

Article

System Requirements for Flexibility Markets Participation: A Stakeholder-Centric Survey from REEFLEX Project

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Abstract

The transition of electric systems from a centralized, fossil-based model toward a decentralized, renewable-powered architecture is reshaping the way electricity is generated, managed and consumed. As distributed energy resources (DERs) proliferate, grid management becomes increasingly complex, especially at the distribution level. In this context, flexibility emerges as a key enabler for more stable and efficient grid operation, while also facilitating greater integration of DER and supporting the electrification of energy demand. Local flexibility markets (LFMs) are gaining importance as structured mechanisms that allow grid operators to procure flexibility services from prosumers, aggregators and other actors. However, to ensure widespread participation, it is essential to develop digital tools that accommodate users of different profiles, regardless of their size, technical background or market experience. The REEFLEX project addresses this challenge by designing and developing 14 interoperable flexibility tools tailored to diverse stakeholder needs. To ensure that these tools are aligned with real market conditions and user expectations, REEFLEX conducted extensive stakeholder-centric surveys. This paper presents the methodology and key findings of those surveys, providing insights into user perceptions, technical requirements and adoption barriers. Results are contextualized within existing literature and other funded initiatives, highlighting implications for the design of inclusive and scalable flexibility markets.

Keywords: smart grids; user-centric design; flexibility management tools; energy flexibility



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1. Introduction

The electrical power system is undergoing a fundamental transformation. Historically dominated by centralized generation, fossil fuels and top-down control, it is evolving toward a decentralized and digitized architecture characterized by bi-directional power flow and the proliferation of Distributed Energy Resources (DERs) such as rooftop solar Photovoltaic (PV) panels and battery storage. The growing affordability and adoption of these technologies, combined with the electrification of some final energy uses—especially in transportation—electric vehicles (EVs)—and heating and cooling—heat pumps, Heating,

Ventilation and Air Conditioning (HVAC) systems, etc. . . ., is reshaping the grid's physical and operational landscape [1]. Governments and regulatory agencies across Europe and globally are promoting this transition through ambitious decarbonization targets, subsidies and digitalization strategies [2,3]. These trends are converging under the broader concept of the smart grid, which integrates energy, Information and Communication Technology (ICT) and automation technologies to create a more intelligent and responsive electricity grid [4–6].

While the shift toward decentralized systems brings environmental and social benefits, it also presents significant technical and operational challenges. The increasing presence of intermittent renewable generation and demand-side electrification introduces new stress on distribution networks, such as voltage fluctuations, reverse power flow and local congestions [7–9]. These conditions are particularly critical for Distribution System Operators (DSOs), who are expected to maintain grid reliability while accommodating millions of flexible devices. However, traditional grid planning and control practices are insufficient to manage this growing complexity. As a result, DSOs are required to coordinate with consumers and flexibility providers at the local level to manage the grid more dynamically [10,11].

Flexibility, the ability of consumers or producers to adjust their electricity consumption or generation profiles in response to external signals (e.g., energy prices, grid conditions), is increasingly recognized as a key enabler of system stability and cost efficiency in decentralized grids [12–14]. Prosumers equipped with flexible assets such as batteries, EVs or smart appliances can act as active participants, offering their flexibility to grid operators. To operationalize this potential, Local Flexibility Markets (LFMs) are being explored across Europe as a mechanism to allow DSOs to procure flexibility services locally, while giving prosumers and aggregators a financial incentive to participate [15,16]. These markets aim to ensure that local resources are effectively coordinated to support grid stability and reduce the need for costly infrastructure reinforcements [17–19]. In addition, the amount of available flexibility, or the penetration level of flexibility, has a high impact on the DSO's optimization process and the final cost of purchase. More availability can be beneficial for all involved parties, as it means less cost for the DSO and better operation for its grids and more income for the aggregator and the customers. Aggregating numerous small customers provides spatially distributed, diversified flexibility that can be activated where and when distribution constraints occur, improving local congestion and voltage management for the DSO [20].

In this evolving context, the REEFLEX project [21] aims to develop interoperable digital tools and market mechanisms (see Appendix A) that enable seamless participation of DSOs, aggregators and end-users in flexibility markets. These tools include IoT-based device orchestration, smart control systems and user interfaces tailored to various stakeholder needs. A key focus of REEFLEX is to ensure that these solutions are not only technically sound but also socially acceptable and economically viable. This aligns with broader European objectives to create a consumer-centric, flexible and inclusive energy system [22]. REEFLEX also contributes to regulatory and interoperability frameworks to promote the scalability and replicability of local flexibility services across Europe.

Despite strong technological advances, the development of flexibility solutions often lacks adequate consideration of user needs and stakeholder expectations. Key issues such as user friendliness, data privacy, motivation and perceived value remain underexplored. As highlighted in recent studies on home energy management and demand-response systems (e.g., [23–25]), even when technologies exist, users often ignore recommendations or remain sceptical due to usability and trust concerns. The success of flexibility markets will depend not only on technological readiness but also on social acceptance and behavioural engage-

ment [26], given common barriers such as lack of awareness, low information-processing skills and user behaviour inertia [27]. To address this gap, the REEFLEX project carried out a comprehensive stakeholder analysis using surveys, interviews and focus groups, targeting a diverse range of actors including prosumers, aggregators and DSOs.

Several recent European initiatives have explored the role of stakeholder engagement in the design of local flexibility markets, often through surveys and pilot evaluations. Common conclusions highlight the importance of user-centricity, automation preferences, data governance and trust in system operators or aggregators. However, these studies are frequently limited to individual stakeholder categories or single-country pilots. The REEFLEX project builds upon this knowledge by conducting a comprehensive, pre-deployment survey that captures expectations across 12 actor/user types and directly links their preferences to a set of 14 digital flexibility solutions under development. This integrated approach enables the early alignment between market design choices and real user needs, with the aim of increasing participation and scalability.

Among earlier efforts, a notable example is the social survey conducted within the European eBalance-Plus project [28], which gathered responses from 3200 households in France, Denmark, Italy, and Spain on two Direct Load Control (DLC) solutions: External Washing Machine Control and External EV Charging Control. The study highlighted cost savings and CO₂ reduction as the main drivers of acceptance, while installation and maintenance costs were the primary barriers. However, its scope was limited to the residential sector, and only two specific DLC solutions, which constrains broader generalization.

Other European projects have also investigated the social and behavioural dimensions of flexibility adoption. For instance, OneNet [29] emphasized interoperability and aggregator-centric automation, where end-users had limited direct interaction but needed assurance of trust and transparency. GLocalFlex [30] and LEO [31] highlighted the role of local communities and municipalities, pointing to moderate acceptance of semi-automated Demand-Response (DR) combined with financial incentives. On the other hand, iFLEX [32] tested AI-based assistants that offered both full automation and user override, showing high acceptance of “set-and-forget” solutions when aligned with comfort and usability. These findings align with broader behavioural research that identifies financial incentives, user-friendly automation and privacy safeguards as the main enablers of participation. However, most earlier studies were confined to specific stakeholder groups, geographical pilots or narrow sets of flexibility solutions. In comparison, REEFLEX targets a broader scope by combining a cross-country, multi-stakeholder survey with direct mapping of preferences to a portfolio of digital flexibility tools, thus enabling comparison across diverse actor categories, while also capturing the balance between technical automation capabilities and social acceptability.

The present work presents the results of the research, aiming to extract actionable insights to guide the design of user-centric flexibility tools and services aligned with market, technical and regulatory requirements. The study adopts a holistic perspective, addressing the adoption process, potential barriers and exploitation scenarios. Furthermore, users have been segmented to derive more precise conclusions, and all relevant components of the value chain that may intervene in the flexibility adoption have been examined.

The remainder of this paper is structured as follows: Section 2 describes the REEFLEX stakeholder survey design and implementation; Section 3 discusses the main results of the surveys; Section 4 presents the key implications for the development of user-centric flexibility tools; finally, Section 5 summarizes the main conclusions in the paper.

2. Survey Methodology

The survey methodology was developed pragmatically to address the specific objectives and needs of the REEFLEX project. Nevertheless, it aligns and incorporates elements of established theoretical frameworks, particularly Structured Stakeholder Analysis (SSA) and sequential survey design practices. This context-driven methodology was designed to collect structured, categorically organized feedback on user requirements, preferences and adoption barriers from 12 different target groups. The results from the survey were used to provide information on the development of the 14 energy solutions and tools within the REEFLEX platform.

Several practical decisions shaped the methodological design. The first step involved using insights from earlier stakeholder engagement activities, which took place during the definition of use cases and business use cases of the project. These early contributions provided qualitative input that helped to shape a single, tailored questionnaire. Using one consistent questionnaire allowed for a systematic exploration of shared barriers and common themes across different stakeholder groups. The questionnaire was reviewed and refined through several rounds of feedback from experts and solution developers within the project. This process aimed to improve the clarity of the questions, confirm their relevance and ensure that the structure remained coherent and aligned with the project's objectives.

2.1. Stakeholder Identification and Categorization

Given the complexity of surveying 12 different target groups and their relation to the 14 different solutions in the REEFLEX project, an ex-ante cross-categorization between the solutions and the target groups was created. This mapping helped to streamline the survey and enhance its efficiency. The structured categorization drew upon the already-established use cases of the project reported in deliverable D2.2—Focus groups and use cases definition [21].

Three main categories were identified according to each stakeholder's market role and potential degree of involvement in the REEFLEX platform:

- I. Non-Expert End-Users: Stakeholders representing the demand side consist of five (5) subgroups based on their context and consumption levels: 1. Residential consumers/prosumers, 2. commercial consumers/prosumers, 3. industrial consumers/prosumers, 4. energy communities and 5. municipalities.
- II. Developers: Stakeholders involved in the technological and commercial development of solutions. These consisted of four (4) subgroups based on their roles in the development and deployment processes: 1. ICT service providers, 2. data analytics providers, 3. energy service providers and Energy Service Companies (ESCOs) and 4. energy technology providers and manufacturers.
- III. Operators: This category comprises stakeholders responsible for integrating, managing and operating energy infrastructure that could use the REEFLEX solutions. They include three (3) subgroups: 1. DSOs, 2. Aggregators and 3. energy storage operators.

2.2. Questionnaire Design and Structure

The design of the questionnaire was formed by the REEFLEX solutions and the stakeholder categorization described in Section 2.1. To ensure relevance and reduce response burden, the survey was structured to guide each participant through a tailored path based on their stakeholder group. This approach enabled the respondents to only view questions that applied to their context, while collecting structured, categorically organized data on common themes across all groups.

The questionnaire was composed of three main sections:

1. **Background and knowledge:** This section captured basic information about the respondent’s role category and their level of familiarity with energy technologies. It was also used to dynamically filter and route respondents to relevant solution sections in the survey.
2. **Solution-specific modules:** This is the central part of the survey and was divided into 14 modules, each corresponding to one of the REEFLEX solutions. Each module began with a brief description of the solution and was followed by a set of consistently applied questions used across all modules, as well as questions tailored to each solution. The respondents were directed to the modules based on a pre-defined mapping shown in Table 1.
3. **Common barriers and preferences:** The final section was shown to all respondents and aimed at capturing overarching themes such as technical and market barriers, motivations for adoptions, automation preferences, willingness to pay and concerns related to privacy and security.

Table 1. Pre-defined stakeholder mapping with respect to the REEFLEX solutions.

Group	Target User	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
I—Non-experts	I.1						X		X						
	I.2				X	X	X	X							
	I.3		X		X	X		X							
	I.4		X		X	X	X								
	I.5		X	X											
II—Technology developers	II.1	X													
	II.2	X													
	II.3									X					
	II.4	X	X	X											X
III—Operators	III.1	X			X		X					X		X	
	III.2	X									X		X		
	III.3					X				X					

S1: Data exchange, handling and interoperability platform; S2: VERIFY: Web-based platform enabling Life Cycle Assessment (LCA)/Life Cycle Cost (LCC) of projects; S3: USE: Platform enabling uniform evaluation of projects; S4: Flexibility potential classification tool for any given asset; S5: Second-life batteries as flexibility assets; S6: Predictive flexibility potential and operation of distributed devices; S7: Non-Intrusive Load Monitoring (NILM) techniques for large consumers’ load; S8: NILM techniques for residential consumers’ load; S9: Innovative inverters for storage systems and electric vehicles–Vehicle-to-Grid (V2G); S10: Algorithms for optimal management of the Grid; S11: End-users’ potential flexibility calculation and aggregation tool; S12: Tool to calculate DSOs flexibility needs; S13: Optimal market selection tool; S14: Peer-to-Peer (P2P) and bilateral energy exchange add-on platform.

The specific mapping between each REEFLEX solution and its relevant target users is presented in Table 1. Grey, empty cells denote stakeholder-solution pairs intentionally

excluded in the survey design, rather than reflecting non-responses. This mapping also forms the basis for the vertical analysis by solution, as described in the section on data analysis methods (Section 2.4).

2.3. Survey Distribution and Data Collection

The final version of the questionnaire was deployed using the Alchemer online survey platform [33], which facilitated structured data collection and storage. The responses were collected over a three-month period, from December 2023 to February 2024. In total, 103 responses were collected from respondents representing all the three target stakeholder groups identified in the categorization phase.

To support wider participation, the questionnaire was translated into Spanish, Greek, Italian and Portuguese using the survey platform's integrated translation functionality. The survey was distributed through multiple channels, including the professional and institutional networks of the project consortium partners and targeted dissemination through project-managed social media channels such as LinkedIn and X (formerly Twitter).

The survey was conducted anonymously and collected no personal or sensitive information. Respondents were informed of the study's purpose and the anonymous handling of their answers, in line with GDPR transparency requirements.

2.4. Data Analysis Methods

The data collected through the questionnaire was analysed using a structured approach, drawing from both quantitative and qualitative techniques appropriate for the survey's closed and open-ended questions. Most of the data was collected through categorical questions (e.g., multiple-choice, scaled ratings), which were analysed using frequency distribution, cross-tabulations and comparative summaries across stakeholder categories. For open-ended inputs (e.g., 'Other, please specify' or text supplements), responses were linked to the most relevant predefined categories to allow for basic quantification. This ensured consistency while still capturing additional suggestions, concerns, and preferences beyond the fixed options.

Given the variation in the number of responses received across solutions, cases with fewer than 10 responses were not subject to statistical interpretation but were treated descriptively instead. Responses in the 10–15 range were reported with caution, while larger response counts provided a more robust basis for comparisons.

In parallel with these data-level techniques, the analysis was also organized according to the structure and objectives of the survey. Specifically, two complementary analytical dimensions were used to reflect the design and intended use of the questionnaire data:

- Horizontal analysis: applied to part 1 (background and knowledge) and part 3 (common barriers and preferences), examined general trends and aggregated from all stakeholders.
- Vertical analysis: applied to part 2 (solution-specific modules), focused on the individual REEFLEX solutions and the feedback from their mapped target user groups (see Table 1).

This distinction ensured that both cross-cutting themes and solution-specific insights were captured, supporting both strategic comparison and targeted refinement of the REEFLEX innovations.

2.5. Methodological Limitations

The survey methodology was designed to be practical and to align with the needs of the REEFLEX project. In light of this, the methodological limitations are acknowledged as follows:

Survey design and comprehension:

- The questionnaire was developed early in the project (before the pilot users were identified).
- To manage scale and complexity, all stakeholder groups and solutions were included in a single, centralized questionnaire. While this ensures consistency, it may have resulted in less targeted feedback.
- Some solution descriptions in the solution specific modules were found to be overly technical for non-expert users. This may have affected respondents' understanding and perception, potentially reducing the accuracy of their feedback.

Sampling and participation bias:

- The survey was distributed primarily through consortium networks and project communication channels, introducing potential selection bias toward stakeholders already engaged with energy research or related initiatives.
- Participation was voluntary, which may have contributed to self-selection bias, favouring respondents with already high motivation or familiarity with the subject matter.
- Final response distribution was uneven, with some subgroups within the three categories underrepresented or not represented at all.

Data analysis constraints:

- Limited response volume restricts the statistical significance and the generalizability of the findings for some solutions.
- The initial response analysis and interpretation were conducted by a single analyst, which introduces potential subjectivity into the qualitative component of the analysis.

Despite these constraints, the diversity of the solutions and stakeholder groups covered provides valuable insights that lay a foundational step in understanding user requirements and the insights may be transferable to broader energy system contexts beyond the REEFLEX project with additional scoping and regulatory analyses.

3. Results

The presentation of the results is in accordance with the three-part structure of the questionnaire. The first subsection (Section 3.1) provides an overview of the respondents' background and knowledge status quo, including their role and familiarity with energy flexibility and existing involvement in energy management systems. The second subsection (Section 3.2) presents a vertical analysis of the responses to the 14 REEFLEX solutions, showing stakeholder-specific feedback for each innovation. Finally, the third subsection (Section 3.3) summarizes the general adoption barriers, automation preferences and willingness to participate factors from all respondent groups. Where relevant, both aggregated results and stakeholder-specific differences are reported.

3.1. Participants' Background and Knowledge

From the 103 complete responses that were collected during the survey period, the majority (69) were non-expert end users, while the remaining respondents were evenly split between technology developers (17) and operators (17). Geographically, most participants are located in Europe, particularly the countries where the REEFLEX consortium members reside, with few responses outside of Europe, as illustrated in Figure 1 with blue dots.

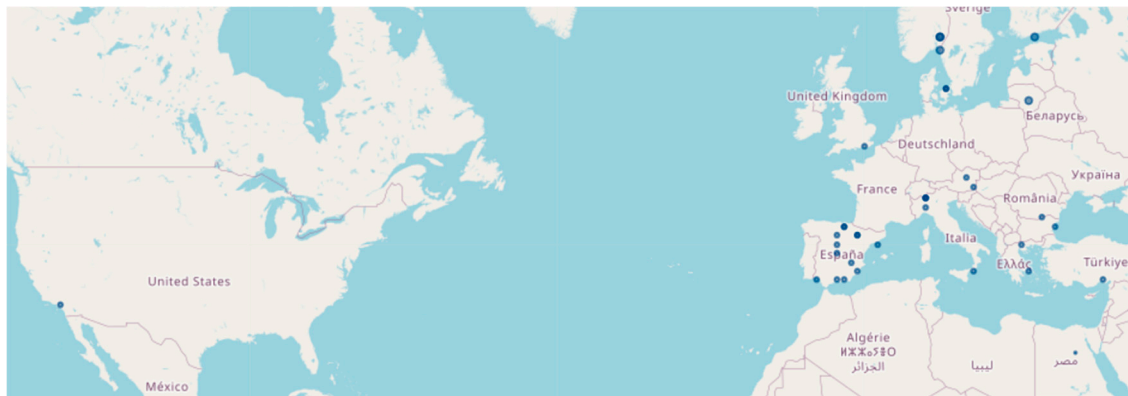


Figure 1. Geographic distribution of survey respondents.

The following analysis explores respondents' familiarity with and usage of energy management and energy flexibility tools. Several key themes are found such as disparities in adoption of the tools, differences in the types of tools across target users and a preference for a comprehensive solution for management and flexibility. More detailed insights are discussed in the following subsections.

3.1.1. Knowledge and Use of Energy Management Tools

All the 103 respondents provided feedback regarding their use of energy management or monitoring tools. The overall usage was relatively low, with only 39.8% indicating that they currently use such tools. Specifically, usage differed by stakeholder category:

- Non-Expert Users: only 33% reported using some energy management tool.
- Developers and Operators: approximately 53% reported usage, indicating a higher adoption rate.

The tools reported to be in use by the respondents included:

- Basic or In-House Systems: Non-experts mainly reported relying on simple monitoring devices and smart meters, as well as some condominium billing systems for tracking individual consumption.
- Unexpected Mentions: A few non-expert respondents indicated the use of open-source software (e.g., OpenHab) that was not originally listed in the survey options.
- Commercial Software: Of the 21 respondents who reported using commercial systems, more than 65% used comprehensive management systems such as SCADA, BMS or ERP. Other responses included applications provided by energy companies and one instance of the off-the-shelf tool Tibber.

3.1.2. Knowledge and Use of Energy Flexibility Tools

When asked about energy flexibility tools, over 85% demonstrated familiarity with the concept, which may be attributed to the survey's participation bias. However, only 19% of the respondents indicated that they use a tool dedicated to energy flexibility.

Further analysis of these responses revealed:

- Nearly half of those flexibility tools reported are within the same energy management system.
- One respondent mentioned using only a "smart wall box for EV charging" as a dedicated energy flexibility tool.
- The disparity between high awareness (over 85%) and low adoption rate (only 19%) highlights a critical gap between knowledge and practical implementation of energy flexibility tools.

Satisfaction rates with energy management tools, as well as energy flexibility tools were evenly distributed, with most respondents indicating either satisfied or neutral rate. This distribution may be linked to a lack of alternatives, leaving room for competition from new solutions.

3.2. Solution-Specific Modules

This section presents the vertical analysis of the 14 REEFLEX solutions evaluated through the survey. Each solution module was shown only to respondents mapped as relevant target users (see Table 1); therefore, not all participants answered every solution-specific set of questions. While some modules included tailored questions based on the nature of the solution, all modules followed a common structure designed to assess perceptions of value, adoption potential and implementation preferences.

Table 2 provides a consolidated overview of the core evaluation dimensions across all REEFLEX solutions. It includes:

- Perceived Helpfulness (Time Horizon): Respondents’ views on when the solution is likely to be most valuable to their business, distinguishing between immediate (now), medium-term (within 5 years) and long-term benefits.
- Identified Barriers: The most frequently reported challenges to adoption, grouped into regulatory, technical, economic and other categories (e.g., complexity, integration issues).
- Preferred Hosting Mode: User preferences for where the solution should be deployed (e.g., central cloud, edge/local, hybrid or proprietary).
- Willingness to Adopt: The degree of openness to adoption and financial contribution, expressed in low, medium or high terms.
- Payment Preference: Preferred business model for accessing the solution, including ownership, leasing or subscription-based options.

Table 2. Summary of the core evaluation metrics common for all solutions (n: number of responses per solution).

REEFLEX Solutions	Perceived Helpfulness	Identified Barriers	Preferred Hosting Mode	Willingness to Adopt	Preferred Payment Model
S1: Data exchange, handling and interoperability platform (n = 27)	Mid-term 15/27 (56%) Now 8/27 (30%)	Regulatory/technical/economic 12/27 (44%) Other: Hardware requirements, integration with existing systems 5/27 (19%) Already exists 4/27 (15%)	Cloud 21/27 (78%) Edge 5/27 (19%)	Low 12/27 (44%) Medium 12/27 (44%)	Subscription 20/27 (74%) Own 6/27 (22%)
S2: VERIFY: Web-based platform enabling LCA/LCC of projects (n = 21)	Now 7/21 (33%) Mid-term 5/21 (24%)	Other: low awareness, complexity and multi-party coordination needs 7/21 (33%) Regulatory/economic: market not open, no aggregator regulation 4/21 (19%)	Central cloud 14/21 (67%)	Medium 13/21 (62%)	Subscription 16/21 (76%)
S3: USE: Platform enabling uniform evaluation of projects (n = 18)	Not Helpful 6/18 (33%) Now 5/18 (28%)	Already existing solutions 5/18 (28%) Other: complexity and impracticality for residential users 5/18 (28%)	Central cloud 12/18 (67%)	Low 10/18 (56%)	Subscription 11/18 (61%)
S4: Flexibility potential classification tool for any given asset (n = 28)	Now 9/28 (32%) Mid-term 8/28 (29%)	Regulatory/economic: incomplete SRI development, high costs, unclear legislation 11/28 (39%) Existing tools 3/28 (12%)	Central cloud 20/28 (71%)	Medium 14/28 (50%)	Subscription 18/28 (64%)

Table 2. Cont.

REEFLEX Solutions	Perceived Helpfulness	Identified Barriers	Preferred Hosting Mode	Willingness to Adopt	Preferred Payment Model
S5: Second-life batteries as flexibility assets (n = 14)	Mid-term 6/14 (43%) Long-term 4/14 (29%)	Regulatory/economic: high initial investment, markets not open for storage 7/14 (50%) Other: Reduced lifetime 2/14 (14%)	N/A	N/A	Lease/as a service 9/14 (64%)
S6: Predictive flexibility potential and operation of distributed devices (n = 70)	Now 26/70 (37%) Mid-term 19/70 (27%)	Regulatory/economic: high costs, no ROI, lack of regulation or flexibility markets 20/70 (29%) Other: complexity, low awareness 17/70 (24%)	Central cloud 44/70 (63%)	Low 36/70 (51%)	Subscription 42/70 (60%)
S7: Non-Intrusive Load Monitoring (NILM) techniques for large consumers' load (n = 11)	Now 6/11 (55%) Mid-/Long-term 2/11 (18%)	Regulatory/technical: accuracy of disaggregation results 6/11 (55%)	Central cloud 8/11 (73%)	Medium 9/11 (82%)	Subscription 6/11 (55%)
S8: Non-Intrusive Load Monitoring (NILM) techniques for residential consumers' load (n = 52)	Now 23/52 (44%) Do not know 15/52 (29%)	Regulatory/technical: cybersecurity, too technical, cost, unclear value 15/52 (29%) Other: lack of smart devices, usability concerns 15/52 (29%)	Central cloud 26/52 (50%) Edge 18/52 (35%)	Low 33/52 (64%)	Subscription 27/52 (52%)
S9: Innovative inverters for storage systems and electric vehicles (V2G) (n = 7)	Mid-term 4/7 (57%) Long-term 3/7 (43%)	Already exists 3/7 (43%) Regulatory/technical 3/7 (43%)	N/A	N/A	Lease/as a service 5/7 (71.4%)
S10: Algorithms for optimal management of the Grid (n = 11)	Mid-term 7/11 (64%) Long-term 2/11 (18%)	Regulatory/technical/economic: data protection, legal barriers 7/11 (64%) Other: not scalable, needs to integrate with SCADA 3/11 (27%)	Private cloud 7/11 (64%) Third part cloud 4/11 (36%)	Low 6/11 (55%) High 3/11 (27%)	Subscription 6/11 (55%) Own 4/11 (36%)
S11: End-users' potential flexibility calculation and aggregation tool (n = 6)	Mid-term 4/6 (67%)	Regulatory/technical: energy community regulations, aggregation minimum capacity 3/6 (50%)	Central cloud 4/6 (67%)	Medium 5/6 (83%)	Own 3/6 (50%) Subscription 3/6 (50%)
S12: Tool to calculate DSO flexibility needs (n = 10)	Mid-term 6/10 (60%) Now 4/10 (40%)	None 4/10 (40%) Technical: interoperability 3/10 (30%) Other: Lack of control infrastructure, data privacy 2/10 (20%)	Central cloud 8/10 (80%)	Medium 6/10 (60%)	Subscription 6/10 (60%) Own 4/10 (40%)
S13: Optimal market selection tool (n = 7)	Now 4/7 (57%) Mid-term 2/7 (29%)	None 5/7 (70%) Regulatory: flexibility market access 1/7 (14.3%)	Central cloud 6/7 (86%)	High 3/7 (43%) Low/Medium 2/7 (29%)	Own 4/7 (57%) Subscription 3/7 (43%)
S14: P2P and bilateral energy exchange add-on platform (n = 3)	Now/Mid-term/Long-term 1/3 (33.3%)	Regulatory 1/3 (33.3%)	Private cloud 2/3 (67%)	Low 2/3 (67%)	N/A

Results with n < 10 are considered anecdotal; results with n = 10–15 are presented descriptively with caution.

The aggregated results reveal several cross-cutting patterns in stakeholder perceptions of the REEFLEX solutions, particularly those with larger sample sizes (>15 responses, e.g., S1, S2, S3, S4, S6, S8). Most of these modules were regarded as helpful primarily in the mid-term, suggesting a recognition of their strategic potential once enabling frameworks mature. Immediate value (“helpful now”) was also acknowledged for select solutions, especially those with lower integration barriers or clearer end-user applications (e.g., S1,

S6, S8). Findings from modules with 10–15 responses (S5, S7, S10, S12) were included for completeness but are interpreted descriptively and with caution, while those with fewer than 10 responses (S9, S11, S13, S14) are considered anecdotal and not generalizable.

Across nearly all solutions, regulatory, technical and economic challenges emerged as dominant barriers such as high upfront costs, lack of flexibility, market regulation or system integration requirements. Technical issues are often related to system interoperability, equipment installation and aggregation limits. Regulatory concerns included the absence of clear flexibility market rules, legal liability and the need for collective decision-making. Economically, stakeholders cited high upfront costs, uncertain returns and low remuneration. Privacy concerns were noted alongside usability challenges, such as insufficiently intuitive interfaces or unclear value propositions.

In terms of deployment, there was a consistent preference for central cloud hosting, although edge or hybrid models were also cited for solutions involving localized data handling (e.g., S8). Recurring payment models (i.e., subscription, leasing) were clearly preferred across most solutions, reflecting a general hesitancy toward large capital investments or ownership responsibilities. Finally, willingness to participate or pay skewed toward medium or low levels for many solutions, highlighting a cautious stance among stakeholders pending greater clarity on value delivery, incentives and support mechanisms.

3.3. Common Barriers and Preferences

The final part of the questionnaire was designed to capture broader concerns, perceived barriers and motivational drivers that influence the adoption of energy flexibility solutions. Unlike the solution-specific modules, this section focuses on system-level and cross-cutting themes that apply across all solutions. The analysis is structured in two complementary blocks, each summarized and explored in more detail for each stakeholder group:

- **Barriers and Concerns:**

This block identifies the key obstacles to adoption across stakeholder groups, including market-access, operational and privacy-related barriers. These responses can provide insights on what needs to be addressed, whether through technology design, regulation or support mechanisms and can inform the development of business value propositions that directly respond to stakeholder concerns.

- **Enablers and Motivational Drivers:**

This block focuses on the factors that encourage stakeholder adoption. It first captures respondents' motivations for participating in energy flexibility initiatives (e.g., financial, environmental), then explores how much operational control they are willing to give through automation preferences and finally identifies which data security mechanisms would build long-term trust. These responses reflect critical aspects of decision-making and adoption dynamics as perceived by the target users of energy flexibility solutions.

It is important to note that although this section was designed to address broader user considerations, the questions were provided after participants had completed the solution-specific modules. Therefore, this ordering may have influenced their perspective, consciously or not and potentially anchored some of their responses to the specific solutions they had just evaluated. Furthermore, the number of responses per stakeholder groups is uneven; sample sizes for residential and commercial prosumers ($n = 52$ and 9 respectively) are robust, while other smaller groups are included for completeness despite being indicative or anecdotal.

3.3.1. Non-Expert Users (n = 69)

This stakeholder group represents a critical side in the energy transition, the end users. Despite their diversity, their feedback reveals consistent patterns that highlight structural and perceptual barriers to participation in flexibility markets.

As shown in Table 3, the most common challenges are regulatory and market-related. Residential and commercial prosumers reported low financial remuneration (78.8% and 66.7%, respectively), alongside difficulty accessing flexibility markets and unclear or unsettled regulation (ranging from 63% to 75%). Energy communities (n = 3) and municipalities (n = 4) echoed similar concerns, with additional mentions of lack of aggregation experience, although these smaller samples should be considered indicative rather than generalizable. Overall, these trends suggest that limited market visibility, underdeveloped frameworks and low economic incentives remain key obstacles to participation.

Table 3. Barriers and Concerns—Non-Expert Users (n: number of responses per target user).

Target User	Regulatory & Market Access	Operational & Functional Barriers	Privacy, Security & Data Concerns
Residential Prosumers (n = 52)	Low financial remuneration 41/52 (78.8%) Difficulty accessing flexibility markets 33/52 (63.5%) Lack or not settled legislation 33/52 (63.5%)	Integration difficulty 28/52 (53.8%) New technology malfunction 27/52 (51.9%) Lack of digital infrastructure 26/52 (50.0%)	Personal data leaks 35/52 (67.3%) IoT Devices security risks 26/52 (50.0%)
Commercial Prosumers (n = 9)	Difficulty accessing flexibility markets 6/9 (66.7%) Lack of transparency/regulation 5/9 (55.6%) Low financial remuneration 6/9 (66.7%)	New technology malfunction 5/9 (55.6%) Insufficient data volume 5/9 (55.6%) Integration difficulty 4/9 (44.4%)	Business data leaks 8/9 (88.9%) Privacy laws compliance 6/9 (66.7%) IoT Devices security risks 5/9 (55.6%)
Industrial Prosumers (n = 1)	Lack or not settled legislation Difficulty accessing flexibility markets Lack of previous aggregation experience	New technology malfunction Integration difficulty Insufficient data volume	Business data leaks Personal data leaks IoT Devices' security risks Privacy laws compliance
Energy Communities (n = 3)	Low financial remuneration (66.7%) Difficulty accessing markets (66.7%) Lack of transparency/regulation (66.7%)	Integration difficulty (66.7%) Insufficient data (66.7%) Lack of digital infrastructure (66.7%) Reduced comfort (66.7%)	Business data leaks (100%) Personal data leaks (66.7%) IoT device risks (66.7%)
Municipalities (n = 4)	Difficulty accessing flexibility markets 2/3 (75.0%) Lack of transparency/regulation 2/3 (75.0%) Lack of previous aggregation experience 2/3 (75.0%)	Integration difficulty 4/4 (100%) Insufficient data volume 3/4 (75.0%) New technology malfunction 2/4 (50.0%)	Personal data leaks 3/4 (75.0%) IoT Devices security risks 2/4 (50.0%) Privacy laws compliance 2/4 (50.0%)

From an operational standpoint, the most frequently cited barrier was integration complexity, followed closely by new technology malfunctions and lack of supporting digital infrastructure (ranging from 44% to 75%). The small sample response from energy communities and municipalities showed the highest concentration of functional barriers, with additional concerns around user comfort and reduced usability, pointing to the importance of easy, intuitive plug-and-play solutions for non-experts.

As for privacy and data governance, residential users were especially concerned about personal data leaks (67.3%) and IoT device security (50%), while commercial and industrial users also raised concerns over business data protection and legal compliance.

Considering that the end-users are not typically tech-savvy, they still carry significant expectations for regulatory clarity, ease of use and trustworthy data handling. Addressing their concerns will require solutions that are economically viable, user-centric and transparent in data handling, while also being adaptable to their different ownership structures and local digital maturity levels.

Table 4 shows that ownership and adoption drivers among non-expert users point to varying motivations and expectations shaped by asset control, environmental values and system usability. Residential users (n = 52) predominantly own their energy assets (61.5%), with the remainder using a mix of models, whereas commercial users (n = 9) lean more heavily on mixed or service-based setups. Across these two segments, financial compensation emerges as the strongest motivator, with similar indicative results from the other stakeholder subgroups. Non-financial drivers are also present: supporting decarbonization appears consistently among top three motivators, especially for municipalities (n = 4) and energy communities (n = 3).

Table 4. Enablers and Motivations—Non-Expert Users (n: number of responses per target user).

Target User	Energy Assets Ownership	Motivations to Adopt	Automation Control Preference	Privacy-Related Trust Enablers
Residential Prosumers (n = 52)	Mostly own assets 32/52 (61.5%), with some mix/as-a-service	Financial compensation 46/52 (88.5%) Support decarbonization 28/52 (53.8%) Reliability of electric supply 14/52 (26.9%)	Critical: Semi-automatic 25/52 (48.1%), with a near-even split between automatic and manual Non-critical: Automatic 26/52 (50.0%), Semi-automatic 22/52 (42.3%)	Easy data selection 24/52 (46.2%) Long-term support 23/52 (44.2%) Automatic updates 19/52 (36.5%)
Commercial Prosumers (n = 9)	Mixed ownership/leasing/as-a-service 4/9 (44.4%)	Financial compensation 8/9 (88.9%) Value-added services 5/9 (55.6%) Support decarbonization 4/9 (44.4%)	Critical: Semi-automatic strongly preferred 7/9 (77.8%) Non-critical: Semi-automatic (55.6%), Automatic 4/9 (44.4%)	Automatic updates 5/9 (55.6%) Long-term support 5/9 (55.6%) Local law enforcement 5/9 (55.6%)
Industrial Prosumers (n = 1)	As-a-Service model	Financial compensation, Value-added services, Reliability of electric supply	Critical & non-critical loads: Fully automatic	Easy data selection, Automatic updates, Long-term support, Law enforcement
Energy Communities (n = 3)	Mostly mixed models (66.7%), some ownership	Financial compensation 3/3 (100%) Support decarbonization 2/3 (66.7%) Reliability of electric supply 2/3 (66.7%)	Critical: Automatic 2/3 (66.7%), Semi-automatic 1/3 (33.3%) Non-critical: Even split across all modes 1/3 (33.3% each)	Long-term support 3/3 (100%) Easy data selection 2/3 (66.7%) Automatic updates 2/3 (66.7%) Law enforcement 2/3 (66.7%)
Municipalities (n = 4)	Mostly own 2/4 (50%), rest split between mix and service	Support decarbonization 4/4 (100%) Reliability of electric supply 4/4 (100%) Financial compensation 3/4 (75%)	Critical: Equal preference for automatic and semi-automatic 2/4 (50% each) Non-critical: Equal preference for automatic and semi-automatic 2/4 (50%)	Long-term support 3/4 (75.0%) Local law enforcement 3/4 (75.0%)

Preferences around automation suggest that semi-automatic control is generally favored for critical loads, particularly by commercial users (77.8%), who may prefer manual intervention when needed. Residential and municipal users, however, show more evenly

split views, indicating openness to varied levels of control. For non-critical loads, automation is more readily accepted, especially among commercial and industrial users (n = 1) who responded.

When it comes to privacy-related trust enablers, expectations center around transparency and long-term support. The ability to easily select what data to share, along with confidence in regular security updates, features prominently across all groups. Notably, commercial users and municipalities stress the importance of compliance with local law enforcement, pointing to heightened concerns about legal liability and governance within their roles.

3.3.2. Technology Developers (n = 17)

The developers represent the technical pillar in the energy flexibility ecosystem as they interact with each other to design and deploy the software and services that enable user participation in flexibility markets. Their perspectives are critical in evaluating the feasibility, scalability and long-term viability of digital flexibility solutions. As enablers rather than end users, their concerns often centre on market design, interoperability with other solutions and business viability.

As shown in Table 5, regulatory and market barriers were reported by nearly all developer subgroups. ICT providers (n = 7) and ESCOs (n = 3) were particularly affected by limited access to flexibility markets, unclear or missing legislation and low financial remuneration. While all developer subgroups report these constraints, ESCOs and energy tech providers (n = 6) appeared especially sensitive to policy and financial uncertainty, suggesting the need for clearer pathways to market participation and incentive structures. While these patterns appear consistent, the small sample sizes mean they are indicative and should not be generalized.

Table 5. Barriers and Concerns—Technology Developers (n: number of responses per target user).

Target User	Regulatory & Market Access	Operational & Integration	Privacy, Security & Data Concerns
ICT Service Providers (n = 7)	Difficulty to access flexibility markets 6/7 (85.7%) Lack or not settled legislation 5/7 (71.4%) Low financial remuneration 4/7 (57.1%)	Integration difficulty 4/7 (57.1%) Lack of digital infrastructure 3/7 (42.9%) Reduced comfort 3/7 (42.9%)	IoT Devices security risks 5/7 (71.4%) Business data leaks 5/7 (71.4%) Personal data leaks 4/7 (57.1%)
Data Analytics Providers (n = 1)	Low financial remuneration Lack of transparency/regulation Difficulty to access markets	Integration difficulty New technology malfunction	IoT Devices' security risks Business data leaks Privacy laws compliance
Energy Service Providers/ESCOs (n = 3)	Lack or not settled legislation 3/3 (100%) Low financial remuneration 2/3 (66.7%) Lack of transparency (66.7%)	Integration difficulty (100%) Lack of digital infrastructure 2/3 (66.7%) Insufficient data volume 2/3 (66.7%)	IoT Devices security risks 3/3 (100%)
Energy Tech Providers (n = 6)	Low financial remuneration 5/6 (83.3%) Lack of transparency/regulation 4/6 (66.7%) Lack of previous aggregation experience 3/6 (50%)	Reduced comfort 5/6 (83.3%) Integration difficulty 3/6 (50%) Lack of digital infrastructure 3/6 (50%)	IoT Devices security risks 5/6 (83.3%) Personal data leaks 5/6 (83.3%)

Operational and integration barriers were also reported. Integration difficulty was a recurring theme across all developers, coupled with missing infrastructure or insufficient data availability. ESCOs, despite a very limited sample size, reported the highest operational burden, with all three respondents citing integration complexity and lack of digital

infrastructure. Energy tech providers, in contrast, flagged issues with user acceptance and reduced comfort.

Privacy and security concerns, such as IoT device risks and business data leaks, were also reported, especially among ICT and tech providers (n = 7 and 6 respectively). The focus on business-level concerns, including cybersecurity and intellectual property, highlights the need for secure-by-design solutions with transparent data governance frameworks.

In conclusion, while these findings must be treated cautiously, they nonetheless suggest a high level of technical and regulatory sophistication within developer stakeholders, paired with clear expectations for platform interoperability, compliance and reliability. Solutions targeting these groups must account for their dual role as both enablers and adopters of energy flexibility, requiring tools that align with their operational constraints and data sensitivities.

Responses to adoption drivers, automation preferences and trust enablers reflect strong alignment with functional value, technological control and compliance-oriented transparency, as shown in Table 6. The findings presented hereafter are indicative due to the small number of responses, but they highlight some consistent themes.

Table 6. Enablers and Motivations—Technology Developers (n: number of responses per target user).

Target User	Energy Assets Ownership	Motivations to Adopt	Automation Control Preference	Privacy-Related Trust Enablers
ICT Service Providers (n = 7)	Mainly owned 6/7 (85.7%), followed by as-a-service 1/7 (14.3%)	Financial compensation 7/7 (100%) Environmental support 4/7 (57.1%) Reliability of energy supply 3/7 (42.9%)	Critical: Semi-automatic 4/7 (57.1%) Non-critical: Automatic 4/7 (57.1%), Semi-automatic 3/7 (42.9%)	Easy to select data to share 4/7 (57.1%) Long-term support 4/7 (57.1%) Local law enforcement 3/7 (42.9%)
Data Analytics Providers (n = 1)	As-a-Service model	Value-added services, Environmental support, Reliability of electric supply	Critical & non-critical loads: Fully automatic	Easy to select data to share, Automatic updates, Long term support, Local laws enforcement
Energy Service Providers/ESCOs (n = 3)	Fully owned (100%)	Financial compensation 3/3 (100%) Environmental support 3/3 (100%) Value-added services 1/3 (33.3%)	Critical: Semi-automatic 2/3 (66.7%) Non-critical: Semi-automatic 2/3 (66.7%)	Long-term support 3/3 (100%)
Energy Tech Providers (n = 6)	Owned 3/6 (50%), Mixed ownership/leasing/as-a-service 3/6 (50%)	Financial compensation 5/6 (83.3%) Environmental support 4/6 (66.7%) Value-added services 3/6 (50%)	Critical: Semi-automatic 5/6 (83.3%) Non-critical: Automatic 4/6 (66.7%)	Long-term support 5/6 (83.3%) Local law enforcement 4/6 (66.7%) Automatic updates 3/6 (50%)

In terms of asset ownership, developers as a group prefer owning their energy assets. ICT service providers (n = 7) and ESCOs (n = 3) report full or near-full ownership, suggesting a desire for operational autonomy. Energy tech providers (n = 6), by contrast, reflect more variability—half reported mixed ownership models, possibly reflecting diversified portfolios or partnerships. The sole data analytics respondent (n = 1) reported a full as-a-service model, consistent with their software-driven orientation.

Financial incentives remain the most cited motivation, particularly among ICT service providers (7/7), ESCOs (3/3) and energy tech providers (5/6). Notably, environmental motivations rank high across all groups (e.g., 3/3 for ESCOs, 4/6 for tech providers), suggesting a shared commitment to supporting decarbonization. Value-added services also carried moderate weight, especially for analytics and tech firms.

Automation preferences vary slightly depending on the load type. For critical loads, developers show a strong preference for semi-automatic control, especially among tech vendors (5/6) and ESCOs (2/3), reflecting a balance between reliability and control. For non-critical loads, automatic control is more accepted, preferred by ICT and energy tech providers.

When it comes to trust enablers related to privacy, long-term support stands out as a valued feature. It was cited by all three ESCOs and five of the six tech providers, followed closely by data selection tools and compliance with local laws. This suggests developers, even with this small sample size, place high importance not only on technical guarantees, but also on ensuring legal alignment and user-facing control features that can build trust in platform use.

Altogether, developers, even with a limited sample size, point primarily to motivation by financial viability and environmental contribution, while expecting moderate automation with strong safeguards. Trust, for this group, appears to be built around support continuity, transparency and legal clarity, all of which should be central in designing engagement and delivery models.

3.3.3. Operators (n = 17)

The operators represent the infrastructural aspect of the energy system. Their role centres around either managing the physical grid or as intermediaries between the end-users and wholesale markets or both. They facilitate the activation of energy flexibility and the integration of decentralized energy resources. Their concerns are essential for designing platforms that can integrate with their own and align with real-world constraints.

Table 7 shows that the most prominent issues for operators lie within the regulatory and financial domains. Among DSOs (n = 10), the majority cited a lack of funding for necessary equipment (7/10) and low remuneration (6/10), alongside uncertainty due to unsettled flexibility-related legislation (6/10). These concerns highlight that economic and policy conditions remain a key bottleneck for DSO engagement, though the findings should still be interpreted cautiously given the small sample size. In parallel, integration difficulty (6/10) and technical unreliability (4/10) were also reported, pointing to the challenge of embedding new systems into legacy infrastructure without compromising reliability.

Table 7. Barriers and Concerns—Operators (n: number of responses per target user).

Target User	Regulatory & Market Access	Operational & Integration	Privacy, Security & Data Concerns
DSOs (n = 10)	Lack of funding for equipment 7/10 (70%) Low financial remuneration 6/10 (60%) Lack or not settled legislation 6/10 (60%)	Integration difficulty 6/10 (60%) New technology malfunction 4/10 (40%) Reduced comfort 2/10 (20%)	Personal data leaks 8/10 (80%) Business data leaks 8/10 (80%) IoT Devices security risks 7/10 (70%)
Aggregators (n = 6)	Difficulty accessing flexibility markets 6/6 (100%) Lack or not settled legislation 4/6 (66.7%) Low financial remuneration 3/6 (50%)	Integration difficulty 4/6 (66.7%) New technology malfunction 4/6 (66.7%) Lack of digital infrastructure 3/3 (50%)	Privacy laws compliance 5/6 (83.3%) Personal data leaks 4/6 (66.7%) IoT Devices security risks 3/6 (50%)
Storage Operators (n = 1)	Difficulty accessing flexibility markets Lack of previous aggregation experience Lack or not settled legislation Lack of funding for equipment	New technology malfunction Integration difficulty Lack of digital infrastructure	Business data leaks Privacy laws compliance

Aggregators (n = 6) expressed different but related barriers. All respondents (6/6) identified difficulty accessing flexibility markets, coupled with concerns over legislative clarity (4/6) and economic viability (3/6). Their technical concerns leaned more heavily toward integration complexity (4/6), system malfunction risks (4/6) and insufficient digital infrastructure (3/6). These results are anecdotal but nonetheless suggest barriers tied to the intermediate role of operators managing diverse assets in near real-time.

One anecdotal response from a grid-level storage operator reported barriers across regulatory, technical and economic dimensions. These included lack of legislation, limited funding and integration challenges, underscoring the lack of policy frameworks and market mechanisms for storage-based flexibility provision in their respective markets.

Privacy and data-related risks were consistently flagged across operator types. DSOs cited personal and business data leak risks (8/10) and IoT-related security risks (7/10), while aggregators emphasized compliance with privacy regulations (5/6) and data security vulnerabilities. These concerns, despite the small samples, illustrate that trust in data handling practices is not only a concern for end-users but also for infrastructure actors operating under stricter accountability.

Table 8 summarizes the indicative preferences regarding adoption drivers and trust enablers among operators. DSOs (n = 10) primarily operate under mixed ownership models (7/10), with adoption driven by electricity supply reliability (9/10), alongside financial compensation (6/10) and decarbonization goals (6/10). The responses show a strong preference for automatic control in both critical (8/10) and non-critical loads (7/10), reflecting the importance of real-time, low-intervention operation. Trust appeared to be anchored in system robustness, with high priority placed on automatic updates (7/10), long-term support (7/10) and data selection control (5/10).

Table 8. Enablers and Motivations—Operators (n: number of responses per target user).

Target User	Energy Assets Ownership	Motivations to Adopt	Automation Control Preference	Privacy-Related Trust Enablers
DSOs (n = 10)	Mostly mixed models 7/10 (70%), some ownership	Reliability of electricity supply 9/10 (90%) Financial compensation 6/10 (60%) Support decarbonization 6/10 (60%)	Critical: Automatic 8/10 (80%) Non-critical: Automatic 7/10 (70%)	Automatic updates 7/10 (70%) Long-term support 7/10 (70%) Easy data selection 5/10 (50%)
Aggregators (n = 6)	Mostly as-a-service 3/6 (50%), followed by Mixed 2/6 (33.3%)	Financial compensation 6/6 (100%) Value-added services 4/6 (83.3%) Support decarbonization 2/6 (33.3%)	Critical: Semi-automatic 4/6 (66.7%) Non-critical: Automatic 5/6 (83.3%)	Automatic updates 5/6 (83.3%) Long-term support 3/6 (50%) Local law enforcement 3/6 (50%)
Storage Operators (n = 1)	As-a-Service model	Reliability of electric supply	Critical & non-critical loads: Fully automatic	Automatic updates, Long-term support

Aggregators (n = 6), in contrast, rely more on as-a-service models (3/6), valuing financial compensation (6/6) and value-added services (5/6) as primary motivators. Their preferences reported semi-automatic control for critical loads (4/6) and automatic control for non-critical loads (5/6), suggesting a balance between control and convenience. Trust enablers included automatic updates (5/6) and moderate support for long-term platform viability (3/6) and compliance (3/6).

The sole storage operator response reported, also using an as-a-service model, prioritized reliability and full automation for all load types, with emphasis on automatic updates and long-term support.

Together, these patterns, though based on small response samples, highlight a shared demand for automated, low-friction platforms, underpinned by technical reliability and data governance, which are seen as critical for scaling flexibility asset management.

4. Implications for Flexibility Markets & Discussion

The results obtained from the REEFLEX stakeholder surveys offer valuable insights into the current barriers, expectations and preferences that shape flexibility market participation across diverse user groups. In this section, the REEFLEX survey results are compared with existing literature, policy documents and outcomes from other European projects—such as OneNet, GLocalFlex and iFLEX—to identify common trends, confirm external validity and highlight areas of innovation or divergence.

4.1. Contextualization of REEFLEX Findings Within Existing Research

To position the REEFLEX stakeholder survey findings within the broader landscape of flexibility market participation, a qualitative comparison has been conducted with insights from other projects and literature on energy flexibility. Table 9 provides a comparative summary of recent flexibility market studies across four key dimensions that reflect both technical and behavioural enablers of flexibility market participation. Specifically, Adoption Patterns examine how different user groups are engaged and under what conditions, while Motivation assesses the key drivers for participation, such as financial savings or environmental values. Automation Preferences explore user acceptance of automated control solutions and their usability; to enhance reproducibility of the qualitative comparison in this particular dimension, a coding scheme has been developed and applied for this column, i.e., Automation Code (AC) indicator [34]. Specifically, automation acceptance levels are coded on a scale from 0 to 4, where 0 indicates no automation preferred/manual only, 1 indicates low acceptance (manual override prioritized), 2 indicates moderate acceptance (semi-automated with regular user interaction), 3 indicates high acceptance (automated solutions with user override) and 4 indicates full acceptance (“set-and-forget”/AI-driven with minimal user involvement). Each study included in Table 9 was recoded according to this scheme, alongside the original narrative descriptions. Finally, Privacy and Trust address concerns around data governance, transparency and perceived fairness.

Table 9. Qualitative comparison of REEFLEX findings with other studies on flexibility market participation.

Source /Study Type /Year	Adoption Patterns	Motivation	Automation Preferences/ Automation Code (AC)	Privacy and Trust
REEFLEX/EU Project /2023–ongoing	Adoption varies by stakeholder type; aggregators and energy communities show more readiness than individual prosumers.	Monetary savings are prioritized, though resilience and sustainability rank higher for some segments.	High preference for automated, simple-to-use solutions with override features /AC: 3.	GDPR compliance and trust in platform/aggregator are crucial for participation.
Behavioral Barriers to Engage Customers in Flexibility Markets/Research [27]/2024–2025	Focus on residential and Small and Medium-sized Enterprises (SME) consumers; participation is shaped by cognitive effort, trust and risk perception.	Financial incentives are dominant; environmental or comfort benefits enhance uptake.	Preferred model includes automated responses with manual override and clear feedback /AC: 2.	Participation depends on transparency, perceived fairness and control over data.

Table 9. Cont.

Source /Study Type /Year	Adoption Patterns	Motivation	Automation Preferences/ Automation Code (AC)	Privacy and Trust
GLocalFlex /EU Project [35] /2023–2026	Adoption involves building operators, municipalities and local aggregators across six pilot sites; flexibility is accessed under varied local frameworks.	Motivated by economic value for participants and community-level energy efficiency.	Distributed energy assets are controlled via interoperable platforms with user-centered pilots /AC: 2.	Trust is built through open standards, data protection and transparency in market participation.
LEO/ UK Project /2023–2024	Active citizen and community participation in local energy trials; flexibility is traded within regional coordination platforms.	Participants value both financial returns and energy self-sufficiency/local benefits.	Local energy management systems enable semi-automated DR actions with user interaction /AC: 2.	Community-led governance structures and local transparency mechanisms build trust.
IEA /Institutional Study [36]/2023–2024	End-user adoption remains modest outside regulated programs; low effort and reward clarity improve participation.	Cost savings and convenience dominate across user groups.	“Set-and-forget” automation is favored, especially if it maintains comfort and usability /AC: 4.	High trust is required in providers and platforms; privacy concerns hinder broader adoption.
OneNet /EU Project/2020–2023	DERs and flexibility are accessed via aggregators and platform orchestrators; indirect user involvement.	Participation is designed to align with market opportunities for flexibility provision.	Automation is handled at API/aggregator level with limited end-user interaction /AC: 3.	Addressed through interoperable architecture and adherence to open digital standards.
FLEXCoop [37]	A fully fledged tool suite for energy cooperatives (aggregators) and prosumers involved in the Demand Response process	Grid stability and alleviation of network constraints	Aggregators’ and prosumer assets are involved /AC: 2.	GDPR compliance in the energy sector.
ACCEPT [38]	Development of a compact toolbox to promote flexibility on energy community level and prosumer level.	Promote sustainability, encourage the development of DER and gain benefits for the energy community members	Controllable assets are controlled via the developed platform, to enhance self-consumption, cost optimization strategies/AC: 3.	GDPR compliance and trust, secure and anonymized transactions through blockchain approaches
iFLEX [32]	Deployment of AI-driven assistants for demand and production flexibility management.	Empower energy consumers by making it as easy as possible for them to participate in demand response programs	The consumer has full control of the flexibility, the operation can be fully automated/AC: 4.	GDPR compliance in the energy sector.
“A Decentralized Local Flexibility Market for Local Energy Communities to Mitigate Grid Congestion: A Case Study in Sweden” [39]	Flexibility offers from prosumers are matched with the needs of DSOs and TSOs	Financial benefits, congestion management	Controllable domestic devices to achieve flexibility goals/AC: 2.	Network-aware and decentralized modeling to address privacy concerns
Leafs project [40]	The DSO encourage the participation of the prosumers in different grid operation through suitable tariffs.	Minimize the costs of every single prosumer	The impact of single prosumer-dispatch operation strategies (using ICT applications)/AC: 3.	GDPR compliance in the energy sector.

Overall, it can be concluded that REEFLEX’s survey aligns with literature [40–43] in underscoring the primacy of financial incentives, the need for automation with user control

and the importance of trust and privacy assurances for engagement, as highlighted in Section 3.

4.2. REEFLEX Perspectives on Flexibility Participation: Challenges and Enablers

The REEFLEX stakeholder survey provides direct, role-specific insights into the obstacles that hinder participation in flexibility markets (Section 3.3). These findings are qualitatively compared with recent literature (Section 4.1) and institutional studies (e.g., JRC, BRIDGE, ENTSO-E). As summarized in Table 10, REEFLEX results validate key barriers already discussed in the literature, such as regulatory ambiguity (Sections 3.3.1 and 3.3.3), lack of standard interfaces (Section 3.3.1) and limited financial clarity (Sections 3.3.1 and 3.3.3). Moreover, REEFLEX offers distinct stakeholder-level perspectives that deepen understanding regarding trust and privacy (Section 3.3.1), where end-users express more concern than reported in system-level studies, as well as awareness and engagement (Sections 3.3.1 and 3.3.2)—which are notably lower among SMEs and municipal actors than typically acknowledged. These findings suggest that flexibility adoption strategies must not only address technical and economic enablers, but also tailor communication and trust-building efforts to specific user types.

Table 10. Barriers to Flexibility Market Participation and Strategic Responses.

Barrier	REEFLEX's Added Value	Stakeholder Affected	Description	Opportunity/Strategy
Regulatory complexity and uncertainty [27,29,43,44]	Confirms misalignment in aggregator roles and entry barriers for new actors. (See Section 3.3.1 and Table 3)	Aggregators, new entrants	Inconsistent definitions, lack of clarity on market access and aggregator roles.	Regulatory sandboxes, DSO-aggregator role clarity and local pilot schemes to inform future frameworks.
Technical integration & interoperability [35,36,43,44]	Highlights concerns about integration from both prosumers and SMEs—not just DSOs. (See Section 3.3.1 and Table 3)	Prosumers, DSOs, tech providers.	Asset and platform heterogeneity create barriers to scale; no standard interfaces.	Promote open-source APIs, harmonized data models (e.g., OneNet [4.2], GLocalFlex [4.3]) and plug-and-play solutions.
Weak financial incentives or unclear business case [27,45]	Emphasizes the disconnect between perceived risk and real revenue potential. (See Sections 3.3.1 and 3.3.3)	All end-users.	Limited visibility of economic returns; high perceived risk and complexity.	Dynamic pricing, loyalty schemes, simple savings-based DR programs, revenue stacking models.
Trust and privacy concerns [27,31,44]	Offers qualitative depth on user hesitancy, especially among non-technical users. (See Section 3.3.1, Tables 3, 5 and 6)	Residential users, SMEs.	Concerns over external control, data misuse or hidden costs.	GDPR compliance, user dashboards, transparent control schemes, community-based delivery.
Low awareness and engagement [27,31,45]	Underscores major engagement gaps among smaller institutions and low-income actors.	Citizens, smaller stakeholders.	Many potential users are unaware of DR or do not see its relevance.	Outreach campaigns, co-design of services, community pilots, smart billing to show savings potential.

4.3. From REEFLEX Surveys to Market Architecture: Comparative Lessons for European Demand-Side Flexibility

Table 11 synthesises contemporary European work on demand-side flexibility by juxtaposing four analytical dimensions—survey-derived user insights, the procurement framework selected and the resulting market implications—comparatively across eleven flagship projects. To avoid Table 11 becoming just a list of unrelated cases, we used a

common protocol to link survey results to the procurement choices. Four simple criteria guided the comparison:

- Evidence source—only survey or participatory inputs (e.g., questionnaires, focus groups, workshops) were considered, coded for signals like digital readiness, risk tolerance, simplicity vs. complexity, and value orientation.
- Procurement type—each project’s choice was classified as tariff-based, market-based, or hybrid.
- Fit with behaviour—we then checked whether the chosen design matched the user preferences (tariffs for risk-averse users, markets for digitally confident users, hybrids when preferences were mixed).
- Market effects—finally, we asked how each design shaped access (who can join), liquidity (enough bids to work), and value distribution (local vs. external).

Table 11. Survey-Driven Procurement Pathways: Positioning REEFLEX among Leading European Flexibility Demonstrators.

Project (Primary Source)	Principal Survey-Derived Insights	Procurement Framework Selected	Market Implications
REEFLEX	Surveys distinguish between digitally mature aggregators and communities and households that require very simple participation, “set-and-forget” automation with manual override and strict GDPR compliance.	A hybrid architecture was adopted: local day-ahead auctions for portfolios managed by aggregators or energy communities, combined with a baseline network-tariff rebate that individual users may later convert into full market participation by delegation.	This two-track design translates asymmetric readiness into broad initial coverage while still creating liquidity in local markets.
GLocalFlex	Workshops in six pilot districts reveal that participants are willing to face spot prices provided bidding is fully automated and no intermediary is involved.	The consortium, therefore, introduced a pure peer-to-peer market from the outset, omitting any regulated tariff back-stop.	The project tests whether algorithmic automation alone can connect small-scale assets to real-time prices without additional tariff incentives.
OneNet	Household respondents accept price volatility only when an aggregator buffers risk, whereas large industrial users prefer direct market access.	A layered market structure was implemented: portfolio bids at the distribution level for small users, bilateral or transmission-level contracts for industry, with legacy retail tariffs preserved.	Survey segmentation results in differentiated exposure to risk, aligning contractual complexity with each actor’s stated tolerance.
iFLEX	Seventy per cent of 1 280 respondents approve of an AI assistant that schedules loads, provided they retain a veto; financial and environmental motives are equally strong.	A tariff-centred dynamic time-of-use scheme broadcasts prices, while the AI assistant optimises consumption; entry into explicit markets remains optional.	The project retains tariff instruments to satisfy the demand for simplicity, concealing market complexity behind automated optimisation.
ACCEPT	Co-creation sessions indicate that community members prioritise internal revenue recycling and equity over short-term bill savings.	A virtual-netting tariff is applied within each community; only surplus flexibility is traded externally.	Procurement is refocused on keeping value inside the community, reflecting survey findings on local economic preferences.
FLEXCoop	Prosumer cooperatives emphasise grid-stability contributions and strict privacy safeguards.	A co-operative tariff operated by the energy co-op is paired with an optional aggregator-facilitated export to wholesale markets.	The primary settlement mechanism remains tariff-based, with market channels offered as a supplementary revenue stream.

Table 11. Cont.

Project (Primary Source)	Principal Survey-Derived Insights	Procurement Framework Selected	Market Implications
Project LEO	Place-based trials in Oxfordshire show that citizens value local self-sufficiency and neighbourhood benefits alongside price savings.	A regional coordination platform combines community tariffs with neighbourhood-level auctions.	Procurement first seeks local balancing before exposing flexibility to wider price signals, in line with geographically grounded motivations.
Swedish Local Flex-Market case	Case-study surveys report that prosumers will provide flexibility if congestion relief is remunerated transparently and locally.	Distribution-system-operator congestion auctions are layered onto revised capacity-based network tariffs.	Transparent, location-specific value streams address the users' stated need for clear local benefits.
LEAFS (Austria)	Household interviews highlight a preference for minimal administrative burden and explicit monetary signals from the grid operator.	Tailor-made DSO tariffs with direct control of storage and flexible loads; no external market component during pilots.	Tariff instruments are deemed sufficient to match the limited flexibility that users are willing to provide.
FLEXGRID	Small retailers express concern about unbounded downside price risk and request revenue protection.	Distribution-level auctions are supplemented by cap-and-floor revenue guarantees; broad tariff reform is omitted.	Financial hedging within the market design addresses risk aversion without reverting to regulated tariffs.
EUuniversal	Surveys show DSOs and aggregators are market-ready, SMEs participate if platform fees are modest and households want an "autopilot."	The Universal Market Enabling Interface supports local auctions for advanced actors while allowing DSOs to grant optional network-charge discounts for all users.	A hybrid model similar to REEFLEX offers a simple tariff entry point alongside open markets for value stacking, reflecting the mixed readiness profile.

This stepwise approach made it possible to compare diverse projects in a consistent and transparent way.

Each row represents an individual project and traces a direct line from the behavioral evidence gathered during pilots, focus groups or questionnaires to the concrete contractual form chosen for procuring flexibility, thereby illuminating how divergent social preferences dictate distinct market architectures.

REEFLEX occupies the benchmark position. Its surveys differentiated digitally sophisticated aggregators and energy communities from the broader household segment; the latter demanded an uncomplicated "set-and-forget" experience with manual override and stringent GDPR compliance. The consortium therefore imposed a hybrid regime in which day-ahead distribution-level auctions cater to aggregator portfolios, while a baseline network-tariff rebate offers a low-threshold entry path for individual consumers. The baseline network-tariff rebate does not correspond to any existing national tariff article or legally codified pilot regulation. Instead, it is a project-level settlement mechanism designed within the demonstrators. Household participants are credited or debited relative to a computed baseline consumption profile. This mechanism emulates the effect of a tariff rebate, thereby lowering the entry barrier for non-expert users while running in parallel with explicit local flexibility markets for aggregators and advanced actors. Where national frameworks do not yet support such tariff products, REEFLEX applies virtual/what-if settlement in its pilots. This two-track design maps behavioral asymmetry onto institutional arrangements, ensuring universal access without sacrificing liquidity in local markets REEFLEX CORDIS [46].

In contrast, GLocalFlex [30] drew on workshop feedback from six pilot districts that revealed a pronounced appetite for real-time price earnings when bidding can be fully automated and intermediary-free. Acting on this signal, the project dispensed with tariff

safety nets and launched a pure peer-to-peer marketplace from inception, thereby using algorithmic automation as the sole bridge between small-scale assets and wholesale-linked spot prices GLocalFlex. OneNet [47] reported a more nuanced readiness spectrum: household respondents accepted volatility only when sheltered by an aggregator, whereas large industrial actors preferred direct exposure. Accordingly, the project instituted a layered EU market stack—portfolio bids at the distribution level and bilateral or transmission-level contracts for industry—while deliberately retaining legacy retail tariffs as a behavioral backstop OneNet Project.

Projects that retained tariffs as the primary channel did so because their surveys highlighted simplicity and risk aversion as decisive. iFLEX found that seventy per cent of over 1200 respondents welcomed an AI assistant optimising bills on their behalf, provided they retained veto power; financial and environmental motives carried equal weight. The consortium, therefore, broadcast a dynamic time-of-use tariff and placed the optimisation burden on the assistant, leaving explicit market participation as a voluntary extension rather than an obligation iFLEX project [32]. Similar motivations guided LEAFS: household interviews in Austria indicated a desire for minimal administrative overhead and explicit monetary signals directly from the grid operator. Consequently, tailor-made distribution-system-operator tariffs with active control of storage and flexible loads were deemed sufficient; no external market component was tested during pilots [48].

Community-centred projects translated local value preferences into bespoke procurement models. ACCEPT used co-creation sessions to reveal that members favoured internal revenue recycling and equitable sharing over immediate bill reductions; as a result, a virtual-netting tariff settles flexibility internally and exports only surplus to external markets, CORDIS. FLEXCoop registered a cooperative ethos that prioritised grid-stability services and stringent privacy safeguards, leading to an in-cooperative tariff with optional aggregator-facilitated export to wholesale platforms FLEXcoop Project. Project LEO in Oxfordshire observed that citizens valued local self-sufficiency and neighbourhood benefits alongside price savings, prompting the design of a regional coordination platform that blends community tariffs with neighbourhood-level auctions, thus ensuring local balancing precedes wider market exposure Oxford City Council [49].

Case-study work in Sweden confirmed that prosumers will supply flexibility if congestion relief payments are transparent and locally focused. The researchers consequently proposed distribution-system-operator congestion auctions layered atop revised capacity-based tariffs, so that price signals directly address the spatial and temporal nature of grid stress [39]. By contrast, FLEXGRID surveys identified strong risk aversion among small retailers; respondents requested protection against unbounded downside prices. The resulting design therefore retained distribution-level auctions but embedded cap-and-floor revenue guarantees, offering financial hedges within the market architecture without reverting to rigid tariff instruments FLEXGRID [50]. Finally, EUuniversal confronted a mixed readiness profile—distribution operators and aggregators declared themselves market-ready, small and medium-sized enterprises would join if platform fees were modest, while households demanded an “autopilot.” The Universal Market Enabling Interface thus pairs local auctions for advanced actors with optional network-charge discounts available to all users, reproducing the REEFLEX logic of a simple entry tariff coupled with an open market for value stacking CORDIS [51].

Taken as a whole, the matrix reveals three systemic patterns. First, where surveys report broad digital literacy and tolerance for price variability, designers gravitate to fully market-based procurement. Second, when simplicity or privacy dominate user preferences, tariff-driven approaches prevail. Third, in contexts of heterogeneous readiness, hybrid models emerge, providing low-barrier tariff incentives as an on-ramp while reserving

explicit markets for actors willing and able to exploit them. The empirical alignment between user insights and contractual form across all eleven initiatives underscores the central thesis: successful flexibility procurement hinges not solely on technical optimisation but equally on the social acceptability uncovered through rigorous stakeholder research.

5. Conclusions

The transformation of electric systems from centralized architectures to decentralized, distributed energy frameworks is making grid operation significantly more complex. The increasing integration of DERs, electric vehicles and electrification of energy demand requires new coordination strategies to ensure reliability, stability and efficiency. In this evolving context, flexibility has emerged as a key enabler for DSOs and market actors to manage local grids dynamically. Flexibility markets, especially at the local level, are expected to become essential mechanisms to support this transition.

However, for flexibility markets to reach their full potential, it is critical to design tools and platforms that allow all types of prosumers—regardless of their size, expertise or digital maturity—to actively participate. The REEFLEX project addresses this challenge by developing 14 interoperable tools that cover various aspects of flexibility framework. To ensure these tools are truly aligned with market needs and user expectations, REEFLEX conducted a comprehensive set of stakeholder-centric surveys targeting a broad spectrum of actors, including end-users, developers and system operators.

The methodology combined structured questionnaires tailored to user types with qualitative and quantitative analysis of responses. The results show some interesting results; for example, most of potential users indicate financial compensation and decarbonisation support as the most important motivation to adopt these technologies, only municipalities show different results.

However, several barriers still hinder the broader adoption of these solutions. Privacy and data-related vulnerabilities were persistently identified across various operator categories. Distribution System Operators (DSOs) reported risks associated with the leakage of personal and business data (8/10) and security threats related to the Internet of Things (IoT) (7/10), whereas aggregators underscored the necessity of adhering to privacy regulations (5/6) and the presence of data security weaknesses. These apprehensions, notwithstanding the limited sample sizes, signify that confidence in data management practices is a pertinent issue not solely for end-users but also for infrastructure stakeholders who are subject to more stringent accountability measures.

What sets this study apart is its systematic mapping of stakeholder perceptions to a portfolio of 14 digital solutions currently under development. Unlike previous surveys that assess general attitudes or post-pilot acceptance, the REEFLEX approach gathers structured, pre-implementation feedback across 12 stakeholder categories, using a shared set of tools, definitions and metrics. This level of granularity enables direct alignment between user expectations and technical functionalities, enhancing the real-world applicability of the findings. The survey thus serves not only as a research instrument but also as a design input to shape more inclusive and user-centric flexibility services.

When compared with results from other European initiatives and literature, the REEFLEX survey outcomes are broadly consistent—confirming shared concerns about usability, regulatory uncertainty and the need for co-designed solutions. In addition, REEFLEX confirms many recurring findings—such as the primacy of financial incentives (as in eBalance-Plus), the importance of trust and transparency (as stressed in GLocalFlex and LEO projects), as well as the growing preference for automated “set-and-forget” solutions with override options (as demonstrated in iFLEX and IEA studies). However,

REEFLEX adds value by explicitly mapping preferences to a concrete portfolio of flexibility tools under development.

Overall, the paper highlights the importance of grounding innovation in real user needs and operationalizes this principle through the application of a standardized coding scheme that connects user automation preferences to a diverse set of tools under development. The insights gained are expected to guide the design and deployment of the REEFLEX tools and contribute to the broader European strategy for inclusive and scalable local flexibility markets. This stakeholder-driven approach can serve as a replicable model for future European efforts to scale inclusive, trusted and effective flexibility markets.

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Abbreviations

The following abbreviations are used in this manuscript:

AI	Artificial Intelligence
API	Application Programming Interface
BMS	Batteries Management System
B2G	Battery to Grid
DER	Distributed Energy Resources
DLC	Direct Load Control
DLT	Distributed Ledger Technology
DR	Demand Response
DSO	Distribution System Operator
ERP	Enterprise Resource Planning
ESCO	Energy Service Company
ETIP SNET	European Technology and Innovation Platform for Smart Networks for Energy Transition
EU ETS	European Union Emissions Trading System
EV	Electric Vehicle
GDPR	General Data Protection Regulation
HVAC	Heating, Ventilation and Air Conditioning

ICT	Information and Communication Technology
IoT	Internet of Things
KPI(s)	Key Performance Indicator(s)
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LFM	Local Flexibility Market
NILM	Non-Intrusive Load Monitoring
P2P	Peer-to-Peer
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goals
SME	Small and Medium-sized Enterprises
SRI	Smart Readiness Indicator
SSA	Structured Stakeholder Analysis
TSO	Transmission System Operator
V2G	Vehicle to Grid

Appendix A. Description of REEFLEX Core Solutions

To support the deployment and adoption of local flexibility markets, the REEFLEX project develops and integrates a suite of 14 innovative solutions. These tools address different layers of the flexibility value chain—ranging from data interoperability, asset monitoring, flexibility forecasting and aggregation, to market interaction and evaluation. Each solution is designed with user-centric principles and aims to enhance the capabilities of prosumers, DSOs, aggregators and other energy stakeholders. This annex provides a concise description of each of these core solutions and the main results provided by the survey made to potential tools users [52]:

Appendix A.1. Data Exchange, Handling and Interoperability Platform

A foundational data platform designed to ensure seamless, secure and standardized data exchange across all actors in the flexibility value chain. It enables semantic interoperability using the REEFLEX Energy Data Model and integrates multiple ingestion methods (batch, API, real-time). It supports anonymization, access control and compatibility with existing systems, allowing distributed energy resources (DERs) and prosumers to participate in energy services and markets in a secure and scalable way.

Main results

- **Time Relevance:** Responses strongly support the platform’s relevance both currently and within the next 5 years, with less than 15% indicating otherwise.
- **Innovative Features:** Respondents evaluated identified features based on their relevance over time, showing strong interest for now and in the mid-term future.
- **Adoption Barriers:** Various barriers were identified, including regulatory, technical, economic and privacy concerns, with notable examples provided, such as interoperability, higher investment and low remuneration, regulatory entry barriers.
- **Access Preferences:** The majority (77.8%) prefer a cloud-based solution, while some express a preference for a mixed mode, potentially blending cloud and local hosting for security of sensitive data.
- **Participation and Payment:** Despite interest in the platform, willingness to participate or pay is mostly medium or low, with a preference for the platform-as-a-service model over pay-to-own.

Appendix A.2. VERIFY—Web-Based Platform for LCA/LCC of Projects

VERIFY is a comprehensive online platform for performing Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) of energy assets and systems. It goes beyond standard

tools by incorporating real-time data streams and synthetic simulations to evaluate environmental and economic impacts of REEFLEX solutions over both short-term and long-term horizons (up to 20 years). The tool includes modules for CO₂ footprint analysis, KPI-based evaluation, clustering and connection to EU Emissions Trading System data, providing rich insights for prosumers, operators and policymakers.

Main results

- Time Relevance: Perception of the VERIFY tool's helpfulness over time is uncertain, with a slight lead for respondents considering it helpful now.
- Adoption Barriers: Identified barriers include a notable increase in unspecified barriers categorized as "other," along with concerns about the tool's ambiguity and lack of specificity on capabilities and scope.
- Access Preferences: Most respondents prefer the VERIFY tool to operate as a cloud-based solution, with one indicating lack of interest.
- Participation and Payment: Willingness to pay for the service is medium, with a preference for the subscription model, along with interest in pay-per-use and pay-based-on-savings options.

Appendix A.3. USE—Platform for Uniform Evaluation of Projects

USE is a web-based open-source tool for multidimensional evaluation of smart energy and smart city projects. It combines technical, environmental, social and economic indicators into normalized and weighted indices. These allow urban planners, project developers and authorities to monitor progress and assess sustainability performance. Within REEFLEX, the platform will be adapted with additional KPIs for integrated energy systems and configured to support demonstration sites in measuring and comparing their alignment with sustainability goals such as the Sustainable Development Goals (SDGs).

Main results

- Tool Perception: Respondents express uncertainty about the USE tool, with a higher concentration on the "not helpful" choice.
- Adoption Barriers: Various barriers are perceived, notably the existence of similar tools and concerns about framing the tool within the appropriate scope, along with technical complexities.
- Access Preferences: There's a strong preference for hosting the tool on a cloud.
- Participation and Payment: Willingness to pay for the USE tool is mostly low to medium, with a preference for the as-a-service model. Some respondents expressed interest in pay-per-use and pay-based-on-savings options, we conclude it may be a misunderstanding about the tool's scope.

Appendix A.4. Flexibility Potential Classification Tool for Any Asset

This tool provides a systematic method for assessing and classifying the flexibility capability of energy-consuming or storing devices. It builds upon and extends the EU's Smart Readiness Indicator (SRI) to rate devices not only in buildings but also across sectors. It enables standardization of device profiles for flexibility aggregation, dispatch and market participation. The output includes a machine-readable classification and a flexibility descriptor protocol that will feed other REEFLEX tools, such as aggregation platforms or market selection algorithms.

Main results

- Tool Perception: Over 60% of respondents perceive the tool as helpful now or within the next five years.

- **Adoption Barriers:** Identified barriers include regulatory, technical and economic factors, with a notable mention of missing features such as smart appliances, potentially serving as an entry barrier.
- **Specific Barriers:** Technical barriers include the scarcity of smart appliances and concerns about user-friendliness, while regulatory issues involve underdeveloped smart readiness levels and legislative challenges. Economic barriers include high costs and a lack of market for offering flexibility.
- **Access Preferences:** Respondents still prefer the cloud-based option, with some expressing interest in a mixed option with local hosting for data protection.
- **Participation and Payment:** Willingness to pay for the tool is medium, with a preference for the as-a-service model. Other responses indicate interest in a payment model based on savings/earnings.

Appendix A.5. Second-Life Batteries as Flexibility Assets

This solution focuses on reusing electric vehicle (EV) batteries for stationary applications in buildings or communities. By integrating second-life batteries into the flexibility portfolio, REEFLEX addresses both environmental and economic challenges. It explores viable business models such as leasing and service-based approaches, while also tackling technical barriers like lifetime uncertainty and integration with grid services. These batteries can support congestion management, self-consumption and energy arbitrage within local flexibility markets.

Main results

- **Asset Relevance:** Respondents view using second-life batteries as flexibility assets as more relevant in the mid- and long-term rather than immediately.
- **Adoption Barriers:** While some respondents see no reason not to adopt the solution, specific barriers are highlighted, with reduced battery lifetime being a technical concern and regulatory limitations on storage usage for flexibility.
- **Specific Barriers:** Main barriers include technical concerns about reduced battery lifetime, regulatory limitations on storage usage and initial investment costs. Developers should address these barriers of cost and performance.
- **Ownership Preferences:** Around 65% of respondents prefer a leasing model for the solution, likely to reduce investment risks, while the remainder prefer owning the asset.

Appendix A.6. Predictive Flexibility Potential and Operation of Distributed Devices

This solution uses artificial intelligence and data analytics to forecast the flexibility potential of DERs, such as batteries, EVs, HVAC systems and other controllable loads. It enables predictive scheduling and optimal dispatch based on market signals and grid conditions. The predictive models are trained with historical and real-time data and support automated coordination with aggregators and DSOs to maximize value and minimize operational conflict.

Main results

- **Solution Perception:** Over 75% of respondents rate the solution as helpful, with a minority unsure or considering it not helpful.
- **Feature Relevance:** Respondents show strong interest in identified platform features both currently and within the next 5 years. Main interest is shown in the features of visualisation and reporting, optimisation and forecasting.
- **Adoption Barriers:** Despite a high percentage selecting “none of the above,” various barriers are still identified, including technical, regulatory and economic concerns, along with missing features such as AI utilization and enhanced automation.

- **Specific Barriers:** Technical barriers include the need for compatible smart appliances and concerns about ease of use. Regulatory barriers include missing legislation and a lack of flexibility in the national market. Economic barriers include difficulty breaking even, high investment costs and low returns.
- **Access Preferences:** The majority prefer a cloud-based solution, with some uncertainty or preference for specific features. Concerns about missing features are mentioned.
- **Participation and Payment:** Willingness to participate or pay is mainly low to medium, aligning with concerns identified in the barriers question. The as-a-service payment model is preferred, with interest in options like payment based on savings/earnings and free trial periods to mitigate initial investment risks.

Appendix A.7. Non-Intrusive Load Monitoring (NILM) for Large Consumers

This tool leverages NILM technology to analyze overall energy consumption profiles of industrial and tertiary buildings and disaggregate them into individual load components. Without requiring multiple sensors, it identifies specific loads with flexibility potential, enabling smarter control strategies and more efficient participation in demand response or flexibility markets. It is especially useful in large infrastructures with high energy consumption and limited metering granularity.

Main results

- **Solution Perception:** Most respondents find the tool helpful or relevant now and in the mid-term.
- **Feature Relevance:** Respondents find the tool's features appealing in the meantime and within the next 5 years.
- **Adoption Barriers:** While most respondents indicated the presence of barriers, only one technical barrier regarding the accuracy and reliability of disaggregation was mentioned.
- **Access Preferences:** The cloud-based option is preferred by most respondents.
- **Participation and Payment:** Respondents express a medium to high willingness to pay for the solution. As for the payment model preferred, approximately 55% prefer the subscription model, 36% choose the pay-to-own model, with some uncertainty among respondents.

Appendix A.8. NILM for Residential Consumers

This residential NILM tool enables the analysis of household energy use by disaggregating smart meter data into device-level consumption. It identifies behavioral patterns, detects flexible appliances (e.g., washing machines, water heaters) and supports user-friendly feedback. The goal is to empower prosumers with real-time awareness and automation options for flexibility participation while ensuring privacy and minimal technical requirements.

Main results

- **Solution Perception:** There's uncertainty regarding the helpfulness of the tool over time, with a slight lead for respondents considering it helpful now, while a significant portion is unsure.
- **Feature Relevance:** While there's some interest in the tool's features, over 30% of respondents either don't know or don't consider them relevant, with some experts doubting the algorithm's reliability.
- **Participation Barriers:** Respondents highlight diverse barriers to participation, with various concerns ranging across technical, regulatory, economic and privacy issues.
- **Specific Barriers:** Technical concerns include technology inaccuracy and complexity, while regulatory barriers include a lack of flexibility market for residential consumers.

Economic concerns involve unclear gains and high costs, while privacy concerns include cybersecurity.

- Access Preferences: There's a tendency towards cloud-based hosting, although some residential users don't grasp the importance of hosting location.
- Participation and Payment: Willingness to pay for the tool tends towards low to medium, with preferences split between the subscription model and payment based on profits earned using the tool.

Appendix A.9. Innovative Inverters for Storage and Electric Vehicles (V2G)

This solution focuses on the development and deployment of bidirectional inverters that allow energy to flow between storage systems or EVs and the grid. These inverters enable Vehicle-to-Grid (V2G) and Battery-to-Grid (B2G) capabilities, allowing users to export energy during peak times or in response to market prices. They include smart control features for grid synchronization, safety and revenue optimization and are critical for unlocking mobility-related flexibility.

Main results

- Solution Relevance: Respondents rated inverters for storage and V2G as mostly helpful in the mid- and long-term.
- Feature Relevance: Evaluation of platform features over time aligns with the perceived helpfulness, showing consistency in relevance. Notably, one respondent highlighted it should be interoperable with their control system "Enerbrain".
- Barriers: Over 40% of respondents already have existing solutions, while other barriers include technical interoperability issues, regulatory gaps and economic concerns such as pricing.
- Preferred Payment Method: The majority (more than 71%) prefer the "lease" option over owning the asset outright.

Appendix A.10. Algorithms for Optimal Management of the Grid

This toolset includes advanced algorithms for DSOs and aggregators to manage the grid under increasing variability and DER penetration. It integrates forecast data, network constraints and market inputs to produce actionable control signals. These algorithms help prevent grid congestion, optimize asset dispatch and coordinate flexibility activation across all levels, from residential zones to substations.

Main results

- Solution Relevance: Over 80% of respondents rate the solution as helpful in the mid- to long-term.
- Barriers: Various barriers are identified, including technical, regulatory, economic and privacy concerns, such as flexibility market entry barriers, interoperability issues, legal barriers, scalability of asset-based monitoring and data protection.
- Access Preferences: The majority prefer a cloud-based solution, with operators showing a preference for integrating the algorithm or tool into their legacy systems to avoid interoperability issues.
- Participation and Payment: Willingness to pay for the service varies, with 54.5% indicating low willingness, 27.3% high and 18.2% medium. Preferences for payment models include a subscription model favoured by more than half, while others prefer the pay-to-own model, with some expressing interest in additional customer support packages, suggesting a mixed option.

Appendix A.11. End-User Flexibility Calculation and Aggregation Tool

A user-centric tool designed to estimate the individual and collective flexibility of end-users. It evaluates the types of devices, usage patterns and control preferences to calculate available flexibility under different scenarios. The tool also supports dynamic aggregation strategies, grouping users by technical, behavioral or market criteria to create clusters capable of participating in flexibility services.

Main results

- **Solution Perception:** More than 66% of respondents perceive the tool as helpful in the mid-term, followed by perceiving it as helpful now.
- **Barriers:** Perceived barriers for the solution account for 50% of responses, with concerns about flexibility from end-users being stressed, particularly regarding regulatory issues and entry barriers.
- **Participation Frequency:** Respondents indicate offering availability for flexibility markets, but provision of flexibility can occur as little as once a month, depending on the operator.
- **Number of Participants:** Answers are split equally regarding the number of participants, which leaves us with a question about the type and number in each case.
- **Participant Aggregation:** Half of respondents expressed interest in aggregating both residential and industrial participants, despite that they aggregate only one profile, with one respondent elaborating on the feasibility of aggregating only industrial participants currently.
- **Access Preferences:** The majority (66.7%) prefer the cloud-based option for hosting the solution.
- **Participation Interest:** The tool or platform shows medium to high willingness to participate, indicating potential interest based on the tool description.
- **Payment Model Preferences:** The preferred payment model is split evenly between the pay-to-own and subscription models.

Appendix A.12. Tool to Calculate DSO Flexibility Needs

This solution enables DSOs to estimate how much flexibility is needed in different parts of their network and under what conditions. It combines load forecasting, grid topology, DER location and asset status to provide spatial and temporal flexibility demand curves. This information supports proactive planning, congestion forecasting and local market bidding.

Main results

- **Solution Perception:** Respondents view the solution as more helpful in the mid-term rather than immediately.
- **Feature Relevance:** Identified platform features received strong interest in the current status and within the next 5 years.
- **Barriers:** 90% of respondents highlight barriers, including technical issues like inconsistent data and interoperability, economic concerns about the high cost of monitoring equipment and privacy considerations.
- **Access Preferences:** The central cloud option remains the most common hosting choice for this tool.
- **Participation Interest:** Willingness to pay for the DSO tool sees moderate interest.
- **Payment Model Preferences:** The preferred payment model is a subscription-based model.

Appendix A.13. Optimal Market Selection Tool

This decision-support tool guides flexibility providers (e.g., aggregators, energy communities) in selecting the most appropriate market to offer their services—be it local, national, bilateral or P2P. It considers market access rules, profitability, user preferences and timing to recommend the optimal strategy. This reduces transaction costs and maximizes returns for flexible asset owners.

Main results

- Solution Perception: Respondents view the tool as helpful both now and in the mid-term.
- Feature Relevance: Features align with the overall view of the tool, showing similarity in importance.
- Barriers: Few barriers are identified due to the lack of responses, primarily focusing on regulatory barriers related to distributed loads.
- Access Preferences: Preference is for the tool to be hosted on a cloud-based platform.
- Participation Interest: Responses indicate uncertainty regarding willingness to pay.
- Payment Model Preferences: The preferred method of payment leans slightly towards the pay-to-own model, with 57% in favour compared to the subscription model.

Appendix A.14. P2P and Bilateral Energy Exchange Add-On Platform

An add-on module to the REEFLEX platform that enables peer-to-peer (P2P) or bilateral energy trading between prosumers or between prosumers and aggregators. It uses blockchain/DLT (Distributed Ledger Technology) to ensure transparency, trust and traceability of transactions. This tool is key for unlocking decentralized, community-based energy exchange models aligned with energy democracy principles.

Main results

- Solution Perception: Respondents view the tool as helpful both now and in the mid-term.
- Feature Relevance: Features align with the overall view of the tool, showing similarity in importance.
- Barriers: Few barriers are identified due to the lack of responses, primarily focusing on regulatory barriers related to distributed loads.
- Access Preferences: Preference is for the tool to be hosted on a cloud-based platform.
- Participation Interest: Responses indicate uncertainty regarding willingness to pay.
- Payment Model Preferences: The preferred method of payment leans slightly towards the pay-to-own model, with 57% in favour compared to the subscription model.

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