of future community energy and DSO-flexibility frameworks. In Austria, iFAAP's core implementation challenge is operational integration with heterogeneous EMS environments and the demonstration of value for SME-scale industrial actors operating without dedicated in-house energy market expertise — a challenge representative of a large share of the European industrial base. In the BG/GR pilot, iFAAP must accommodate two distinct national regulatory regimes within a single cross-border use case, providing technical and contractual interoperability across the Greek and Bulgarian market interfaces while managing the coordination requirements of implicit cross-border aggregation through a certified Greek aggregator.

From a replication potential standpoint, the diversity of the pilot set is a deliberate asset. By spanning four distinct national regulatory environments — ranging from Italy and Greece, which represent relatively mature and articulated DSF frameworks, to Austria and Bulgaria, which represent earlier-stage market conditions — the LEONARDO project generates evidence applicable across the broad spectrum of regulatory contexts present in the EU. Findings from the Italian pilot on multi-level market participation and cooperative DSO integration are replicable in Member States where community energy operators or locally embedded utilities assume similar combined roles. Findings from the Austrian pilot on SME-scale industrial flexibility and local DSO coordination are relevant for the many EU countries where the industrial base is dominated by medium-sized enterprises with limited energy market expertise. Findings from the Greek pilot on independent aggregator frameworks and explicit DSF market participation are directly applicable to the growing number of Member States operationalising similar frameworks under Directive 2024/1711. Findings from the Bulgarian pilot on the regulatory gap between formal DSF recognition and practical market activation are relevant for a significant number of EU Member States still in the early stages of demand-side flexibility framework implementation.

The cross-border use case linking Bulgaria and Greece carries particular systemic relevance. If the implicit cross-border aggregation model — where Bulgarian industrial flexibility participates in the Greek balancing market through a certified Greek aggregator exploiting available interconnection capacity — proves technically and commercially feasible, it would establish a precedent replicable along other EU cross-border interconnections where the regulatory maturity of adjacent national markets is asymmetric. The forthcoming Network Code on Demand Response (ACER proposal, March 2025, expected 2027) is moving toward harmonised technical requirements for cross-border demand-side participation; the BG/GR pilot is positioned to generate the first operational evidence on what such arrangements require in practice, in terms of contractual architecture, telemetry obligations, settlement procedures, and TSO coordination mechanisms.

Taken together, the convergences and divergences identified in this chapter point to a consistent conclusion: while the EU legislative framework is progressively establishing the necessary conditions for industrial demand-side flexibility across Member States, the translation of these conditions into operational market participation by large industrial consumers remains highly context-dependent and faces structural barriers — organisational, technical, economic, and institutional — that persist even where the formal

regulatory enablers are in place. The LEONARDO project, through its three pilot sites and the cross-border use case linking Bulgaria and Greece, is designed to generate the operational evidence and the analytical tools needed to support the policy and market development that can close this gap at scale.

5 Stakeholder Functional and Business Requirements

Stakeholder consultations carried out within Task 2.1 provide important insights into the conditions under which industrial actors and related ecosystem participants may engage in Demand-Side Flexibility initiatives.

The collected inputs reflect practical perspectives on operational contexts, organisational considerations, digital maturity and perceived opportunities or constraints related to flexibility participation.

This chapter presents a structured overview of stakeholder feedback across the pilot regions, covering functional, technical, business and organisational aspects relevant for industrial flexibility participation.

By consolidating these perspectives, the chapter contributes to a better understanding of stakeholder conditions and expectations that are relevant for the subsequent steps of the project.

5.1 Objective and Methodological Approach

5.1.1 Consultation Objectives and Overall Approach

The consultation activities carried out within Task 2.1 were designed to collect structured stakeholder input on industrial flexibility activation across the LEONARDO pilot regions.

To support a consistent approach across pilots, a common consultation framework was prepared, including stakeholder mapping activities, stakeholder-specific questionnaires, supporting presentation materials and guidance documents for workshops and bilateral exchanges. In parallel, a dedicated desk-research template was used to collect information on regulatory, market and organisational framework conditions.

The consultations combined different engagement formats, including workshops, bilateral meetings, interviews and written questionnaire responses, allowing both structured and qualitative input to be collected from stakeholders across the different pilot ecosystems.

5.1.2 Stakeholder Consultation Process – Italian Pilot Region

Stakeholder consultations in the Italian pilot region were designed to gather early and structured insights on the conditions, constraints and opportunities relevant to industrial demand-side flexibility activation in the Storo Industrial Cluster and the wider Italian energy context. The consultations aimed to introduce the LEONARDO project and its expected pilot activities, identify the functional and technical requirements of industrial actors and related stakeholders, understand organisational and business conditions shaping flexibility participation, and prepare the ground for subsequent pilot implementation and platform development activities.

Engagement was structured around two complementary phases. In the first phase, a stakeholder workshop was organised on 13 January 2026 at the premises of an industrial partner in Storo, in conjunction with the Kick-Off Meeting of the FLEXIA project, a parallel national initiative funded by the Italian Ministry of Environment and Energy Security. This workshop brought together 13 participants - 9 stakeholders and 4 members of the FBK coordination team - representing technical suppliers, industrial end-users, the local DSO,

and researchers. The event provided an initial forum for collective discussion on requirements, barriers and potential use cases, and served to introduce the forthcoming questionnaire process and the related data collection activities for WP3.

In the second phase, a structured questionnaire was distributed to a broader set of stakeholders. The questionnaire was tailored and split by stakeholder type, covering five distinct modules corresponding to industrial end-users, technical providers, regulatory and policy actors, business and financial actors, and distribution system operators. In parallel, a series of bilateral online meetings was organised with selected respondents to deepen specific aspects and to validate questionnaire responses. This two-phase approach enabled both broad coverage across stakeholder categories and deeper engagement with key actors directly involved in the pilot implementation.

Number and categories of stakeholders involved pilot region IT

In total, 21 organisations were involved in the Italian consultation process, complemented by 8 follow-up in-depth interviews with selected stakeholders. The stakeholder mix covered all relevant categories for industrial flexibility activation:

- Industrial end-users (7): including discrete manufacturing, continuous process industries (pharmaceutical, paper, petrochemical), textile/apparel and energy asset owners;
- Technical providers (3): EMS/SCADA integrators, automation specialists and SaaS platform providers;
- Regulatory / research actors (4): provincial energy agency and research institutions;
- Business / financial actors (3): aggregators, flexibility market operators and commercial service providers;
- Distribution System Operators – DSOs (4): including local, national and urban DSOs involved in flexibility pilots.

With regards to the significance of the respondents for LEONARDO project, it is worth noting that the questionnaire and the subsequent interviews were conducted with local and national stakeholders. In particular, 10 stakeholders can be identified as local (being mostly active in the Province of Trento) and out of those only 6 are active in the Storo Industrial Cluster: 1 DSO, 3 Technical Providers, 2 industrial End-Users. The analysis conducted in these chapters is therefore related not only to the specific characteristics of the LEONARDO Italian Pilot located in the Storo Industrial Cluster, but rather to a wider national perspective on the current status of industrial flexibility services and programmes currently active in Italy.

TABLE 2: OVERVIEW OF QUESTIONNAIRE RESPONDENTS BY STAKEHOLDER CATEGORY – PILOT IT

Stakeholder Category	Count	Description
Industrial End-Users (Module A)	7	Energy supply consortium; large discrete manufacturer; large pharmaceutical (continuous process); large paper company (continuous process + cogen); large petrochemical (continuous process); large textile/apparel manufacturer (batch + cold storage); SaaS/energy assets owner. 3 of 7 also participated in an in-depth interview.

Technical Providers (Module B)	3	EMS/SCADA integrators, SaaS platforms, industrial automation specialists; one also acts as DR aggregator. 2 of 3 also participated in in-depth interviews.
Regulatory / Policy Actors (Module C)	4	Provincial energy agency; three university/research institutions.
Business / Financial Actors (Module D)	3	DR aggregator/technology provider (also in Module B); flexibility marketplace operator; large flexibility aggregator active in national and local markets. 1 of 3 also participated in an in-depth interview.
Distribution System Operators (Module E)	4	Rural/cooperative DSO with energy production (also in Modules C/D); DSO with own local flexibility scheme (urban); national DSO; local rural DSO. 2 of 4 also participated in in-depth interviews.
TOTAL	21	Italian national context and Storo Industrial Cluster. 8 organisations also participated in follow-up interviews.

Note: Three questionnaire respondents completed more than one module.

Consultation formats applied pilot region IT

Stakeholder consultations in the Italian pilot region were carried out through three complementary formats, each suited to different engagement objectives and stakeholder profiles.

The opening stakeholder workshop, held in January 2026, served as a collective introductory forum. The session was structured around three main objectives: presenting the LEONARDO project and its pilot rationale; facilitating an open discussion on end-user requirements, regulatory barriers, and potential flexibility use cases; and presenting the next engagement steps, including the forthcoming questionnaire and data collection activities. The format combined a project presentation, moderated group discussion, and direct exchange with stakeholders, allowing both broad and practice-oriented dialogue. Given that the event was co-located with the FLEXIA project kick-off, it also benefited from the active participation of industrial partners and technical providers already engaged in the local pilot context.

The structured questionnaire, distributed as a tailored document split by stakeholder type, represented the main systematic data collection instrument. Each module was designed to capture functional, technical, business and organisational aspects relevant to the respective stakeholder role. The questionnaire covered topics including process characteristics and flexibility potential, monitoring and EMS infrastructure, data availability and exchange, experience with flexibility schemes and market participation, and expectations regarding platform functionalities. The format allowed consistent coverage of key topics across all stakeholder categories while enabling stakeholder-specific depth in each module.

Bilateral follow-up interviews were conducted with selected respondents following questionnaires' submissions. The interviewed stakeholders have been identified among the most interested in participating to the project activities as well as for deepening the analysis on specific topics, selecting the most experienced questionnaires' respondents on industrial flexibility ventures. These sessions, organised as semi-structured online meetings, allowed

a deeper exploration of technically or commercially sensitive aspects that are less suited to written questionnaire responses. Interviews were particularly valuable for understanding operational detail on flexibility asset characteristics, market participation mechanics, DSO coordination models, and platform interaction preferences. The combined use of these three formats - workshop, questionnaire, and bilateral interview - provided both breadth of coverage and depth of insight, and is consistent with the multi-format approach applied across the LEONARDO pilot regions.

Status of stakeholder engagement pilot region IT

Stakeholder engagement in the Italian pilot region has been successfully completed through the first round of consultations described above. The questionnaire process and the structured bilateral interviews have concluded, and the findings have been consolidated into this analysis.

Overall, the consultations demonstrated a high level of interest in the LEONARDO project and in the development of the iFAAP platform. Stakeholders expressed strong willingness to continue their involvement during pilot implementation, including participation in co-creation workshops, prototype testing, and validation activities. Eight organisations explicitly confirmed availability for pilot testing or co-creation workshop participation at the close of the questionnaire.

Further engagement steps are already underway or planned in the coming months. These include the definition and validation of pilot use cases with local industrial partners and CEDIS, the collection of detailed technical data on asset characteristics and flexibility potential through the WP3 data collection process, and the preparation of the pilot experimentation activities planned for the subsequent project phases. The established communication channels with all major stakeholder groups will be maintained throughout the project to support iterative validation of iFAAP functionalities and ensure continued stakeholder alignment.

5.1.3 Stakeholder Consultation Process – Austrian Pilot Region

In the Austrian pilot region, stakeholder consultations under Task 2.1 were designed to gather early insights on technical conditions, organisational needs and market perspectives relevant to the activation of industrial demand-side flexibility. The consultations also aimed to introduce the LEONARDO project, explain the expected role of regional actors and prepare the ground for subsequent pilot activities.

The initial intention was to organise a broad multi-stakeholder workshop bringing together representatives from industry, energy services, grid-related actors and technology providers in a joint setting. As it proved challenging to convene all relevant stakeholders within a short timeframe, the consultation strategy was adapted towards a more targeted and efficient approach. Instead of relying solely on one large joint event, the European Centre for Renewable Energy (EEE) organised a series of smaller group meetings and bilateral exchanges with stakeholders from different sectors.

During these meetings, the project objectives, pilot rationale and expected contribution of stakeholders were presented using a structured project presentation. In parallel, the structured questionnaire and related discussion topics were used as a guiding framework to collect relevant information. This included technical characteristics of potential flexibility

assets, data availability, operational constraints, organisational decision processes and perceptions regarding future participation in flexibility markets.

This adjusted consultation approach enabled more focused discussions, facilitated stakeholder-specific exchanges and improved the quality of responses, particularly where commercially sensitive or technically detailed issues were involved. It also helped establish direct communication channels with relevant actors for the later stages of pilot preparation and validation activities.

Number and categories of stakeholders involved pilot region AT

In the Austrian pilot region, stakeholder consultations involved approximately eight organisations representing a diverse set of stakeholder categories relevant to the flexibility topic and regional energy system integration. The consultation process was designed to ensure that both technical and market-oriented perspectives, as well as regional replication aspects, were considered.

The consulted stakeholder categories included distribution system operators and grid-related actors, industrial companies represented through established bilateral exchanges with the pilot technology partner EVON, energy service providers with expertise in metering, settlement and market processes, technology and energy system providers, software and IT solution providers, applied research institutes, and research organisations with practical experience in renewable energy systems and real-life testing environments.

In addition, representatives of the Climate and Energy Model Region ecoEnergyland were involved. This stakeholder group offered a regional development perspective, particularly regarding renewable energy deployment, energy communities and the transferability of project outcomes. Given that ecoEnergyland is part of a wider Austrian network of more than 120 Climate and Energy Model Regions, consultations also considered the broader replication potential of LEONARDO results beyond the immediate pilot region.

This stakeholder mix provided a balanced perspective across grid operation, industrial implementation, digitalisation, market participation and regional policy transfer.

Consultation formats applied pilot region AT

In the Austrian pilot region, stakeholder consultations were mainly carried out through in-person meetings in a workshop-style format. These sessions combined elements of project presentations, moderated discussions and direct interviews, allowing a flexible exchange adapted to the specific stakeholder group involved.

Typically, each meeting started with a short introduction to the LEONARDO project, its objectives and the relevance of industrial flexibility within the regional context. This was followed by structured discussions based on the structured questionnaire and related topic areas.

The consultation format therefore represented a hybrid approach between workshop, expert discussion and semi-structured interview. This proved particularly suitable for collecting stakeholder requirements, as it enabled open dialogue while still ensuring that key topics such as technical conditions, data availability, operational constraints and market perspectives were addressed consistently across meetings.

The meetings were organised in smaller group settings, which facilitated more detailed and practice-oriented discussions, enabled active involvement of all participants and allowed stakeholder-specific issues to be addressed in greater depth, including technically sensitive or operationally specific topics.

Status of stakeholder engagement pilot region AT

Stakeholder engagement in the Austrian pilot region has been successfully initiated through a first round of consultations, representing an important early step in the overall engagement process. Relevant stakeholder groups were approached and involved through the formats described above, allowing an initial exchange on the project and its objectives.

Overall, the consultations showed a positive level of interest in the LEONARDO project and its planned activities. Stakeholders expressed openness towards further information exchange and continued involvement during the project implementation.

It was therefore agreed to continue the established dialogue beyond this first phase. Further exchanges, follow-up meetings and additional stakeholder interactions are foreseen in the coming months in line with project progress and upcoming activities.

5.1.4 Stakeholder Consultation Process – Bulgarian–Greek Pilot Region

The stakeholder consultation in the Bulgaria–Greece pilot region was carried out by UPAT, in cooperation with the GR pilot (HELLENiQ ENERGY) and the BG pilot (STOMANA Industry). Reflecting the cross-border nature of the pilot — which covers an in-border industrial cluster in the Sofia balancing area and a cross-border aggregation case linking the Sofia and Thessaloniki balancing areas — the engagement extended beyond the two pilot industries to include the actors whose involvement is needed to make industrial flexibility operational in the two national systems: the transmission and distribution network operators and the electricity market operator on the Greek side, a certified aggregator and ESCO active in the Greek market, and a set of technology providers from both countries.

Stakeholders were contacted on the basis of their operational or institutional role in the pilot's flexibility value chain, through the existing project network and through bilateral exchanges, and were then asked to complete the structured WP2 questionnaire prepared under Task 2.1. Where more than one internal perspective was relevant within the same organisation, the questionnaire was filled in by different respondents in parallel, in order to capture both operational and strategic viewpoints. This individual engagement was complemented by the 1st BG/GR Pilot Workshop of 20 February 2026, coordinated by UPAT together with the GR and BG pilots.

The consultation pursued two objectives: identifying the technical, organisational, regulatory and business conditions under which Greek and Bulgarian industrial actors can realistically participate in flexibility activation, and surfacing the constraints that may affect the design and deployment of the iFAAP platform in the cross-border context. The collected input feeds the requirement patterns reported in Sections 5.2 and 5.3 and will support the definition of the pilot use cases under Task 2.3.

Number and categories of stakeholders involved pilot region GR/BG

The resulting stakeholder sample covers industrial actors, market participants, network operators, technology providers and research-oriented organisations relevant to the

flexibility value chain in the BG/GR pilot context. Table 3 provides an overview of the organisations involved in the questionnaire process and their respective stakeholder categories.

TABLE 3: OVERVIEW OF QUESTIONNAIRE RESPONDENTS BY STAKEHOLDER CATEGORY – PILOT BG/GR

STAKEHOLDER CATEGORY	COUNTRY
Industrial end-user (energy-intensive)	Bulgaria
Industrial end-user (energy-intensive)	Bulgaria
Industrial end-user (external observer, peer steel sector)	Austria (cross-pilot peer)
Flexibility aggregator / ESCO / power supplier	Greece
Nominated Electricity Market Operator (NEMO)	Greece
Transmission System Operator (TSO)	Greece
Distribution System Operator (DSO)	Greece
Technology provider (EMS/SCADA integrator)	Greece
Technology provider (IT solutions for energy and utilities)	Pan-European (GR delivery)
Engineering and consulting (power grids, HV/MV substations, industrial projects)	Greece
System integrator (energy monitoring, automation, telemetry for industry)	Bulgaria
Research and technology centre (advanced manufacturing)	Spain (cross-project peer)

Consultation formats applied pilot region BG/GR

The consultation in the BG/GR pilot region was conducted through a combination of two complementary formats. The first is the structured WP2 questionnaire on Industrial Flexibility Requirements developed under Task 2.1, organised into a mandatory Core Block for all respondents and five role-specific modules covering, respectively, industrial end-users, technical providers, regulatory and policy actors, business and financial actors, and distribution system operators. The questionnaire was distributed in written form to the identified respondents, who completed only the modules relevant to their role in the energy system. This format was selected as the most efficient means of collecting comparable, evidence-based input across heterogeneous stakeholder categories within the timeframe of Task 2.1, and of feeding the analysis presented in Sections 5.2 and 5.3. Where more than one internal perspective was relevant within the same organisation, the questionnaire was completed in parallel by different respondents, in order to capture both operational and strategic viewpoints; this was the case for the Greek industrial end-user with two contributions covering the operational/technical and the strategic/business and aggregator's perspectives respectively, and for the TSO, with three contributions from different internal units.

The second format is a dedicated regional event, the first BG/GR Pilot Workshop held on 20 February 2026, coordinated by UPAT in cooperation with the GR and BG pilots. The workshop brought together representatives of the GR pilot (HELLENiQ ENERGY), the BG pilot (STOMANA Industry) and a broad set of external Greek and Bulgarian stakeholders covering the full flexibility value chain, including the Greek TSO and NEMO, the aggregator and ESCO segment, and several technology providers and system integrators active in the two countries. The workshop served three complementary purposes: presenting the LEONARDO project objectives and the planned BG/GR use cases to the regional flexibility ecosystem, collecting qualitative feedback on the technical, business and regulatory conditions for industrial flexibility activation in the cross-border context, and supporting the iterative validation of the requirement patterns emerging from the questionnaire responses.

These two formats were complemented, where appropriate, by bilateral exchanges and clarification meetings with selected respondents, in order to deepen the understanding of specific operational, business or regulatory points raised in the written input. These exchanges did not take the form of structured interviews and served primarily as a validation layer, ensuring a consistent interpretation of the consolidated stakeholder input.

Status of stakeholder engagement pilot region BG/GR

Stakeholder engagement in the BG/GR pilot region is currently ongoing. The first engagement cycle has been substantially completed and consists, on one side, of structured questionnaire responses consolidated from five distinct organisations, including industrial end-user, TSO, DSO, EMS provider, aggregator and technology providers. On the other side, the first cycle includes the first BG/GR Pilot Workshop held on 20 February 2026, which extended the engagement footprint to approximately thirteen distinct organisations across the Greek and Bulgarian flexibility ecosystems.

A second engagement cycle is foreseen in the remaining months of Task 2.1, with multiple objectives: consolidating the Bulgarian-side coverage through additional structured questionnaire responses from Bulgarian industrial end-users and network operators; deepening the input collected from the relevant Greek stakeholders. Additional support of the iterative validation of the requirement patterns identified in this deliverable through bilateral follow-ups with already-engaged stakeholders. The status of stakeholder engagement will be updated accordingly in the corresponding sections of D2.2 (Task 2.3) as the consultation progresses.

The following table (Table 4) summarises the main stakeholder consultation characteristics across the LEONARDO pilot regions, including stakeholder coverage, consultation formats and current engagement status.

TABLE 4: COMPARATIVE OVERVIEW OF STAKEHOLDER CONSULTATION ACTIVITIES ACROSS PILOT REGIONS

Aspect	IT	AT	BG/GR
Main consultation approach	Workshop, structured questionnaire and follow-up interviews	Smaller workshop-style meetings and bilateral exchanges/interviews supported by	Structured questionnaire, regional pilot workshop and bilateral clarification exchanges

		questionnaire-guided discussions	
Main stakeholder categories involved	Industrial end-users, DSOs, aggregators, technology providers, research and policy actors	Industrial actors, DSOs, energy service providers, technology providers, research organisations and regional actors	Industrial actors, TSO, DSO, NEMO, aggregator/ESCO, technology providers and research organisations
Approximate number of organisations involved	21 organisations + 8 follow-up interviews	Approx. 8 organisations	Approx. 12 organisations
Consultation formats applied	Workshop, questionnaire, interviews, bilateral meetings	In-person discussions, workshop-style exchanges, semi-structured interviews	Questionnaire, workshop, bilateral clarification exchanges
Current engagement status	First consultation round completed	First consultation round initiated and ongoing	First engagement cycle substantially completed and ongoing
Next planned steps	Pilot validation, co-creation workshops and technical data collection	Continued stakeholder dialogue and follow-up exchanges	Additional questionnaire responses and iterative validation activities

5.2 Functional and Technical Requirements

This section presents a structured synthesis of stakeholder feedback related to the functional and technical conditions influencing industrial Demand-Side Flexibility activation across the LEONARDO pilot regions. The analysis reflects stakeholder perspectives on operational practices, technical infrastructures, monitoring environments, data handling, interoperability and coordination requirements relevant to flexibility participation.

The findings are organised according to the stakeholder groups consulted within each pilot region, highlighting similarities and differences in technical conditions, operational constraints and expectations regarding flexibility-related services and digital support functionalities.

5.2.1 Pilot-specific insights (functional and technical) – Pilot IT

The Italian pilot is centred on the Storo Industrial Cluster (Province of Trento, northern Italy), operated by CEDIS – Consorzio Elettrico di Storo, a cooperative DSO. The cluster involved in the project comprises 3 industries consuming approximately 10 GWh/year of electricity and featuring 1.1 MWe PV systems. A key enabling asset for the pilot is a 1 MWe H2 electrolyser combined with 3.3 MWe of dedicated PV, and a 2.4 MWe/5 MWh BESS being commissioned in the cluster by a local energy company as part of a Recovery Fund project.

LEONARDO will explore how CEDIS can coordinate local industrial consumers to co-optimise wholesale market procurement, potential Local Flexibility Market (MLF) activation, and local DSO-level flexibility market operation.

This section presents the functional and technical conditions influencing industrial demand-side flexibility activation in Pilot IT, synthesised from 21 questionnaire responses and 8 in-depth interviews. The analysis is structured by stakeholder group to reflect how requirements and conditions differ across the categories consulted. Where interview evidence deepens or qualifies questionnaire findings, this is explicitly noted.

Industrial end-users

The seven industrial end-users consulted represent a wide spectrum of process types and digital maturity levels, covering the full range of Italian industrial flexibility profiles, from highly constrained continuous processes to schedulable batch and discrete manufacturing, and including a novel power-to-hydrogen asset.

In terms of process types and operational contexts, the group spans: an energy supply consortium acting as intermediary for pooled energy procurement; a discrete metalworking manufacturer with shift-programmable production lines and auxiliary assets (EV charging, thermal storage, PV); a pharmaceutical company operating continuous fermentation bioreactors with cycle times up to 120 hours; a paper and energy company with continuous process manufacturing and active cogeneration; a petrochemical operator producing electricity and gas on-site with high fuel-switching potential; an apparel and textile manufacturer with batch production and cold storage operations; and an energy assets owner integrating PV, a H2 electrolyser, and a BESS in the Storo cluster.

Current engagement with demand management and flexibility mechanisms varies substantially. The energy consortium and the paper and energy company are the most experienced: the former combines market-indexed contracts, PPAs, on-site renewables, and active balancing and capacity market participation; the latter directly participates in electrical interruptibility, gas interruptibility, the Capacity Market, and the UVAM balancing mechanism, using existing industrial assets at minimal additional CAPEX. The petrochemical operator participates in DR and ISO 50001 programmes. The pharmaceutical and apparel manufacturers apply flexibility primarily for internal optimisation, with ISO 50001 engagement but limited direct market participation. The discrete manufacturer and energy assets owner have not yet engaged in flexibility markets; the energy assets owner is preparing to participate once the H2+BESS hub is fully operational.

Process continuity is the primary technical constraint for continuous-process industries. The paper manufacturer noted explicitly that its process cannot be externally regulated except via total interruption. The pharmaceutical respondent confirmed that fermentation processes lasting up to 120 hours cannot be interrupted without compromising production. For the discrete and batch manufacturers, shift and personnel scheduling is the binding constraint: production changes must be communicated at least one week in advance. Storage assets, EV charging, and thermal storage can respond within minutes. The apparel manufacturer can respond to external commands within one minute for its schedulable loads. The electrolyser can provide flexibility but requires controlled ramping to preserve asset lifespan; the BESS can respond in seconds.

Monitoring infrastructure ranges from highly advanced to basic. The pharmaceutical manufacturer operates a DCS with approximately 4,000 process tags and an EMS with approximately 500 energy tags, both at 1–5 second resolution. The petrochemical operator has 6-second resolution monitoring at unit level but lacks a site-wide integration layer. The paper company uses SCADA for continuous process and cogeneration monitoring. The discrete manufacturer monitors production lines and PV at 5-minute resolution. The energy consortium uses POD/PDR-level metering with aggregated management software. The apparel manufacturer uses EMS and BMS at 15-minute resolution. The energy assets owner is deploying a new EMS for the H2+BESS hub, with NIS2 compliance required.

The key gap shared across multiple end-users is the absence of an integrated optimisation layer connecting production scheduling, energy procurement, and flexibility activation in a unified interface. Data governance policies for external sharing are largely absent or informal across the group. Most respondents manage data internally without formal third-party data-sharing frameworks, though none raised specific GDPR concerns for flexibility applications.

Regarding iFAAP expectations, industrial end-users assigned the highest scores to the monitoring module and to reporting and benchmarking (category averages of 3.8 and 4.5 respectively), consistent with a priority on visibility and performance documentation before automation. The automation module received a slightly lower category average, reflecting the preference, confirmed in interviews, for advance scheduling interfaces and human-confirmed activation rather than fully automated control commands.

In addition to the aggregated stakeholder synthesis presented above, selected interview findings are summarised below to illustrate specific operational requirements and concerns expressed by individual industrial stakeholders:

- Interview finding – Industrial End-User (Innova, discrete manufacturer, Storo): The manufacturer specified a web portal as the preferred interaction mode with iFAAP, enabling visualisation of activation requests from the BSP or DSO and advance scheduling of flexibility events. A historical log of activations and accrued revenues was identified as essential. Cybersecurity concerns regarding production disruption from external attacks were explicitly raised; override capability for production emergencies is a hard requirement.
- Interview finding – Industrial End-User (Polytec, energy assets owner, Storo): The asset owner expressed preference for a portal-based communication channel with the aggregator for setting availability constraints and viewing activation history. Activation notifications should be delivered by mail with human confirmation rather than fully automated external commands, given concerns about uncontrolled interventions on critical plant equipment (electrolyser and BESS). The electrolyser requires advance planning and a controlled ramp rate to avoid reducing asset lifespan; PV and BESS can respond in seconds to minutes. The full system will be managed via a centralised aggregation layer (EMS) interfacing with both external platforms and the internal site control channel.

Technology providers

Three technical providers responded to the consultation, all active in the Storo pilot area. The group includes an EMS/SCADA integrator with in-house developed energy management systems; a large ISO 27001-certified SaaS platform provider supporting

integration with major industrial platforms (Schneider Electric, Siemens, Allen-Bradley, Honeywell); and an industrial automation and EMS specialist working with distributed industrial assets. Two of the three participated in follow-up interviews.

In the Storo context, the EMS integrator is responsible for the system managing the H2+BESS hub and the Storo industrial assets, while the automation specialist provides the overarching aggregation and SCADA layer connecting pilot assets to the FLEXIA platform and to CEDIS. A key design principle confirmed in interviews is that flexibility services can be implemented as software add-on modules to existing EMS architectures, avoiding full system replacement and significantly reducing integration CAPEX.

Modbus TCP/RTU is the universal baseline protocol for industrial field integration across all three providers. At the platform level, OPC-UA, MQTT/MQTTS, and REST APIs are used. BACnet, KNX, and LonWorks cover building management integration. All three providers reference NIS2 compliance as a requirement for systems with grid connectivity; one holds ISO 27001 certification. The providers note that activating flexibility services significantly increases the external exposure of EMS systems compared to monitoring-only configurations, requiring enhanced access management, authentication, and incident response procedures.

Three systemic interoperability challenges were consistently identified: the absence of a universally adopted communication standard at the field level, making each integration effectively a custom project; proprietary EMS architectures without accessible external APIs, requiring gateways for platform connectivity; and inconsistent data models across systems preventing automated aggregation. A fourth challenge specific to the Italian market context is the management of multi-level control hierarchies, coordinating between individual asset EMS, BSP activation instructions, and DSO network requests, for which no standardised protocol currently exists.

The SaaS provider operates with 15-minute data resolution as the standard market interval, with 1-minute resolution available for higher-precision applications. Internal latency is approximately 1 minute; external exchange latency is typically 15 minutes. A structural gap identified is that current Italian local flexibility markets still operate at low automation levels and the development of a standardised API layer is identified as the critical dependency for automated market participation.

Technical providers rated the monitoring and automation modules highest (category averages of 5.0), consistent with their role in deploying and operating these systems. Simulation and forecasting scored lower (4.0), and reporting received the lowest category average (3.7), suggesting these functions are seen as less central to the provider's own operational contribution.

In addition to the aggregated stakeholder synthesis presented above, the following interview finding provides a more detailed illustration of integration and interoperability requirements identified by technical providers:

- A reliable shared API from the iFAAP platform is the critical dependency for the Storo pilot since it would allow different EMS systems to exchange data without custom point-to-point integrations. At the field level, Modbus is sufficient; only software updates to the deployed EMS are needed. NIS2 compliance for the H2+BESS hub EMS is confirmed as a design requirement.

Distribution system operators

Four DSOs participated in the consultation, including the local cooperative DSO (CEDIS), an urban DSO operating an active local flexibility market scheme, a national DSO participating in a local flexibility pilot, and a second rural cooperative DSO in the pilot area. Two participated in follow-up interviews. The DSO perspective in this analysis covers both the specific Storo network context and the broader Italian DSO landscape.

CEDIS manages a distribution network with approximately 34 GWh/year of total consumption, serving 4,500 customers across 148 km², with approximately 10 GWh/year withdrawn from the national grid and approximately 9 GWh/year fed back to the TSO. The primary operational objective is to maximise local self-consumption and minimise grid export through electrification, storage, and flexible demand management. The network is already equipped with 15-minute electronic remote-controlled smart meters at all connection points. A key infrastructure asset is CEDIS's closed fibre-optic network connecting substations, providing a secure high-bandwidth backbone for flexibility communication.

Current CEDIS monitoring capabilities are limited for active flexibility management: existing SCADA provides telecontrol for hydroelectric assets and voltage and power monitoring for substations, but no real-time network monitoring algorithms. Meters are read daily rather than in real time. Achieving near-real-time operational capability would require deploying additional sensors on network nodes. CEDIS expressed specific interest in developing dynamic pricing signals and time-of-use tariff structures for its industrial members as a practical coordination mechanism, subject to regulatory framework compatibility.

The urban DSO provides an advanced reference for mature local flexibility market operation in Italy. Its pilot project scheme procures flexibility through monthly forward auctions with dual-component remuneration (availability + activation), using a defined baseline methodology and a 60% delivery threshold. BSP participation already exceeds demand. Smart meter coverage is already sufficient for all participating PODs; the gap is entirely in automation and coordination tooling. The strategic priority is expanding participation to lower grid levels and to industrial assets not yet represented in the flexibility market. The main operational bottleneck confirmed in interview is that flexibility activation is still performed manually by email, a method the DSO itself assesses as insufficient for scaling. A dedicated structured activation platform with automated activation signalling and delivery verification is an immediate operational priority.

The national DSO highlighted the EU Network Code on Demand Response (NCDR, currently under preparation) as the future regulatory anchor for DSO-based flexibility service data exchange formats, and identified TSO-DSO coordination as an essential structural requirement for resources that simultaneously provide national and local services, a specific challenge in the Italian UVAM architecture.

DSO respondents rated the monitoring module and alerts and notifications highest (category average 5.0 for both), while reporting and simulation received lower scores (3.7 and 4.0), consistent with DSOs prioritising real-time operational visibility and alerting over analytical reporting functions.

In addition to the aggregated stakeholder synthesis presented above, the following interview finding provides a more detailed illustration of operational and data-management requirements identified by DSO stakeholder:

- CEDIS owns metering data from its network assets. The frequency and format of data currently available to flexibility service providers needs to be substantially expanded from daily to near-real-time. Any new digital system deployed within the CEDIS network, including the planned network EMS, must be NIS2 compliant.

Business and financial actors

Three business and financial actors participated in the consultation: a DR aggregator and technology provider, a flexibility marketplace platform operator, and a large flexibility aggregator with an active national and local portfolio. The latter participated in an in-depth interview. All three are highly familiar with Italian flexibility mechanisms (self-rated knowledge level 5 out of 5 for all three respondents).

The large aggregator manages an active portfolio spanning residential PV+BESS via UVAM, manufacturing industry DR for processes above 8 MW, and an end-to-end automated DR ecosystem. Automatic resource optimisation algorithms and predictive models for DSO request estimation are already operational. In the pilot project MLF scheme (Local Flexibility Market) where it participates, this actor has already implemented automated API-based interfacing with the GME platform for bid submission, one of the few confirmed implementations of automated market participation in Italian local flexibility markets. The marketplace operator facilitates monthly local flexibility tenders between DSOs and BSPs.

From a technical perspective, commercial actors provide the clearest articulation of the platform integration requirements for iFAAP: automated API-based interfacing with GME is a core functional requirement; a shared API standard allowing different EMS systems to communicate with a common flexibility platform is identified as the critical missing link in the current Italian market infrastructure; direct local edge-based communication with assets, bypassing manufacturer cloud dependencies, is needed to reduce latency, lower operational costs, and ensure near-real-time data availability for portfolio management. The PGUI (Power Grid User Interface), used for blockchain-certified measurement and verification of flexibility service delivery, is cited as a relevant auditability model for iFAAP.

Commercial actors assigned the highest iFAAP ratings in the entire sample (category average of 4.9), rating monitoring, automation, and simulation and forecasting at 5.0. This reflects a strong alignment with fully integrated platform capabilities and an expectation that iFAAP will support end-to-end automated flexibility management from asset monitoring to market activation.

The following interview finding illustrates selected integration and latency-related challenges highlighted by commercial actors/aggregators during the consultation process.

- The aggregator underlined the fact that the BSP, in order to perform automatic control of its assets, usually has to interface with a cloud platform managed by the asset manufacturer. This implies costs and latency (with APIs triangulating between the BSP's control platform, the asset, and the manufacturer's cloud platform), particularly for battery-type assets. When assets from different manufacturers are involved, the situation becomes difficult to manage. Moreover, it does not always meet the need for near real-time data availability. The solution that was implemented involved creating local APIs capable of communicating with the asset by directly using the residential Wi-Fi network, and setting up field gateways able to handle this reception and control. However, the local API and the gateway represent a significant fixed

cost; therefore, the resource to which the gateway is connected must be able to make this service worthwhile, providing a non-negligible level of modulation while minimizing uncertainties and periods of unavailability.

Regulatory and policy actors

Four regulatory and policy actors participated in the consultation: the Provincial energy agency and three university and research institutions. These actors provided a policy assessment and academic perspective, and had the highest average knowledge levels in the sample (average 4.2 out of 5).

From a functional perspective, regulatory actors are primarily interested in the monitoring and simulation and forecasting modules of iFAAP, consistent with their interest in data quality, system evaluation, and policy impact assessment rather than in operational activation. They rated the monitoring module at 3.8 and simulation and forecasting at 4.0, with lower scores for automation and reporting.

On the regulatory landscape, these respondents confirmed that Italian industrial consumers are eligible to provide flexibility services. The main functional observation from this group is that the regulatory framework - TIDE (in force January 2025), ARERA Resolution 352/2021 local market pilots (MindFlex, RomeFlex, Edge), and the forthcoming NCDR - provides the formal basis for flexibility participation, but practical guidance documentation and streamlined participation procedures are still insufficiently developed, particularly for smaller actors. GDPR was identified as the primary data-sharing barrier. Cultural resistance to change within industrial organisations was also noted as an underappreciated but relevant obstacle.

Across 21 questionnaire respondents and 8 in-depth interviews, the following patterns emerge as robust and cross-validated by multiple evidence sources:

On functional and technical requirements:

- Granular energy monitoring is the universal prerequisite. This finding is confirmed by all stakeholder categories and all interview subjects. No flexibility service can be designed, activated, measured or remunerated without reliable consumption data at the point of production or delivery.
- Industrial flexibility potential is highly process-type specific. Continuous-process industries (paper, chemical, pharmaceutical) have minimal intrinsic core-process flexibility; their main flexibility levers are storage systems, auxiliary utilities, and fuel switching. Batch and discrete manufacturers have greater scheduling flexibility, constrained primarily by personnel and shift planning. This distinction is critical for iFAAP's flexibility characterisation module.
- Response times of 15 minutes to several hours are the realistic industrial window. Only storage assets (BESS, thermal storage, EV charging) can respond in seconds to minutes. Process-level flexibility requires advance planning (hours to days for continuous processes, minimum one week for shift-dependent operations).
- Multi-protocol interoperability remains an unresolved systemic challenge. Modbus is the universal baseline; OPC-UA and MQTT are the standard for higher-level integration. But absence of a unified data model and prevalent proprietary interfaces mean every integration is effectively a custom project.

- Market platform integration (GME and other market platforms API, DSO local market interfaces) is a concrete and widely shared technical expectation for iFAAP, confirmed by interviews with both commercial actors and DSOs.

5.2.2 Pilot-specific insights (functional and technical) – Pilot AT

The Austrian pilot is located in the region of Southeastern Styria and focuses on the aggregation of industrial demand-side flexibility from medium-sized industrial consumers with existing digital energy management capabilities. In the Austrian context, the relevance of flexibility has increased in recent years due to the rapid expansion of photovoltaic generation, growing electrification trends and the resulting operational challenges in distribution grids. Particularly in rural and semi-rural areas, decentralised renewable generation can create local congestion, voltage deviations and increasing pressure on existing network infrastructure. Against this background, flexibility is increasingly discussed in Austria as a complementary measure to conventional grid reinforcement and as a means to support more efficient system integration of renewable electricity.

The Austrian pilot combines perspectives from several stakeholder groups relevant to this development, including industrial actors represented through the pilot implementation environment, the regional distribution system operator, an Austrian energy service provider, research and software stakeholders, applied research organisations and regional energy-transition actors. The consultation process therefore provided a multi-perspective view on the functional and technical conditions required for future flexibility activation.

Industrial end-users

Industrial electricity consumers are regarded as one of the most relevant but also most heterogeneous sources of future demand-side flexibility in Austria. In contrast to households or standardised commercial consumers, industrial electricity demand is closely linked to production processes, operating schedules, thermal conditions, product-quality requirements and company-specific priorities. As a result, flexibility potential cannot be assessed in a generic manner, but must be analysed individually for each site, process environment and operational boundary condition.

In Austria, current discussions on industrial flexibility are closely linked to the increasing share of renewable electricity, the growing electrification of industrial energy demand and the need to use existing grid infrastructure more efficiently. Relevant flexibility potential may exist across sectors such as food processing, mechanical production, metals, paper, chemicals, cold storage and other energy-intensive industries. However, the type, duration, response time and practical usability of flexibility differ significantly depending on the production environment.

From a technical perspective, common flexibility options include load shifting, peak-load reduction, temporary load modulation, process rescheduling, storage use, pre-heating or pre-cooling strategies, optimisation of auxiliary systems and improved coordination with on-site generation. In industrial practice, particular relevance is often attributed to cooling systems, compressed air, thermal buffers, motor-driven processes, batch production and the scheduling of energy-intensive process steps.

At the same time, practical activation requires more than technical potential alone. Continuous production lines usually allow only limited intervention windows, while batch-based processes may provide greater scheduling flexibility. Temperature-sensitive sectors such as food production are constrained by hygiene requirements, cold-chain integrity and product stability. In many companies, theoretical flexibility potential therefore differs from practically usable flexibility because operational risks, staffing models, maintenance schedules or production priorities limit real activation possibilities.

From a functional perspective, flexibility solutions must be compatible with normal plant operation and easy to integrate into existing workflows. This typically requires clear prioritisation of production over external flexibility signals, configurable process limits, transparent activation logic, possibility for operator override, reliable communication of activation requests and low additional workload for plant personnel. In addition, companies generally require clear visibility of expected economic benefits, documented performance results and confidence that flexibility actions will not create unintended process disruptions.

Another important factor is the digital maturity of industrial sites. Companies with established energy management systems, sub-metering, process monitoring and automation interfaces are structurally better positioned to identify and use flexibility than sites relying only on monthly billing data or limited internal transparency. This means that industrial flexibility is not only a question of available load potential, but also of data quality, process understanding and the capability to connect flexibility functions with existing control systems.

These general observations are reflected in the two participating industrial contexts of the Austrian pilot. Gsellmann represents a feed production environment with milling, mixing, drying and other mechanically intensive process steps, where flexibility is mainly linked to batch scheduling, motor-intensive processes and peak-load management. Fleischhof Raabtal represents a meat-processing environment with continuous refrigeration demand, cold storage and hygiene-sensitive operating conditions, where flexibility is more strongly constrained by product quality, temperature limits and process continuity.

In both cases, the relevant challenge is therefore not merely whether electricity consumption can be shifted, but whether such actions can be integrated into normal plant operation without affecting production reliability or product quality. A favourable starting point of the Austrian pilot is the existing energy management and automation system of EVON’s at the participating sites. This provides access to operational data and process behaviour, while also creating a practical basis for integrating future flexibility functions into existing control environments, including monitoring, optimisation, automated actions and user-oriented operational support.

Distribution System Operator

In Austria, distribution system operators are currently facing a significant transformation of the electricity system. Grids that were historically planned for relatively stable demand and one-directional power flows must increasingly accommodate decentralised photovoltaic generation, rising electrification and more dynamic local consumption patterns. This is particularly relevant in rural and semi-rural regions, where existing network structures were often not dimensioned for simultaneous high feed-in from distributed generation or rapidly changing local demand.

As a consequence, issues such as local voltage rise, transformer loading, reverse power flows and reduced capacity for additional renewable connections are becoming more visible across many Austrian distribution networks. In this environment, flexibility is increasingly considered a useful complement to conventional grid reinforcement, especially where physical network expansion would require high investment, lengthy implementation or complex approval procedures.

At the same time, the practical use of flexibility remains challenging. Many Austrian distribution grids were not originally designed for active real-time management at lower voltage levels. While higher grid levels are generally supported by established control systems, visibility in medium- and especially low-voltage networks is often more limited. The ongoing smart meter rollout has improved data availability, but standard processes are still largely based on 15-minute interval values that are usually transferred with delay. These data structures were primarily introduced for billing, settlement and market processes rather than for operational flexibility management.

As a result, many DSOs still rely on a combination of network models, historical profiles, selected measurement points and forecasts rather than on a continuous real-time overview of all relevant local grid conditions. For future flexibility use, however, more timely and location-specific information will be necessary, particularly in areas with high photovoltaic penetration, electrified heating demand, electric mobility growth or recurring local bottlenecks.

From a technical perspective, flexibility therefore requires improved grid observability, better forecasting of load and photovoltaic generation, reliable communication pathways and verification that activated flexibility has actually been delivered. From a functional perspective, any solution must fit into normal grid operations. This means that activation processes need to be transparent, interfaces easy to use, operational effort limited and the expected network benefit clear and reliable.

The Austrian pilot intentionally involved a small regional DSO facing these developments in practice. In addition to operational experience, the organisation has also participated in research and innovation activities related to smart grids and flexibility, which allowed it to contribute both practical and forward-looking insights.

This was clearly reflected during the consultation. The DSO confirmed that industrial flexibility is considered relevant, particularly due to already visible local constraints linked to high photovoltaic penetration and limits for further renewable integration in some areas. At the same time, the stakeholder emphasised that current infrastructures are only partly suitable for active flexibility use. Existing smart meter data was considered useful for settlement purposes, but insufficient for more dynamic operational applications.

The stakeholder therefore highlighted the need for higher-resolution and more timely data, improved visibility of available flexibilities, forecasting functions, congestion indicators and practical activation tools that can be integrated into existing workflows without creating unnecessary complexity. Bilateral arrangements with industrial customers were considered a realistic first implementation step, while broader flexibility market approaches may become relevant once technical and regulatory conditions develop further.

Energy service provider and data management perspective

In Austria, energy service providers increasingly play an important role at the interface between industrial consumers, distribution system operators and electricity market processes. As the energy system becomes more digitalised and decentralised, flexibility depends not only on available technical load potential, but also on whether relevant data can be transformed into operationally usable information. In this context, service providers are particularly relevant because they already work with metering data, settlement structures, customer processes and digital communication across different actors.

From a technical perspective, one of the main challenges in Austria is that many existing data flows were originally developed for billing, settlement and market communication rather than for active flexibility management. Standard smart meter processes are typically based on 15-minute interval data, often transferred with delay, which is suitable for accounting purposes but less appropriate for dynamic flexibility activation or short-term optimisation. In addition, relevant data may be distributed across multiple actors and systems, including industrial EMS platforms, suppliers, metering operators and DSOs.

This means that the key technical requirement is often not the creation of new data sources, but the better use of existing ones. Flexibility services require harmonised time series, synchronised timestamps, reliable interfaces, higher data granularity where needed and secure exchange of information between actors. Without these conditions, theoretical flexibility potential can remain difficult to identify, validate or activate in practice.

From a functional perspective, future flexibility solutions must fit into existing operational and commercial processes. This includes compatibility with billing and settlement workflows, clear responsibilities for data handling, transparent allocation of benefits and practical coordination between participating actors. Service providers also require solutions that are scalable across multiple customers and regions rather than highly customised for individual cases.

These aspects were strongly reflected in the consultation with the energy service provider. The stakeholder highlighted that flexibility is fundamentally a data-driven topic and that the main issue often is not data availability itself, but whether data is harmonised, synchronised in time and accessible in a way that allows operational use. Existing Austrian infrastructures were described as providing a solid basis, but currently more oriented towards settlement and market administration than toward active flexibility services.

The energy service provider also emphasised that new flexibility solutions should build on existing structures rather than disrupt them. From this perspective, relevant future functionalities include streamlined data access, interoperable interfaces, better integration of consumption, generation and grid-related data, and standardised processes that reduce coordination effort between market actors.

Overall, the consultation confirmed that energy service providers can play an important enabling role in the Austrian pilot by translating existing data structures into practical flexibility services. Their contribution is therefore less about owning flexible assets directly and more about making flexibility measurable, tradable, verifiable and operationally manageable.

Research institutions, technical experts and applied innovation perspective

Austria has a well-established landscape of research institutions, technology centres and specialised experts working on renewable integration, industrial energy systems, sector coupling, digital energy management and system flexibility. In recent years, industrial flexibility has gained increasing importance within this environment, as higher shares of variable renewable electricity require more adaptable industrial demand, improved coordination between energy carriers and more efficient use of existing grid infrastructure. Austrian experience shows that industrial flexibility is particularly relevant where companies combine electrified processes, on-site generation, storage options or energy-intensive production steps with changing market and grid conditions.

From a technical perspective, experts generally assess flexibility as a data- and control-driven system topic. The practical use of industrial flexibility depends on sufficiently granular metering, reliable process data, forecasting of demand and renewable generation, interoperable communication interfaces and the capability to connect optimisation functions with existing Energy Management Systems (EMS), automation platforms and plant control systems. At the same time, many Austrian research and demonstration activities have shown that technical potential alone is not sufficient. Industrial flexibility must be compatible with production priorities, quality requirements and staffing realities. This means that successful solutions typically require transparent activation logic, clear process constraints, reliable override possibilities, user-friendly interfaces and visible economic benefits. Where these conditions are missing, theoretical flexibility often remains unused in practice.

These aspects were clearly reflected in the consultation with research institutions, software experts and applied innovation stakeholders in the Austrian pilot. Participants were generally familiar with flexibility concepts and demand-response approaches through previous work in smaller-scale applications such as buildings, distributed energy resources and digital energy systems. At the same time, they considered industrial demand flexibility more challenging because production processes are less standardised, operational constraints are stricter and reliability requirements are higher.

The stakeholders highlighted that industrial flexibility is unlikely to be continuously available and should rather be understood as a situational resource that depends on process windows, operational priorities and available technical margins. However, if activated at the right time, it was considered capable of delivering relevant system value, for example by supporting congestion management, reducing peak loads or improving the integration of renewable electricity. This assessment is closely aligned with Austrian industrial flexibility experience, where targeted activation during specific time windows is often considered more realistic than permanent availability.

From a functional perspective, participants emphasised that implementation requires clear activation rules, compatibility with plant routines and visible financial incentives for participating companies. Solutions should remain practical to use and should not create unnecessary operational burden for industrial staff. Digital platforms were considered valuable where they help combine forecasting, optimisation, coordination and decision support in a manageable form.

A further recurring topic was the gap between technical concepts developed in research environments and practical implementation under real industrial conditions. Stakeholders noted that many solutions appear feasible in theory, but become more demanding when legacy systems, heterogeneous interfaces, cybersecurity requirements and production-

critical operating conditions must be considered simultaneously. This also reflects Austrian industrial experience, where digital readiness and existing automation structures strongly influence the speed of implementation.

Overall, the consultation showed strong interest in the Austrian pilot as a practical learning case. Participants expressed willingness to continue knowledge exchange and to contribute expertise in digitalisation, interoperability and system integration as the pilot progresses.

Regional energy transition actors and replication perspective

Austria has established a broad regional support structure for local energy transition through Climate and Energy Model Regions, municipalities, regional associations and local implementation networks. These actors have played an important role in accelerating renewable deployment, awareness raising, local project development and stakeholder mobilisation. In many regions, practical activities have focused primarily on photovoltaic expansion, building renovation, renewable heat, sustainable mobility and, more recently, energy communities.

As the Austrian energy system becomes more decentralised and electricity-based, regional actors are increasingly confronted with a new challenge: renewable expansion alone is no longer sufficient if local grid capacity, demand patterns and system integration aspects are not considered in parallel. In practice, this means that future regional energy planning will increasingly need to address not only how additional generation is installed, but also how electricity is consumed, shifted, stored and coordinated locally.

From a technical perspective, regional organisations usually do not operate grids or industrial assets directly. Their relevance therefore lies less in direct control functions and more in enabling conditions for flexibility. This includes the identification of suitable local stakeholders, support for pilot implementation, facilitation of communication between actors, dissemination of practical solutions and promotion of digital tools or new business models where appropriate.

From a functional perspective, such actors require flexibility concepts that can be translated into understandable and practical regional measures. Highly complex market or control mechanisms are often less relevant than clear use cases, simple communication messages, replicable examples and approaches that can be communicated to municipalities, businesses and citizens. Regional actors also benefit from tools that help explain the relationship between renewable expansion, local grid limits and the value of more flexible consumption patterns.

These aspects were clearly reflected in the consultation with representatives of the Climate and Energy Model Region ecoEnergyland. Participants confirmed that their main focus has so far been on renewable expansion and practical implementation support, particularly in relation to photovoltaic systems and local energy communities. Flexibility was generally known as a concept, but had not yet been a central topic in their activities.

At the same time, the discussion showed growing awareness that grid-related constraints are becoming more relevant. In particular, high photovoltaic deployment may create local limitations that cannot be solved solely by adding more distribution capacity. Participants recognised that future regional strategies may increasingly need to consider how electricity is used and managed in addition to how it is produced.

The workshop also highlighted that regional actors do not have a direct operational role in grid management. Their contribution is more indirect, for example through awareness raising, local stakeholder engagement, communication of practical solutions and support for initiatives that include flexibility-related elements. There was particular interest in practical examples, simple tools and clear messages that could be transferred to municipalities, companies and citizens.

Given that ecoEnergyland is part of a wider Austrian network of more than 120 Climate and Energy Model Regions, the discussion also highlighted the relevance of replication. Successful approaches developed in one region may be transferable to other Austrian regions facing similar challenges related to renewable expansion, local grid capacity and growing electrification.

Overall, the consultation indicated that regional actors may increasingly broaden their future focus from renewable deployment alone towards a wider system perspective that also includes flexibility, demand management and local system integration.

5.2.3 Pilot-specific insights (functional and technical) – Pilot BG/GR

The stakeholder inputs collected in the BG/GR pilot were consolidated and structured according to the main stakeholder categories represented within the pilot ecosystem. The following sections therefore present the consultation results grouped into industrial end-users, transmission and distribution system operators (TSO/DSO), technology providers, and aggregators/business actors. The presented findings reflect the original stakeholder inputs gathered during the consultation activities and illustrate the different operational, technical, organisational and market-related perspectives relevant for industrial flexibility activation within the cross-border pilot context.

Industrial end-users

Industrial respondents from both countriesfindicated that some form of internal electricity demand management is already in place, although the level of structuring differs across the two sites. The Greek sidereported that decisions on energy management actions are taken jointly by the operations and finance teams on the basis of cost-impact analysis and production requirements, and that they have previously participated in a national load-shedding programme in 2015; energy performance is currently evaluated on an annual basis under the ISO 50001 framework. The Bulgarian side operates within a more articulated arrangement, in which energy management is the responsibility of the Maintenance Department and the dedicated Energy Manager, and reports directly to the Technical Director. Performance is monitored monthly by tracking energy use against production volumes and is then coordinated with the balancing entity for group-level financial optimisation. . Internal optimisation actions reported by this respondent include the daily alignment of production schedules with the energy nominations submitted to the market, peak-load management through the avoidance of simultaneous start-ups of high-power equipment, and the adaptation of the production schedule in case of equipment failure or raw-material shortage in order to remain within the limits of the corporate balancing group.

The operational conditions reported by the consulted industrial stakeholders point to a relatively constrained flexibility in load shifting highlighting that continuity of production and safety are non-negotiable parameters The Bulgarian side framed the question in more

structural terms, identifying the day-ahead nomination logic as the main constraint on real-time flexibility: consumption is planned and submitted to the balancing arrangement by midday on the previous day, with the consequence that real-time adjustments are mostly restricted to emergency situations (such as equipment failures or raw-material shortages) or to limited shifts between production batches. Within these boundaries, the acceptable response time for external control commands reported by the Bulgarian side is in the order of fifteen minutes, while the Greek industrial side did not specify a numerical value for this parameter.

Monitoring and metering infrastructure appears to be already in place across the consulted industrial sites and is consistently reported by the stakeholders as the technical backbone enabling any future participation in flexibility services. The Greek side operates an EMS environment based on Eaton Powernet and Protasis Zenon, with hourly acquisition of active and reactive power. The Bulgarian industrial end users operate a dedicated Power Monitoring System installed on a local server, providing real-time tracking of electricity, natural gas and water consumption, with reporting and analytics available at hourly, daily, monthly and annual intervals; this central system is supported by an internal sub-metering network deployed at distribution-board level on the main production lines, which allows high-granularity data collection and per-process visibility, and which the respondent explicitly identified as a key enabler for the future verification of any flexibility service provided to the grid.

The consulted stakeholders consistently emphasised that operational data are available within their organisations, but that their use for flexibility purposes is conditioned by strict ownership and access policies. The Greek side indicated that data ownership and access rights are , in line with the internal cybersecurity guidelines, and that any external sharing is subject to confidentiality requirements driven by the sensitivity of production data. The Bulgarian side reported that data are owned exclusively by the organisation and that access is restricted to authorised technical staff and to t the corporate balancing entity of the cluster; access to the internal Power Monitoring server is further protected through firewall segmentation, user-authentication levels and isolation of the operational-technology network on dedicated VLANs. The same respondent indicated that, while internal data flows are well structured, the exchange with third parties still relies to a significant extent on manual reporting in spreadsheet form, with the consequent delays and integration overhead.

The Greek sideoperates on OPC-UA, while the Bulgarian side relies primarily on Modbus (TCP/IP and RTU) for the communication of its Power Monitoring System with field devices, complementing this with alignment to IEC 61850 and IEC 60870-5 for power-system communication, IEC 62351 for the security of energy management protocols, the ENTSO-E Common Information Model for data exchange in the European electricity market, and the CENELEC CLC/TC 57 guidelines for power-system management and information exchange.

The experience reported by the consulted stakeholders with flexibility schemes, energy-efficiency programmes and market participation is uneven across the sample, but it is present on both sides of the border and provides a useful baseline for the design of the pilot activities. in a national load-shedding programme in 2015. On the Bulgarian industrial side, it was reported that active participation in the national balancing arrangement, ia currently

taking place on the basis of a day-ahead nomination logic and of an internal settlement that reflects the avoided imbalance costs at group level.

The expectations expressed by the consulted stakeholders towards the automation, forecasting, optimisation and coordination functionalities envisaged for the iFAAP platform are broadly convergent, although the relative emphasis varies depending on the role of the respondent in the flexibility value chain. Across the BG/GR respondents who rated the planned platform modules on a one-to-five scale, the monitoring functionality received the highest scores, closely followed by the simulation and forecasting tools, the alerts and notifications module and the automation module, with the reporting and benchmarking module also receiving consistently positive ratings. From the industrial perspective, the Greek side indicated maximum interest in the full set planned modules, while the Bulgarian side gave the highest priority to the monitoring and to the reporting and benchmarking functionalities, immediately followed by the alerts, automation and forecasting modules.

Beyond the specific items addressed in the previous paragraphs, the consulted stakeholders raised some additional functional and technical aspects considered relevant for the future deployment of industrial flexibility. Specifically the Bulgarian industrial side highlighted that the existing internal sub-metering infrastructure already enables a per-process verification of any flexibility service provided to the grid, and indicated that the iFAAP platform should support the automated verification of delivered flexibility on the basis of fifteen-minute interval data, in line with the settlement intervals towards which the national market is progressively transitioning.

Transmission and Distribution System Operators

The consulted transmission and distribution system operators provided additional perspectives regarding operational response requirements, data exchange practices and the role of flexibility services within system operation and network management.

Complementary indications were provided by the system-operator side: the Greek TSO reported response-time requirements expressed in seconds, consistent with the activation logic of balancing services, which provides a useful reference for the response-time expectations on the demand side.

From the network-operator side, the DSO confirmed that data exchange with industrial customers is currently carried out through near real-time metering data, and the TSO reported the use of a national EMS with near real-time acquisition of operational data. Overall, the picture emerging from the BG/GR consultation is that the limiting factor for industrial flexibility activation does not lie in the availability of monitoring infrastructure, but in the way in which the data produced by these systems can be exchanged, valorised and acted upon at the level of the wider flexibility value chain.

From the network-operator side, the DSO confirmed that data exchange with industrial customers is currently performed through near real-time metering data, while Ithe TSO reported the use of API-based exchanges with industrial counterparties, also based on near real-time acquisition.

The TSO confirmed the use of Modbus and MQTT, in line with its near real-time data acquisition and API-based exchange practices.

The Greek TSO did not report any internal use of demand-side flexibility for its own consumption, but consistently identified industrial flexibility as a relevant tool for system operation, while the Greek DSO reported no current use of industrial flexibility either, with its participation in the field of flexibility currently limited to EU and national R&D projects.

From the system-operator side, the DSO rated all five modules at the maximum or near-maximum level, identifying the ability of the platform to communicate effectively with flexible assets as the most important functional expectation, while the TSO consistently ranked monitoring, automation, simulation and forecasting as high-priority functionalities and indicated that visibility of flexible assets, forecasts, congestion indicators and grid-constraint information would be particularly valuable in supporting system-operation tasks.

A second set of inputs concerns the integration with grid-side information: both the industrial and the network-operator respondents indicated that the availability of grid-constraint indicators, congestion maps and dynamic-tariff signals would significantly enhance the ability of industrial users to anticipate load-shifting opportunities and to align their operational decisions with the actual needs of the system.

Technology Providers

The technology-provider perspective broadens the picture: the consulted technical stakeholders indicated that they routinely integrate market-leading SCADA and EMS platforms in industrial environments, including Siemens, Schneider Electric, ABB, Honeywell and GE Digital, and increasingly combine them with IoT platforms and digital-twin solutions for advanced operational decision-support.

Common to all consulted respondents is the recognition that EMS environments currently fulfil mainly a monitoring and reporting role, and that further integration with forecasting, optimisation and external coordination layers (such as the iFAAP platform) is needed to translate this infrastructure into actual flexibility services.

The technology providers consulted in the BG/GR context highlighted that the prevailing challenges in this area are less about the availability of data and more about the harmonisation of data semantics across vendors, the bridging of legacy systems with limited API capabilities, and the establishment of secure and automated cross-organisational data flows.

The technology-provider perspective broadens the picture further: the consulted technical respondents reported a wider inventory of protocols routinely deployed in industrial and energy projects, including OPC-UA, Modbus TCP/RTU, MQTT, REST APIs, AMQP, DNP3, IEC 60870-5-101/104 and IEC 61850, with the Common Information Model under IEC 61970/61968 increasingly used as a semantic layer to ensure consistent data meaning across heterogeneous vendor platforms.

The interoperability challenges most frequently mentioned by both industrial and technology-provider respondents include the persistence of legacy systems with limited API capabilities, the use of proprietary tags by different vendors that require complex mapping to standard data models, the partly manual nature of data exchange with third parties (often based on spreadsheet files), the difficulty of establishing secure and automated real-time data flows across organisational boundaries, and the fragmentation of national models for

the management of metering and consumption data across European Member States. On the cybersecurity and data-protection side, the consulted stakeholders reported alignment with ISO/IEC 27001, IEC 62443, NIS2 and GDPR, with the Bulgarian respondent additionally referencing the recent national transposition of the NIS2 Directive into the Bulgarian Cybersecurity Act.

A third set of inputs concerns semantic interoperability: the consulted technology providers explicitly identified the native adoption of the Common Information Model under IEC 61970/61968 as a relevant functional requirement for the iFAAP platform, in order to ensure that flexibility-related data can be ingested consistently across heterogeneous vendor environments.

Finally, the consulted stakeholders converged on the consideration that the field-level monitoring and communication infrastructure is generally already in place at the consulted sites, and that the principal added value of the iFAAP platform is expected to lie in the integration and decision-support layer between industrial sites, aggregators and network operators, rather than in the substitution of the existing field-level systems.

Aggregators

The aggregator, confirmed that, under the current Greek market design, industrial consumers can access the balancing market operated by the TSO through certified aggregators, both for balancing capacity (FCR, aFRR and mFRR) and for balancing energy (aFRR and mFRR), in addition to the optimisation of consumption against day-ahead market prices, and that the company itself offers ESCO and demand-response aggregation services to industrial clients.

The following table (Table 5) summarises selected functional and technical aspects highlighted during the stakeholder consultations across the LEONARDO pilot regions.

TABLE 5: COMPARATIVE OVERVIEW OF FUNCTIONAL AND TECHNICAL STAKEHOLDER PERSPECTIVES ACROSS PILOT REGIONS

Aspect	IT	AT	BG/GR
Industrial contexts	Manufacturing, pharmaceutical, paper and petrochemical industries, complemented by DSO, aggregator, technology provider, research and policy perspectives	Feed production and meat-processing industry, complemented by DSO, energy service, research, software and regional energy-transition perspectives	Refinery sector and aluminium industry, complemented by TSO/DSO, aggregator/ESCO, market operator and technology provider perspectives
Existing optimisation practices	Energy scheduling, flexibility-related optimisation, local flexibility market experience and DSO coordination approaches	Initial flexibility considerations, EMS-supported optimisation, bilateral coordination options and grid-related flexibility needs	Internal balancing coordination, production scheduling, balancing market orientation and grid-side flexibility considerations

Monitoring and EMS environments	EMS, SCADA, industrial monitoring systems, smart meters, DSO network monitoring and aggregation interfaces	Existing monitoring and energy-management environments, smart-meter-based settlement data and need for improved grid observability	EMS platforms, Power Monitoring Systems, sub-metering, near-real-time TSO/DSO data and industrial monitoring environments
Data and interoperability aspects	Data access, integration challenges, API requirements, GDPR considerations and need for standardised interfaces across EMS, DSO and market platforms	Practical interoperability considerations, harmonised time series, delayed 15-minute data, secure data exchange and integration with existing Austrian market and settlement structures	Strict data governance, cybersecurity, cross-border interoperability, semantic data models and secure automated data exchange across industrial, market and grid actors
Flexibility-related experience	Participation in flexibility initiatives, national and local market schemes, aggregator activities and DSO flexibility pilots	Early-stage flexibility exploration, no mature DSO flexibility market yet, and interest in bilateral or pilot-based implementation models	Balancing arrangements, demand-response participation, certified aggregator services and TSO/DSO interest in industrial flexibility
Main platform expectations	Monitoring, reporting, forecasting, coordination support, API-based integration, transparent activation logic and human-supervised flexibility activation with override possibilities	Practical integration and coordination support, forecasting, congestion visibility, interoperable data exchange, user-friendly workflows and low operational burden	Monitoring, automation, interoperability, forecasting, verification, grid-constraint visibility and coordination support across industrial, market and network actors

5.3 Business and Organisational Requirements

This section presents a structured synthesis of stakeholder feedback related to the business, organisational and decision-making conditions influencing industrial Demand-Side Flexibility participation across the LEONARDO pilot regions. The analysis reflects stakeholder perspectives on expected benefits, business models, market participation conditions, organisational readiness and perceived barriers affecting flexibility activation.

The findings are structured according to the stakeholder groups consulted within each pilot region, highlighting similarities and differences in business-related expectations, organisational arrangements and market-related considerations relevant to industrial flexibility participation and future service development.

5.3.1 Business and Organisational Requirements – Pilot IT

This section presents stakeholder perspectives on the business, organisational and decision-making conditions that may influence the willingness and ability of industrial actors

and related stakeholders to participate in demand-side flexibility initiatives in the Italian pilot region. The analysis is structured by stakeholder group, reflecting how business conditions and organisational readiness differ across the categories consulted. The section draws on both questionnaire responses and interview findings.

Industrial end-users

Awareness and familiarity with industrial flexibility varies substantially within the industrial end-user group and is strongly correlated with prior market participation. The energy consortium and the paper and energy company rate their familiarity at 4-5 out of 5; the discrete manufacturer and petrochemical operator at 3-4; the apparel manufacturer at 2. This gradient has direct implications for capacity-building design: experienced actors need improved tooling and market simplification, while less experienced participants need practical guidance on translating existing monitoring infrastructure into market participation opportunities.

Focusing specifically on the Storo-based end-users - the discrete manufacturer and the energy assets owner -the average familiarity level is approximately 3 out of 5. This reflects a situation where the assets and the basic monitoring infrastructure are in place or being deployed, but engagement with flexibility market mechanisms and commercial arrangements has not yet begun. The workshop held in Storo in January 2026 confirmed this profile: participants clearly understood the potential of their assets for flexibility provision but identified the lack of structured market access, the complexity of participation procedures, and the absence of incentive tariffs compensating for production process modifications as the primary barriers to engagement.

Perceived benefits differ by experience level. The paper and energy company frames flexibility as a monetisation of embedded industrial capability, revenue from existing assets at near-zero additional CAPEX, rather than as an energy-efficiency or cost-reduction measure. This framing is distinct from that of less experienced actors, who associate flexibility primarily with cost savings and energy efficiency. The petrochemical operator adds process reliability as an explicit benefit: a flexible production system is inherently more resilient to energy supply disruptions. Less experienced manufacturers associate flexibility with cost reduction (apparel, discrete manufacturer) or energy efficiency and CO2 reduction (pharmaceutical, petrochemical). The energy consortium combines cost reduction and energy efficiency with active market participation.

Financial barriers are not the primary concern for operators already engaged in flexibility markets. For those not yet engaged, the key issue is uncertainty about cost recovery for monitoring and control upgrades. The workshop highlighted the importance of incentive tariffs and specific support for EMS adoption as preconditions for wider participation by smaller or less experienced industrial actors. The absence of availability-based payments in the Italian MBR/balancing market (which currently pays only on activation) was identified as a structural financial barrier by multiple respondents across categories.

Organisationally, the energy consortium has a dedicated internal energy manager coordinating procurement and monitoring for member companies. The other industrial end-users manage energy informally through IT departments or production management structures, without dedicated energy management functions. The key internal barriers cited

are shift scheduling constraints, risk perception, and limited technical capacity at the individual site level. Multiple respondents noted that flexibility solutions must be compatible with normal plant operation, require minimal additional workload for plant staff, and must not create the risk of unintended production disruptions.

On cooperation with aggregators, the energy consortium and the paper and energy company have direct experience with aggregator partnerships. The other end-users have not yet engaged. The discrete manufacturer and energy assets owner, both in Storo, expressed willingness to engage through CEDIS or other aggregators, preferring a portal-based interaction model over direct market access. The workshop confirmed that participants across the industrial group saw the generation of new revenues and the reduction of energy costs as the primary business motivations, and that the availability of a software platform integrating data visualisation, forecasting, reporting, and AI-assisted optimisation was considered a prerequisite for effective participation.

Technology providers

Technical providers occupy a bridging position between industrial asset owners and the flexibility market: they provide the monitoring, control and integration infrastructure that makes flexibility measurable, activatable, and commercially manageable. From a business perspective, their main interest is in a stable and scalable market context that justifies investment by their industrial clients in monitoring and EMS upgrades.

Knowledge levels range from 2 to 4 out of 5 among the three providers, reflecting a mix of established market specialists and IT/SCADA companies for whom flexibility is a newer service dimension. One provider explicitly noted that the platform should not be designed ahead of current market capabilities, to avoid misalignment with the actual state of Italian flexibility market automation.

From an organisational perspective, technical providers consistently identify organisational barriers - integrating flexibility management into existing operational routines and shift structures - as the highest-priority constraint for their industrial clients. Low awareness among potential industrial clients of how flexibility market mechanisms work is cited as a significant adoption barrier. Practical case studies and direct guidance from aggregators are considered more effective enablers than formal training programmes.

Financial investment in gateway hardware and EMS integration is only justified once the minimum modulable power per resource can be estimated with sufficient reliability. The pilot-phase status of local flexibility markets and the unclear timeline for integration into TIDE are cited as factors discouraging industrial clients from committing to infrastructure investment.

Technical providers express strong expectations for iFAAP as an integration layer: a standardised API that allows different EMS systems to communicate with the platform without custom integrations is the most concretely articulated requirement. This reflects the current fragmentation of the Italian EMS landscape and the disproportionate cost of bespoke integration projects for individual industrial sites.

Distribution system operators

For DSOs, the business case for flexibility is primarily framed around network services rather than revenue generation: avoided or deferred grid reinforcement, improved asset utilisation,

better integration of distributed renewable generation, and management of local congestion. Unlike market actors, DSOs do not primarily seek revenue through flexibility, but efficiency and cost-effective network operation.

The local DSO in Storo (CEDIS) has a distinctive organisational position: it is simultaneously a cooperative energy service provider and a DSO. Its members - industrial and residential customers - are also its shareholders, creating a structural alignment of interests around self-consumption maximisation. This context makes bilateral contractual arrangements with individual industrial members more appropriate than formal auction-based market mechanisms, at least in the short term. CEDIS confirmed in interview a preference for bilateral contracts rather than a formal local flexibility market, given the small number of large industrial members and the close existing relationships within the cooperative structure. Nevertheless, exploring a potential involvement in flexibility market activities is seen as beneficial for long-term grid reliability and resilience in the scenario of increasing load pressure due to strong electrification trends.

The urban DSO provides a contrasting model: a large-scale formal local flexibility market already in operation as a pilot scheme, with dual-component remuneration, defined baseline methodology, and high BSP participation. Its primary organisational bottleneck is the absence of automated activation infrastructure, the current email-based process is not scalable. Organisationally, the DSO sees its role as procuring network services from LSPs, not as managing direct relationships with industrial end-users.

DSOs across the sample agreed that any flexibility platform must be easy to integrate into existing operational workflows, provide clear and verifiable network service benefits, and minimise additional operational burden. Bilateral arrangements were considered a realistic first step, with broader market approaches becoming relevant as technical and regulatory conditions mature. A flexibility platform was considered valuable primarily as a coordination and activation tool rather than as a commercial optimisation engine.

Business and financial actors

Business and financial actors, aggregators and marketplace operators have the highest awareness levels in the sample (5 out of 5 for all three respondents) and the most detailed understanding of the current Italian flexibility market structure. Their business model is built around enabling industrial participation in flexibility markets, and their organisational requirements for iFAAP are therefore the most specific and commercially grounded.

The dominant revenue model in the Italian industrial aggregation context is profit-sharing based on a consumption baseline, supplemented by revenues from ancillary service provision. The dual-component availability plus activation payment structure - present in local MLF pilot schemes but not in the national MBR/balancing market - is identified as the most commercially attractive arrangement. The availability component is the cornerstone of the investment business case: when planning is accurate, it provides near-certain returns covering all fixed costs and generating a meaningful margin regardless of actual activation frequency, enabling cost recovery and investment planning. The key constraint is estimating verisimilar aggregate power before each auction offer, requiring high-quality asset data, reliable forecasting, and a safety margin to minimise non-delivery risk. By contrast, activation-only payments in the MBR/balancing market

create significant revenue uncertainty and are the primary financial disincentive for infrastructure investment.

The regulatory onboarding burden is identified as a market participation barrier equivalent in significance to technical and financial constraints, particularly for smaller actors (RECs, AUCs, small BSPs). The administrative complexity of resource qualification, data management obligations, and fiscal and invoicing processes for distributed revenues creates disproportionate barriers for non-specialist entities, creating market concentration risks.

On cooperation models, commercial actors described their engagement with industrial clients as dependent on access to reliable monitoring data, clear contractual terms, minimal production disruption, and transparent revenue reporting. They expressed strong expectations for iFAAP as a market integration tool: automated API-based interfacing with GME, direct edge-based asset communication bypassing cloud dependencies, and integration with local flexibility market platforms to simplify BSP onboarding and bid submission are the three most concretely articulated platform requirements.

Regulatory and policy actors

Regulatory and policy actors assess industrial flexibility primarily through a systemic and policy evaluation lens rather than from an operational or commercial perspective. From a business and organisational standpoint, their main contribution to the Italian pilot consultation is an assessment of the enabling and constraining conditions in the regulatory framework, and recommendations for improving stakeholder engagement conditions.

These respondents unanimously identified long-term regulatory stability as the most important enabling condition for industrial flexibility market development. Short programme cycles, uncertain integration timelines for local MLF pilots into TIDE, and the still-evolving NCDR (Network Code on Demand Response) create investment uncertainty that discourages both industrial end-users and service providers from committing to the infrastructure and organisational changes required for sustained market participation.

Perceived benefits associated with flexibility from a policy perspective include cost reduction, energy efficiency, CO2 reduction, and broader system-level benefits such as grid stability and congestion management. Importantly, one respondent highlighted that enabling direct consumer participation in the services market, reducing mandatory aggregator intermediation, would represent a significant incentive for sophisticated industrial actors with sufficient operational capability.

On organisational conditions, regulatory actors ranked organisational barriers among the highest-priority constraints across all five barrier categories assessed. The gap between technical potential and operational reality in industrial settings - driven by shift management constraints, absence of dedicated energy management expertise, and cultural resistance to change - is seen by this group as a more fundamental barrier than purely technical or financial factors. Capacity-building requirements therefore extend beyond technical training to include organisational change management, practical implementation guidance, and the establishment of trusted intermediary relationships between industrial actors and service providers.

Four policy recommendations from these respondents are relevant to the Italian pilot context: extending availability payments to national MBR services (like in aFRR, mFRR); enabling direct market participation for eligible industrial consumers; streamlining administrative and qualification procedures for smaller actors; and developing a coordinated TSO-DSO market design framework that avoids conflict between national and local service activation.

Across 21 questionnaire respondents and 8 in-depth interviews, the following patterns emerge as robust and cross-validated by multiple evidence sources:

- Organisational barriers dominate for industrial users who have not yet engaged with flexibility markets. The key barriers are: shift management constraints, absence of dedicated energy management expertise, and uncertainty about how to translate existing monitoring infrastructure into market participation.
- Revenue predictability through availability-based payments is the single most effective commercial enabler. This is the cornerstone of the investment business case for both industrial users and BSPs.
- A spectrum of business models is needed. Sophisticated large operators prefer direct market participation or bilateral arrangements; smaller or less experienced operators require aggregator intermediation and simplified onboarding. iFAAP must accommodate both profiles.
- Activation communication and override capability are non-negotiable for industrial users. Confirmed by two industrial interviews: a portal-based advance scheduling interface is preferred over automated real-time commands; override capability for production emergencies is required.
- Regulatory complexity is a market participation barrier at least as significant as technical or financial constraints, particularly for small-scale actors. Streamlining administrative procedures would do more to expand market participation than technical tooling alone.

5.3.2 Business and Organisational Requirements – Pilot AT

This section focuses on the business, organisational and decision-making conditions that may influence stakeholder participation in industrial demand-side flexibility within the Austrian pilot context. It summarises how different stakeholder groups assess potential value creation, incentives, internal readiness, cooperation models, responsibilities and participation pathways. The synthesis combines the broader Austrian market context with feedback gathered during stakeholder consultations in the pilot region.

Industrial end-users

In Austria, the business case for industrial flexibility is still developing. For many industrial companies, electricity has traditionally been managed primarily as a cost factor rather than as a strategic source of additional value. However, increasing price volatility, growing electrification and the wider deployment of on-site photovoltaic generation are creating new incentives to optimise electricity demand more actively. Potential business benefits include reduced peak-load charges, improved self-consumption of locally generated electricity, better procurement strategies and possible participation in future flexibility-related service schemes.

At the same time, Austrian industrial practice shows that willingness to participate depends strongly on whether flexibility can be implemented without disturbing production processes.

Companies usually compare potential revenues or savings with internal risks such as production delays, quality impacts, staffing effort or increased operational complexity. For this reason, flexibility measures that support existing optimisation goals are often more attractive than completely new market-oriented activities.

This was also reflected in the stakeholder consultations. The participating industrial contexts were considered technically relevant, but organisational decisions were seen as dependent on clear economic value and low operational risk. Process continuity, production reliability and internal approval procedures were identified as more important than theoretical market revenues. Existing digital infrastructure at the pilot sites was regarded as a positive factor because it lowers the effort required for initial assessments and implementation steps.

From an organisational perspective, industrial flexibility typically involves several internal functions, including management, production, maintenance, technical staff and energy procurement. This can slow decision-making if responsibilities are unclear. Stakeholder feedback therefore indicated that flexibility solutions should provide simple decision support, transparent value estimation and minimal additional workload.

Distribution system operator

From a business perspective, for DSOs flexibility is mainly relevant where it can avoid or delay conventional grid reinforcement, improve asset utilisation or support further renewable integration. Unlike market actors, DSOs do not primarily focus on revenue generation through flexibility, but on system efficiency and cost-effective network development.

At the same time, the organisational role of DSOs in flexibility activation is still evolving. Austrian discussions continue around procurement models, data access, coordination with suppliers and service providers, and the regulatory conditions under which DSOs may use flexibility as an alternative to network expansion.

This was reflected in the stakeholder consultations. The involved DSO considered industrial flexibility potentially valuable, particularly in situations of local congestion or renewable integration limits. However, flexibility was not yet regarded as a standard operational instrument. Unclear frameworks, limited practical experience and the absence of established local mechanisms were identified as relevant barriers.

From an organisational perspective, simple and reliable arrangements were considered more realistic than complex market structures, especially in smaller regional network environments. Stakeholders indicated that any future model should be easy to verify, legally clear and operationally manageable. A flexibility platform was considered potentially useful if it reduces coordination effort, provides visibility of available resources and supports practical decisions.

Energy service provider

In Austria, energy service providers can play an important connecting role between industrial companies, DSOs and electricity market actors. Their potential lies in using existing energy data, settlement processes and customer relationships to develop new flexibility-related services. This is particularly relevant because a growing amount of data is already available, but is not always used in a practical or value-creating way.

From a market perspective, future flexibility models in Austria may include both optimisation based on electricity prices and the targeted activation of flexible demand for grid or system needs. In both cases, service providers can support industrial customers by reducing complexity and handling technical or administrative tasks.

This was also reflected in the consultations. The involved stakeholder emphasised that the main challenge is often not missing data, but fragmented systems, different data formats and limited compatibility between actors. This increases effort and makes broader implementation more difficult.

From an organisational perspective, stakeholders stressed that new flexibility solutions should fit into existing billing, settlement and communication processes. They also noted that customers are more likely to participate when a trusted intermediary supports contracts, data exchange and commercial arrangements. A flexibility platform was seen as useful if it builds on existing structures and makes cooperation between actors easier.

Research institutions, technical experts and applied innovation perspective

Austria has strong experience in applied energy research, digitalisation and industrial innovation. From this perspective, industrial flexibility is generally seen as relevant for renewable integration, industrial competitiveness and more efficient system operation. At the same time, experience shows that technical solutions alone are usually not enough. Clear business models, practical implementation steps and organisational readiness are equally important.

Many flexibility concepts work well in studies or pilot projects, but wider market uptake is often slower when expected revenues are uncertain, responsibilities within companies are unclear or implementation effort is seen as too high. Successful models therefore need to combine technical feasibility with clear economic benefits and simple participation structures.

This was also reflected in the consultations. Stakeholders were familiar with flexibility concepts through previous work in buildings, renewable systems, storage integration and digital energy management. However, industrial environments were considered more demanding because decisions are more strongly linked to cost pressure, process reliability and internal approval procedures.

From a business perspective, participants highlighted that companies are more likely to participate when several benefits can be combined, such as lower energy costs, better use of on-site renewable generation, reduced peak demand and additional revenues. From an organisational perspective, they emphasised the importance of trusted partners, practical examples and clear implementation pathways. A flexibility platform was therefore seen less as a stand-alone technical product and more as a useful tool for coordination, transparency and decision-making.

Regional energy transition actors and replication perspective

Regional energy transition actors in Austria, such as local associations, municipalities and regional implementation networks, usually do not participate directly in flexibility markets. Their business interest is therefore mostly indirect. Flexibility can support continued

renewable deployment, reduce local bottlenecks and create new opportunities for regional projects or business engagement.

Many Austrian regional actors have so far focused mainly on renewable generation, energy efficiency, mobility and awareness raising. As grid-related constraints become more visible, flexibility is increasingly recognised as an additional topic that can help regions continue the transition successfully.

This was clearly reflected in the stakeholder consultations. Participants confirmed that previous regional activities had focused primarily on photovoltaic systems, local projects and communication measures, while flexibility had so far played only a minor role.

From an organisational perspective, stakeholders highlighted that their main strength lies in communication, stakeholder mobilisation and transfer of practical knowledge. They therefore expressed interest in understandable examples, simple tools and approaches that can be shared with municipalities, companies and citizens. Replication was also seen as important, as successful approaches in one region could be relevant for other Austrian regions facing similar developments.

A flexibility platform was mainly considered valuable if it demonstrates local benefits, supports awareness raising and provides transferable examples rather than complex market functions.

5.3.3 Business and Organisational Requirements – Pilot GR/GB

Industrial end-users

The industrial end-user responders from both the Greek and Bulgarian sides - consistently identified cost reduction, energy efficiency and CO_2 reduction as the three main expected benefits, which is in line with the corporate-level rationale for engaging in flexibility activities in energy-intensive sectors.

Across the consulted sample, financial incentives were consistently identified as the most effective lever to motivate industrial participation in flexibility services, with operational incentives mentioned as a relevant complement. In respect to stakeholder views on possible revenue sources, incentives or contractual arrangements, the Greek industrial respondent identified shared-savings models and capacity payments as the most relevant business arrangements for industrial flexibility, complemented by participation in balancing and ancillary services.

In terms of financial barriers, investment constraints or uncertainty affecting participation in flexibility initiatives, the Greek cluster indicated that participation in flexibility services typically requires additional capital investment in control and metering equipment, and that the resulting revenues must reliably exceed the costs associated with potential production losses; the same respondent also pointed to the perception that the current policy framework limits the profitability of flexibility activities and imposes slow administrative processes on investment decisions.

Concerning organisational aspects influencing flexibility adoption, including internal responsibilities for energy management or availability of technical expertise, the Greek cluster indicated that energy management decisions are taken jointly by the operations and

finance teams, on the basis of cost-impact analysis and production requirements and pointed to organisational prioritisation and the speed of internal planning and due-diligence processes as the principal internal barriers to flexibility participation. With respect to familiarity with flexibility concepts or demand-response solutions ,there is a high level of awareness In terms of training or capacity-building needs mentioned by stakeholders, the Greek industrial end-user indicated that demand-response training and grid-regulation training would be the most useful measures to support the adoption of flexibility practices within the organisation.

Concerning stakeholder perspectives on cooperation with aggregators, service providers or market actors, the Greek cluster identified aggregators as the main institutional actor that should lead flexibility activation. In respect to views on business models or market participation opportunities relevant in the pilot context, the Greek cluster identified shared-savings models and capacity payments as the most relevant business arrangements, complemented by participation in balancing and ancillary services.

On expectations regarding value creation through a flexibility platform, the Greek side further specified that flexibility projects should ensure a positive return on investment based on reduced energy costs, ideally complemented by CO_2-related compensation, while the Bulgarian side indicated a payback period of less than three to four years as the threshold above which industrial flexibility investments cease to be of interest.

Related to organisational or economic aspects, the Greek cluster indicated that, to be considered viable, flexibility projects should ensure a positive return on investment based on reduced energy costs, ideally complemented by CO_2-related compensation mechanisms and by easy and quick implementation modalities that minimise the administrative overhead at corporate level.

In respect to financial barriers, investment constraints or uncertainty affecting participation in flexibility initiatives, the Bulgarian aluminium plant identified three converging constraints — the high opportunity cost of flexibility relative to production downtime and material scrap during process restarts, the high upfront capital expenditure required for advanced control systems and battery energy storage, and the volatility of balancing-market prices, which complicates the consolidation of a long-term business case.

In terms of organisational aspects influencing flexibility adoption, including internal responsibilities for energy management or availability of technical expertise, the Bulgarian side operates a more articulated arrangement, in which the responsibility lies with the Maintenance Department and a dedicated Energy Manager, reporting to the Technical Director, and is coordinated at group level with the corporate balancing entity of the cluster; the same respondent identified the day-ahead nomination logic as the main organisational constraint, in that it limits the ability to react to real-time production shifts or to unforeseen technical events.

In respect to awareness levels and familiarity with flexibility concepts or demand-response participation, the Bulgarian side reported a familiarity level of four, which is consistent with its current participation in the corporate balancing arrangement.

Concerning training or capacity-building needs mentioned by stakeholders, the Bulgarian side identified the need for specialised training of the energy management staff on the use

of the iFAAP platform and on real-time energy market tools, in order to bridge the gap between the existing internal monitoring infrastructure and the active participation in flexibility services.

Regarding business models or market participation opportunities on the Bulgarian side, the aluminium plant operates within a corporate balancing arrangement, in which the lead Bulgarian industrial end-user acts as the internal aggregator, and identified additional opportunities that could enhance the business case for industrial flexibility, including direct subsidies for infrastructure such as battery energy storage and advanced EMS solutions, the introduction of reduced network charges for verified flexibility providers, and the establishment of capacity payments rewarding the availability of industrial loads regardless of actual activation.

Aggregator

The same triad of benefits was reported by the aggregator which links its commercial offer of demand-response and ESCO services to industrial clients precisely to the combination of operational cost reduction and environmental performance improvement.

Regarding stakeholder views on possible revenue sources, incentives or contractual arrangements, the aggregator described two main value-generating mechanisms currently accessible to industrial consumers in Greece: the optimisation of consumption against day-ahead market prices, through the shifting of energy use towards periods of lower wholesale prices, and the participation in the balancing market operated by the TSO through certified aggregators, both for balancing capacity (FCR, aFRR and mFRR) and for balancing energy (aFRR and mFRR). The respondent further indicated that the settlement of the flexibility services with the TSO is performed at the aggregator portfolio level, and that a secondary settlement is then carried out by the aggregator towards individual industrial customers under bilateral agreements that can be customised to the specific operational profile of each client.

Regarding financial barriers, investment constraints or uncertainty affecting participation in flexibility initiatives, the aggregator framed the issue from the supply-side perspective, indicating that the combination of modest remuneration, operational risk and the complexity of balancing-market participation results in a value proposition that remains limited compared to the potential impact on industrial productivity. The respondent contrasted this with the day-ahead market, where higher price predictability allows industrial clients to plan more effectively and to capture cost-saving opportunities at significantly lower operational risk.

Regarding awareness levels and familiarity with flexibility concepts or demand-response participation, the aggregator reported the highest level of familiarity on a self-assessed scale from one (limited knowledge) to five (expert level), consistent with its operational role as a certified demand-response provider in the Greek market.

Concerning stakeholder perspectives on cooperation with aggregators, service providers or market actors, the respondent confirmed its operational role as a certified intermediary between industrial consumers and the balancing market operated by the TSO, on the basis of bilateral agreements that can be customised to each industrial client.

Regarding views on business models or market participation opportunities relevant in the pilot context, the aggregator confirmed that industrial consumers can currently access two main value-generating channels: optimisation against day-ahead market prices and participation in the balancing market operated by the TSO through certified aggregators, both for balancing capacity (FCR, aFRR and mFRR) and for balancing energy (aFRR and mFRR).

On expectations regarding value creation through a flexibility platform, the aggregator framed the value-creation expectation in terms of cost savings and revenues, and indicated that a higher level of remuneration in the balancing market would be the most effective signal to engage industrial actors more actively in flexibility services.

Regarding other organisational or economic aspects considered relevant by stakeholders, the respondent framed the same point from the market perspective, indicating that higher remuneration levels in the balancing market would significantly improve the perceived value proposition of industrial flexibility.

Transmission and Distribution System Operators

From the network-operator perspective, both the DSO and the TSO indicated cost reduction, energy efficiency and CO_2 reduction as the primary benefits associated with industrial flexibility, framing them in terms of the contribution that industrial demand-side response can bring to the overall efficiency and sustainability of system operation.

Regarding organisational aspects influencing flexibility adoption, including internal responsibilities for energy management or availability of technical expertise, the TSO indicated that energy management responsibilities are placed within the Operations Department and within the Department of Buildings and Assets and identified internal barriers ranging from technical and regulatory limitations to the limited availability of motivation and technical knowledge in some operational units.

Regarding awareness levels and familiarity with flexibility concepts or demand-response participation, the TSO reported familiarity values ranging from three to five across its three internal contributions, reflecting the different perspectives of the units involved. In the same context, the DSO reported the lowest level in the sample, with a familiarity value of two, in line with the limited current use of flexibility at distribution level in Greece.

Regarding training or capacity-building needs mentioned by stakeholders, the TSO indicated that workshops with a clear explanation of the activation mechanisms and of the financial incentives associated with flexibility services would be a relevant capacity-building tool, both for internal staff and for the wider industrial audience.

Concerning stakeholder perspectives on cooperation with aggregators, service providers or market actors, the DSO indicated a preference for a combination of bilateral contracts, local flexibility-market platforms and TSO–DSO coordination schemes, while the TSO expressed a preference for a similar mix, complemented by procurement via aggregators.

On expectations regarding value creation through a flexibility platform, the DSO identified the ability of the platform to support effective communication with flexible assets as the key expectation, while the TSO indicated that the visibility of flexible assets, forecasts,

congestion indicators and grid-constraint information would be the most valuable contribution from a system-operation perspective.

The following table (Table 6) summarises selected business- and organisation-related aspects highlighted during the stakeholder consultations across the LEONARDO pilot regions.

TABLE 6: OVERVIEW OF BUSINESS AND ORGANISATIONAL STAKEHOLDER PERSPECTIVES ACROSS PILOT REGIONS

Aspect	IT	AT	BG/GR
Main perceived benefits	Cost reduction, energy efficiency, operational optimisation, new revenue generation and improved grid resilience	Operational optimisation, renewable integration, reduced peak loads and support for regional energy transition	Cost reduction, energy efficiency, CO_2 reduction, balancing revenues and improved system efficiency
Main business considerations	Revenue predictability, availability-based remuneration, simplified market participation and scalable onboarding models	Early-stage assessment of flexibility opportunities, low operational risk, practical implementation and clear economic value	Balancing revenues, incentives, return on investment, internal balancing arrangements and investment feasibility
Organisational conditions	Dedicated energy-management structures for advanced actors, aggregator-supported participation models, operational coordination and preference for human-supervised activation	Stakeholder-specific organisational approaches, existing operational workflows, trusted intermediaries and practical coordination structures	Internal energy-management structures, balancing coordination, corporate aggregation models and cooperation between industrial, market and system actors
Main barriers identified	Administrative complexity, uncertain business cases, organisational constraints, limited market accessibility and lack of predictable remuneration	Limited practical experience, unclear frameworks, low market maturity, fragmented responsibilities and concerns regarding operational impacts	Investment costs, operational risks, balancing-market uncertainty, administrative complexity and production-related constraints
Awareness and familiarity	High awareness and market familiarity among aggregators, national DSOs and	Mixed awareness levels across stakeholder groups, with stronger familiarity among	High awareness and market familiarity

	regulatory actors, combined with heterogeneous familiarity and experience levels across industrial stakeholders and smaller local actors	research and technical actors and more limited practical flexibility experience among other stakeholder groups	
Main expectations towards flexibility platforms	Transparent coordination, reporting, simplified market interaction, API-based interoperability, market integration support and human-supervised activation with override possibilities	Practical coordination and integration support, transparency, understandable implementation approaches, decision support and low additional operational burden	Monitoring, forecasting, communication, optimisation, coordination support and support for balancing-market participation

5.4 Cross-Pilot Patterns in Stakeholder Perspectives

The stakeholder consultations carried out across the LEONARDO pilot regions highlighted a number of recurring themes related to industrial flexibility participation, while also reflecting the different industrial, organisational and market contexts represented in the pilots. Across all regions, stakeholders referred to operational feasibility, interoperability, monitoring visibility and coordination conditions as important aspects influencing the practical integration of flexibility-related activities into existing industrial and energy-system environments.

At the same time, the consultations showed clear differences in the maturity and operational context of flexibility-related practices across the pilot regions. In the Italian pilot, national stakeholders reported comparatively advanced experience with flexibility markets, aggregation schemes and local flexibility initiatives compared to smaller actors active in the Storo cluster area. In the BG/GR pilot region, discussions were strongly influenced by balancing arrangements, cross-border coordination aspects and the interaction between industrial actors, aggregators and system operators. In the Austrian pilot region, stakeholder discussions were more strongly focused on operational conditions, regional integration aspects and the practical exploration of flexibility opportunities in industrial environments.

Across all pilots, stakeholders indicated that monitoring and energy-management infrastructures are already available in many industrial contexts, including EMS environments, SCADA systems and sub-metering solutions. However, the consultations also highlighted that the main challenges are often less related to the availability of technical infrastructure itself and more connected to interoperability, data exchange, operational coordination and the integration of flexibility-related processes into existing organisational and operational structures.

The consultations further showed that stakeholder familiarity with flexibility concepts differs across stakeholder categories. Aggregators, market actors and system operators generally

reported a higher level of familiarity with flexibility mechanisms and market participation models, while industrial stakeholders more frequently approached the topic from the perspective of operational feasibility, production constraints and investment considerations. Across the different pilot regions, stakeholders also consistently referred to uncertainty regarding business cases, remuneration structures and operational impacts as important conditions influencing the willingness to participate in flexibility-related activities.

6 Cross-Analysis and Implications for iFAAP and Pilot Preparation

The stakeholder requirements and contextual framework conditions analysed in the preceding chapters provide an important basis for understanding how industrial Demand-Side Flexibility participation can be operationalised within the LEONARDO project. By consolidating these findings, this chapter examines their combined implications for the preparation of pilot use cases and for the identification of design-relevant aspects of the Industrial Flexibility Activation and Aggregation Platform (iFAAP). The cross-analysis supports a structured interpretation of requirement patterns, regulatory constraints and regional specificities, enabling a more informed assessment of coordinated flexibility activation approaches across pilot contexts.

6.1 Synthesis of Key Findings on Flexibility Activation

The consultation activities across the pilot regions highlighted that industrial flexibility participation is influenced by a combination of operational, technical, organisational, business-related and regulatory conditions. While the industrial structures, market arrangements and stakeholder ecosystems differ across the pilots, several recurring requirement patterns emerged throughout the analysis.

From a functional perspective, stakeholders consistently referred to the importance of monitoring visibility, reporting functionalities, forecasting support, alerts and notifications, and transparent coordination mechanisms. Monitoring and operational visibility were repeatedly identified as particularly relevant across industrial, commercial and network-operator stakeholder groups.

The consultations also highlighted the importance of compatibility with existing industrial workflows, operational decision-making procedures and production-related priorities. Several stakeholders referred to the need for operational transparency, human oversight and compatibility with existing EMS and SCADA environments.

Interoperability and secure cross-organisational data exchange emerged as recurring technical considerations across all pilot regions. Stakeholders repeatedly referred to heterogeneous EMS environments, proprietary system architectures, limited API capabilities and fragmented communication approaches as relevant barriers for coordinated flexibility activation. In this context, support for standardised interfaces and commonly used industrial communication protocols was frequently highlighted.

From a business and organisational perspective, stakeholders frequently referred to uncertainty regarding the balance between expected revenues, operational risks and required investments. At the same time, existing EMS infrastructures, aggregation approaches, internal energy-management structures and operational coordination mechanisms were described as important enabling conditions.

Overall, the cross-analysis indicates that coordinated flexibility activation approaches within the LEONARDO project need to accommodate heterogeneous industrial contexts while remaining compatible with the operational, technical and organisational conditions identified across the pilot regions.

6.2 Implications for Pilot Preparation and iFAAP Development

The findings from the consultation activities provide several indicative considerations relevant for the preparation of pilot use cases and for the continued development of the iFAAP platform within the LEONARDO project.

The consultations indicate that future flexibility activation approaches need to remain compatible with heterogeneous operational environments and differing industrial process conditions. Stakeholders repeatedly referred to the importance of maintaining compatibility with existing workflows, operational responsibilities and production-related priorities.

Interoperability and integration capabilities emerged as central considerations for iFAAP development. Stakeholders highlighted the importance of compatibility with existing EMS and SCADA environments, support for heterogeneous communication protocols and secure cross-organisational data exchange mechanisms. Monitoring visibility, reporting functionalities, forecasting support and transparent coordination mechanisms were also repeatedly identified as relevant platform-related expectations.

The consultations additionally indicate that flexibility-service approaches within LEONARDO should support coordination between industrial actors, aggregators and network operators while minimising additional operational complexity. Several stakeholders referred to the relevance of transparent activation procedures, operator oversight and practical integration into existing operational environments.

Across the pilot regions, several recurring requirement clusters relevant for coordinated flexibility activation emerged from the consultation activities. These include interoperability and secure data exchange, compatibility with heterogeneous EMS environments, monitoring and reporting functionalities, forecasting and optimisation support, transparent activation procedures and coordination support across stakeholder categories.

Overall, the consultation findings indicate that future flexibility-service approaches within LEONARDO should remain adaptable to the contextual, operational and organisational conditions identified across the pilot regions.

The following table (Table 7) summarises the main requirement clusters emerging from the stakeholder consultations across the LEONARDO pilot regions and illustrates their indicative relevance for the further development of the iFAAP platform and the preparation of coordinated flexibility activation activities.
Overall, the consultations indicate that the key challenges are not limited to the availability of technical infrastructure, but are strongly linked to interoperability, operational coordination, business feasibility and the practical integration of flexibility services into existing industrial and organisational environments. The identified requirement patterns therefore provide an important basis for the subsequent specification, validation and pilot-related refinement activities within the project.

TABLE 7: CONSOLIDATED REQUIREMENT CLUSTERS EMERGING FROM STAKEHOLDER CONSULTATIONS

Stakeholder Findings	Requirement Clusters	Indicative iFAAP Relevance
Need for operational visibility, asset monitoring and EMS integration	Monitoring & Visibility	Monitoring layer, visibility and asset-tracking functionalities
Interest in forecasting, optimisation and coordination	Forecasting & Coordination	Forecasting and coordinated flexibility services
Interoperability challenges, APIs and secure data exchange	Interoperability & Data Exchange	Standardised interfaces and interoperable communication
Business feasibility, operational constraints and organisational readiness	Operational & Business Feasibility	Practical integration into existing operational and organisational environments

7 Conclusions

The analysis carried out within Deliverable D2.1 shows that industrial Demand-Side Flexibility is increasingly considered an important element for supporting renewable energy integration, balancing electricity systems and improving overall system efficiency. Across all LEONARDO pilot regions, stakeholders recognised the growing relevance of flexibility in the context of rising electrification, increasing renewable energy generation and changing electricity market conditions.

At the same time, the consultations and framework analyses highlighted that industrial flexibility participation is influenced by a combination of technical, operational, organisational, regulatory and economic factors. The findings clearly show that flexibility activation is not only a technical issue, but strongly depends on operational feasibility, existing organisational structures, market conditions and interoperability between different systems and actors.

The stakeholder consultations revealed clear differences between the pilot regions regarding flexibility maturity and operational experience. In the Italian pilot region, national stakeholders already reported experience with balancing markets, aggregation schemes and flexibility-related optimisation approaches, while local ones showed limited familiarity with the topic. In the BG/GR pilot region, discussions were strongly linked to balancing arrangements, system-operation requirements and cross-border coordination aspects. In the Austrian pilot region, stakeholders were more strongly focused on practical implementation conditions, regional integration aspects and the operational exploration of flexibility opportunities.

Across all pilot regions, stakeholders highlighted the importance of reliable monitoring infrastructures, compatibility with existing EMS and SCADA environments, transparent coordination mechanisms and secure data exchange. Monitoring visibility, forecasting support and interoperability between different systems were repeatedly identified as important requirements for future flexibility-related solutions and platform approaches.

The consultations also showed that organisational and business-related aspects play an important role for stakeholder acceptance and participation willingness. Stakeholders frequently referred to operational reliability, production continuity, investment uncertainty and unclear remuneration structures as important influencing factors. In several cases, the complexity of market participation procedures and limited practical experience with flexibility mechanisms were identified as relevant barriers.

At the same time, the consultations confirmed that many industrial environments already possess relevant technical infrastructures, including EMS platforms, SCADA systems, monitoring environments and sub-metering solutions. The main challenge is therefore often less related to the availability of technical infrastructure itself and more connected to interoperability, operational integration and the coordination of flexibility-related activities across different actors and systems.

Overall, Deliverable D2.1 provides a consolidated overview of the main stakeholder perspectives, operational conditions and framework limitations influencing industrial flexibility participation across the LEONARDO pilot regions. The findings contribute to a better understanding of the enabling and limiting conditions for coordinated industrial flexibility activation and support the further alignment between stakeholder needs, pilot-

specific conditions and the ongoing development of flexibility-related approaches within the LEONARDO project.

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