European Commission

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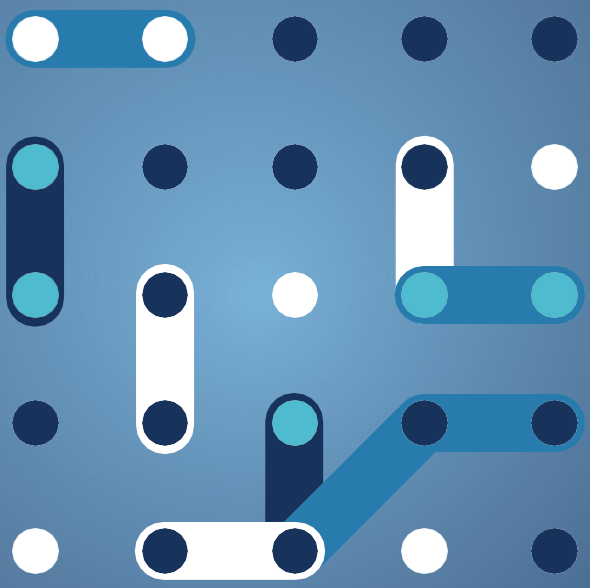
Supporting potential synergies from increased sector coupling, sector integration and system integration

Regulation Working Group



July 2025

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EUROPEAN COMMISSION

Directorate-General for Energy

Directorate B – Just Transition, Consumers, Energy Efficiency and Innovation Unit B5 – Innovation, Research, Digitalisation, Competitiveness

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LEGAL NOTICE

PDF ISBN: 978-92-9405-295-7 doi: 10.2926/5883029 HZ-01-25-106-EN-N

Luxembourg: Publications Office of the European Union, 2025

Manuscript completed in July 2025

First edition

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LIST OF ACRONYMS AND ABBREVIATIONS

DR	Demand Response
DER	Distributed Energy Resources
DSO	Distribution System Operator
EC	European Commission
EU	European Union
EVs	Electric Vehicles
RES	Renewable energy source
SME	Small and medium enterprise
TSO	Transmission System Operator
WG	Working Group

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EXECUTIVE SUMMARY

The successful transition to a climate-neutral European energy system requires a fundamental redesign of its operational and regulatory principles. Sector coupling and system integration are essential pillars of this transformation, as they unlock synergies across electricity, heating, mobility, and gas systems. Action 4 of the BRIDGE initiative addresses this challenge by consolidating practical evidence from more than thirty EU-funded projects, identifying persistent barriers, and formulating strategic recommendations to accelerate the deployment of integrated energy systems.

Between 2023 and 2025, projects reported a progressive shift from technical challenges towards structural and institutional barriers. Initial obstacles, such as data interoperability and privacy, are being progressively addressed through standardisation efforts and enhanced governance mechanisms. However, systemic challenges remain. Fragmented network regulations, complex and inconsistent permitting procedures, and the absence of harmonised market mechanisms, continue to constrain cross-sector implementation.

The evidence collected through Action 4 reveals consistent patterns. In the case of e-mobility, inadequate coordination among stakeholders and outdated network codes continue to hinder the effective deployment of vehicle-to-grid services. In the heating sector, regulatory fragmentation and the lack of appropriate market incentives prevent the scaling-up of thermal flexibility solutions. At the household level, decentralised systems suffer from inconsistent legal frameworks and limited support for prosumer market participation. In the case of emerging energy vectors, such as hydrogen or electrothermal systems, legal uncertainty and complex permitting procedures are the most critical barriers.

Despite these challenges, the report identifies a wide range of best practices and regulatory innovations with strong potential for replication. These include the adoption of open interoperability protocols, the creation of regulatory sandboxes, and the implementation of joint planning frameworks between distribution system operators, aggregators, and local authorities. Pilot projects have successfully tested innovative remuneration schemes for flexibility, new cross-sector business models, and user-centric digital tools that enhance consumer engagement and system efficiency.

Building on this analysis, the report provides a policy roadmap structured around six strategic axes: alignment of regulatory frameworks, fiscal reform for multi-energy systems, expansion of cross-sector flexibility markets, improved governance for local implementation, harmonisation of permitting procedures, and institutionalised stakeholder dialogue. Each axis includes targeted actions designed to unlock investment and operational synergies across the EU energy landscape.

This comparative (Figure 1) summarises the evolution of reported barriers from the 2024 and 2025 Action 4 surveys. It clearly illustrates a general reduction in data-related challenges, such as interoperability and privacy, while highlighting the increasing prominence of regulatory fragmentation, permitting procedures, and stakeholder coordination as systemic bottlenecks. These trends reflect the growing maturity of pilot projects and the urgent need to address institutional constraints through coherent policy action.

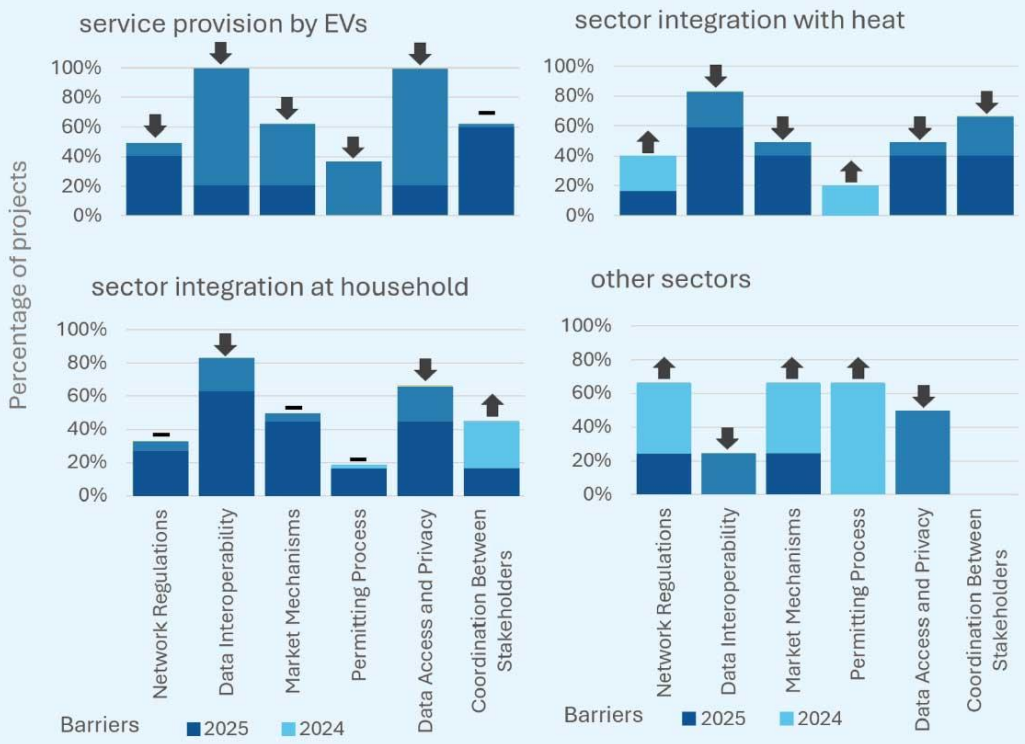


Figure 1. Comparative analysis of the survey results for sector-specific barriers reported by projects in the 2023-2024 and 2024-2025 reports.

Action 4 contributes directly to the EU Competitiveness Compass by clarifying the regulatory and systemic adjustments required to scale innovation and reinforce Europe's industrial and energy leadership. The findings presented serve as a foundation for coordinated policymaking across Member States, supporting the implementation of the European Green Deal and the development of integrated infrastructures aligned with climate neutrality targets.

1 INTRODUCTION TO ACTION 4

Traditionally, the EU energy system has been divided into different segments, with different infrastructure for electricity, oil or natural gas, being developed and operated in isolation from each other. Over the years, this division has resulted in the development of unidirectional connections between specific infrastructure and particular end-use sectors, with linear energy flows (see Figure 2). However, the electrification of end-uses brings the different sectors in connection with each other. In this context, the model based in unidirectional flows of energy results technically and economically inefficient to deliver a decarbonised energy system.

Evidence shows that the coordinated operation of the different energy systems and infrastructure will reduce the cost of the energy transition by enabling a more effective use of existing assets (see Figure 2). In addition, managing the different energy flows as one system increases the chances to adapt to the intermittency and variability of renewable energy sources (RES) that could affect the balance between supply and demand required to maintain stability and reliability of the grid.

In the EU, the integration of the different energy systems is seen as the foundation for the energy system of the future. In this context, the European Commission has launched multiple initiatives that aim to link the different sectors and infrastructure to boost renewables and reduce carbon emissions. A clear example is the *Energy Sector Integration Strategy* that was published[1] on 8 July 2020 in which it was proposed to adopt a holistic view of the energy system rather than a perspective based on single segments. Today, while some notable advancements have been implemented across the Union, several gaps remain.

Figure 1: The energy system of today

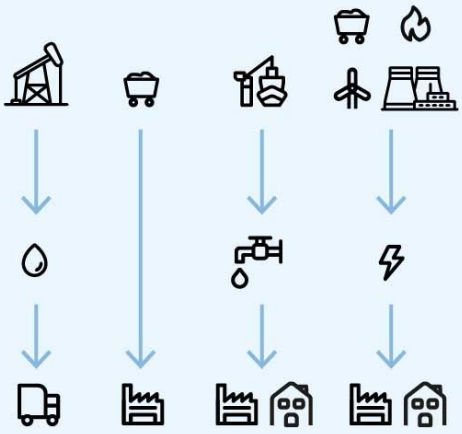
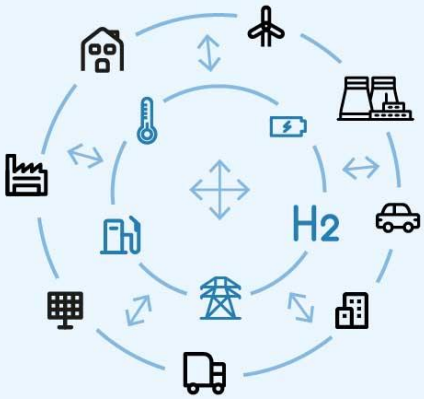


Figure 2: Future EU Integrated Energy System



Source: EU Commission, eu strategy on energy system integration

Figure 2. Comparison between the current linear and segmented EU energy system and the envisioned integrated energy system of the future. Source: European Commission, EU Strategy for Energy System Integration (2020).

[1] https://energy.ec.europa.eu/topics/eus-energy-system/energy-system-integration_en

This report aims to bring together EU-funded projects focused on sector coupling to identify key barriers, best practices, and recommendations encountered during the implementation of innovative solutions in pilot projects. The main objective is to provide a clear overview of regulatory challenges to innovation and to the integration of the EU energy system. This analysis aims to feed the publication[2] by the *EU Competitiveness Compass*, which highlights the need to enhance competitiveness and to ensure sustainable prosperity. In the following sections, we will introduce the Action and outline the methodology used for this report. We will then present the best practices identified for overcoming these barriers, followed by key recommendations to leverage the potential of sector coupling, ensuring its implementation with a grid-friendly approach. Besides, the document presents some proposals to effectively breaking down existing silos—ultimately contributing to the continent's goal of climate neutrality.

[2] https://commission.europa.eu/topics/eu-competitiveness/competitiveness-compass_en

2 ACTION 4 GOALS AND METHODOLOGY

As part of BRIDGE's mission to build on the efforts within various H2020 and Horizon Europe projects, Action explores sector coupling from a broad perspective. Sector coupling encompasses various elements, including buildings and energy storage, and can be analysed through the lenses of:

- Regulatory challenges
- Business models
- Grid implications.

Although there is no universally accepted definition of sector coupling, for the purposes of this report, it is understood as follows:

> Sector coupling involves the increased integration of energy end-use and supply sectors with one another to improve the efficiency and flexibility of the energy system as well as its reliability and adequacy.

In this context, the main goal of Action 4 is to provide insights into sector coupling and discuss the regulatory perspective considering different end-use and supply sectors. In particular, we have placed a specific focus on:

- Service provision by EVs
- Sector integration with heat
- Integration at household level.

This year, Action 4 benefits from joint leadership, bringing together diverse backgrounds and technologies. This report builds on the findings of last year's edition, which identified key barriers to sector coupling based on input from participating projects.

In particular, the projects' participation in Action 4 followed a 3-step methodology with the steps below:

- **Input collection**: Problems, barriers and the way to go – This is a collection of the results from the survey conducted in 2023 and the survey conducted to new additions in 2024.
- **Best practices:** These are collected based on the experiences from the different projects that have reported barriers. On 28 February 2025, the Action leaders organised a workshop to share how the projects addressed specific barriers.
- **Recommendations:** The idea is to provide a set of recommendations to foster sector integration in the EU.

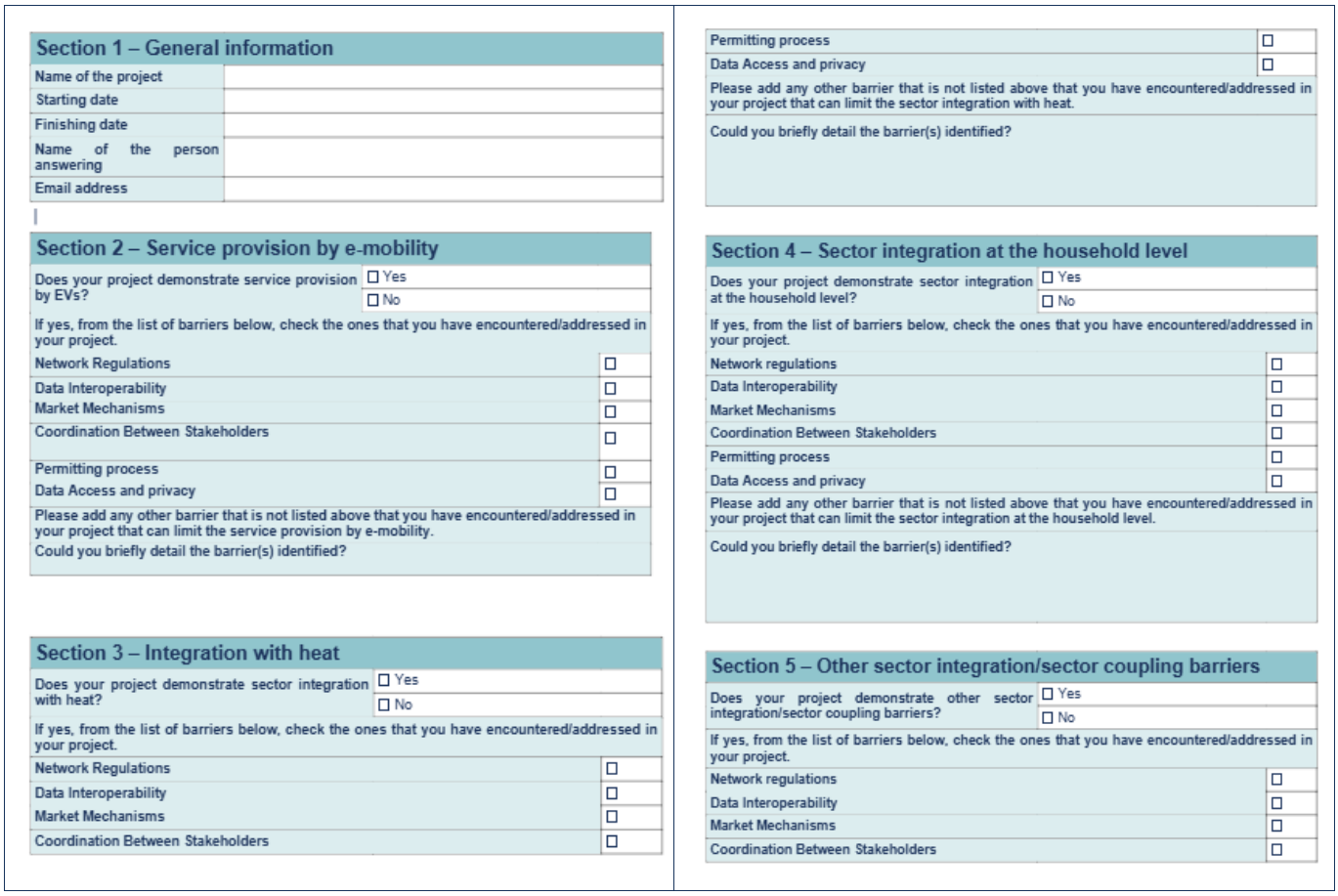
3 PROJECTS PARTICIPATING IN ACTION 4

Air4NRG, CEEGS, DEDALUS, ECHO, ENFLATE, EU-Dream, FEDECOM, FLOW, HYSTORE, Int:Net, ODEON, OMEGA-X, PUSH-IT, SCARLET, SENERGY NETS, STREAM, Thumbs Up, U2Demo.

4 PROBLEM STATEMENT

The traditional unidirectional energy flow model has proved to be inadequate for a decarbonised energy system, necessitating the integration and synergy of various energy sectors. However, a **comprehensive understanding of the primary barriers and best practices for enhanced sector coupling and wider adoption remains elusive.**

This section provides an overview of the main barriers identified by the projects participating in Action 4. We will first present the results of the survey conducted in 2023-2024 and then the results of the survey conducted in 2025. The goal is to showcase the trends and changes of two consecutive years to gather insights on the evolution of the existing barriers for sector coupling/sector integration/system within the EU energy system. The survey is divided into five sections (following the stated methodology), each explained in detail below.



Section 1 – General information

Name of the project	
Starting date	
Finishing date	
Name of the person answering	
Email address	

Section 2 – Service provision by e-mobility

Does your project demonstrate service provision by EVs?	☐ Yes ☐ No
If yes, from the list of barriers below, check the ones that you have encountered/addressed in your project.	
Network Regulations	☐
Data Interoperability	☐
Market Mechanisms	☐
Coordination Between Stakeholders	☐
Permitting process	☐
Data Access and privacy	☐
Please add any other barrier that is not listed above that you have encountered/addressed in your project that can limit the service provision by e-mobility.	
Could you briefly detail the barrier(s) identified?	

Section 3 – Integration with heat

Does your project demonstrate sector integration with heat?	☐ Yes ☐ No
If yes, from the list of barriers below, check the ones that you have encountered/addressed in your project.	
Network Regulations	☐
Data Interoperability	☐
Market Mechanisms	☐
Coordination Between Stakeholders	☐
Permitting process	☐
Data Access and privacy	☐
Please add any other barrier that is not listed above that you have encountered/addressed in your project that can limit the sector integration with heat.	
Could you briefly detail the barrier(s) identified?	

Section 4 – Sector integration at the household level

Does your project demonstrate sector integration at the household level?	☐ Yes ☐ No
If yes, from the list of barriers below, check the ones that you have encountered/addressed in your project.	
Network regulations	☐
Data Interoperability	☐
Market Mechanisms	☐
Coordination Between Stakeholders	☐
Permitting process	☐
Data Access and privacy	☐
Please add any other barrier that is not listed above that you have encountered/addressed in your project that can limit the sector integration at the household level.	
Could you briefly detail the barrier(s) identified?	

Section 5 – Other sector integration/sector coupling barriers

Does your project demonstrate other sector integration/sector coupling barriers?	☐ Yes ☐ No
If yes, from the list of barriers below, check the ones that you have encountered/addressed in your project.	
Network regulations	☐
Data Interoperability	☐
Market Mechanisms	☐
Coordination Between Stakeholders	☐

Figure 3. Structure of the Action 4 survey used to collect insights on regulatory, technical, and operational barriers to sector coupling. The survey was divided into five sections addressing general project information, service provision by e-mobility, integration with heat, household-level integration, and other sector coupling barriers. The responses were used to identify trends, compare data across years, and support the formulation of policy recommendations.

4.1 Results of the survey circulated in 2023-2024

In 2023-2024, 14 projects contributing to Action 4 participated in the survey; questions were focused on:

- If the project was demonstrating service provision by EVs, sector integration with heat, sector integration at the household level, or with other sectors.
- Barriers encountered/addressed or expected to be encountered in the project.

The summary of responses regarding the services is given in Table 1. Overview of project inputs related to sector coupling dimensions based on the 2023–2024 Action 4 survey.Table 1.

Table 1. Overview of project inputs related to sector coupling dimensions based on the 2023–2024 Action 4 survey.

Name of the project (2023-2024)	Does your project demonstrate service provision by EVs?	Does your project demonstrate sector integration with heat?	Does your project demonstrate sector integration at the household level?	Does your project demonstrate other sector integration/ sector coupling barriers?
ACCEPT	No	No	Yes	No
ATTEST	No	Yes	No	No

BeFlexible	Yes	Yes	No	Yes
DATA CELLAR	Yes	Yes	Yes	No
EDDIE	Yes	No	Yes	Yes
EV4EU	Yes	No	No	No
HYSTORE	No	Yes	Yes	No
iFLEX	No	Yes	No	No
INCIT-EV	Yes	No	No	Yes
PARMENIDES	Yes	No	Yes	No
SCARLET	No	No	No	Yes
SENERGY NETS	No	Yes	No	No
STREAM	Yes	No	Yes	No
XL-Connect	Yes	No	No	No
Total Yes	**8**	**6**	**6**	**4**

The survey has focused on provision from EVs: 8 projects out of 14 had this topic in their demonstration activities.

Three projects dealt with 3 resources/sectors, 4 with 2 resources, and 7 projects involved one of the analyzed services; none of them addressed all the 4 services.

The following graphs summarise the barriers reported by the projects. Firstly, they highlighted that the existing regulation didn't allow to fully demonstrate the service provision. Another general barrier was the restriction on data usage.

With respect to the main barriers encountered or addressed, there were **Data Interoperability**, and **Data Access & Privacy**.

80% of projects demonstrating services from EVs have reported the above barriers; Data interoperability was also highlighted by the projects dealing with integration with the Heat sector (83%). These two sectors (EV, Heat) reported as relevant also the **Coordination between Stakeholders**. The **Permitting Process** was considered as relevant only by projects dealing with EVs (30%).

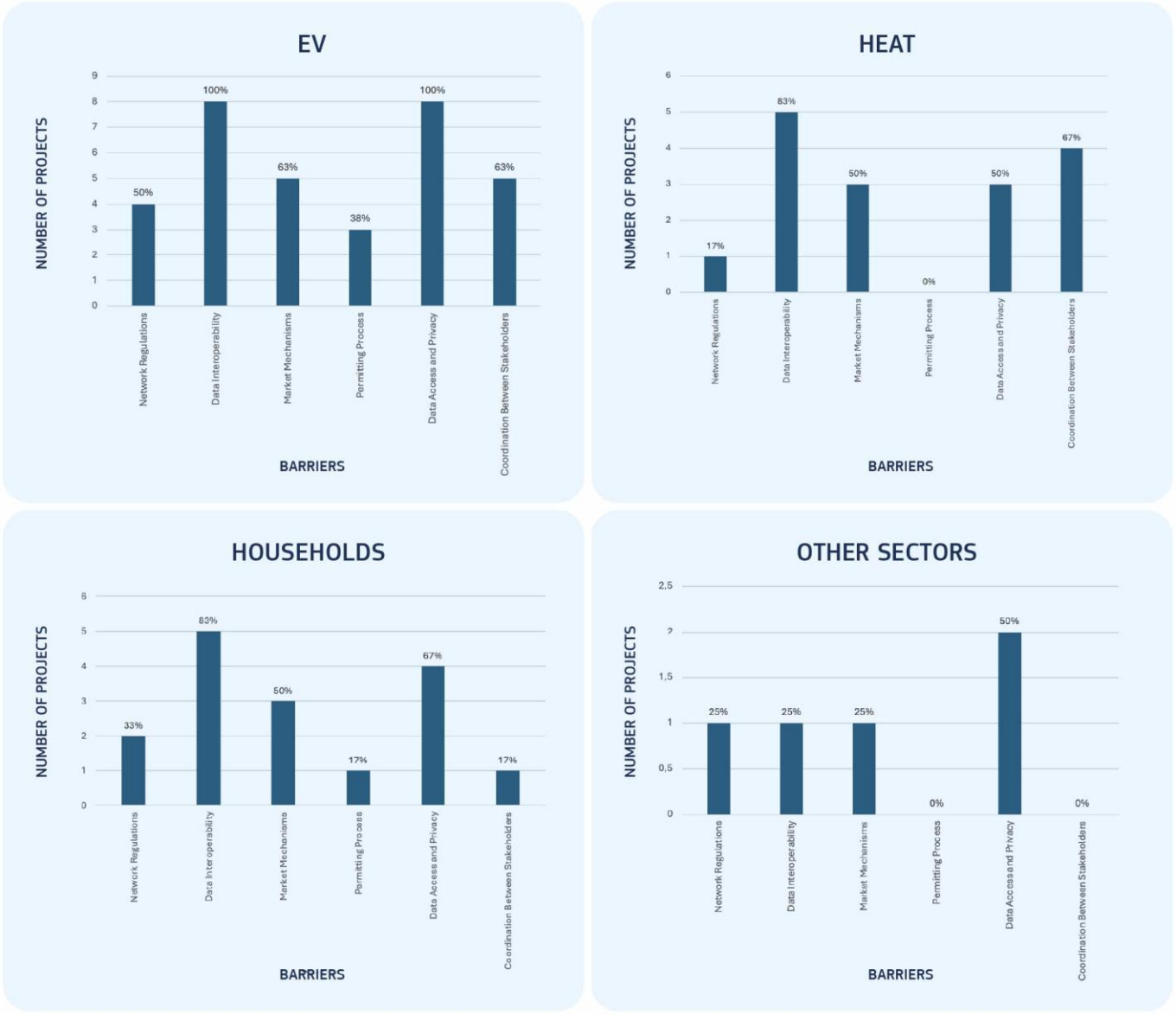


Figure 4. Survey 2023-2024: number of projects that selected the barriers in service provision by EVs, sector integration with Heat, sector integration at Households level, or Other sectors.

4.2 Results of the 2024-2025 survey & analysis of trends and changes

As part of the Action 4 activities, a survey was conducted during the 2024–2025 period to collect updated information on ongoing and new initiatives related to sector coupling across Europe. A total of 15 projects participated in the survey, providing valuable insights into current priorities, areas of focus, and evolving trends.

The table below offers an overview of the main inputs gathered from these projects, categorised by sector coupling dimensions. Key aspects covered include the strategic objectives of each initiative, the specific sectors targeted—such as electric vehicles (EVs), heating, and integrated multi-sector approaches—as well as relevant innovations and implementation challenges. This consolidated view enables a comparative analysis of technological trends, policy integration levels, and cross-sector synergies.

Table 2. Overview of project inputs related to sector coupling dimensions based on the 2024–2025 Action 4 survey.

Name of the project (2024-2025)	Does your project demonstrate service provision by EVs?	Does your project demonstrate sector integration with heat?	Does your project demonstrate sector integration at the household level?	Does your project demonstrate other sector integration/ sector coupling barriers?
Air4NRG	No	No	No	No
CEEGS	No	Yes	Yes	Yes
DEDALUS	No	Yes	Yes	No
ECHO	No	Yes	Yes	No
ENFLATE	No	Yes	Yes	No
EU-Dream	Yes	Yes	Yes	No
FEDECOM	Yes	Yes	Yes	Yes
ODEON	Yes	No	Yes	No
OMEGA-X	No	Yes	Yes	No
PUSH-IT	No	Yes	No	No
SCARLET	No	Yes	No	Yes
SENERGY NETS	No	Yes	Yes	No
STREAM	Yes	No	Yes	No
Thumbs Up	No	No	No	No
U2Demo	Yes	No	Yes	No
Total Yes	**5**	**10**	**11**	**3**

4.2.1 Service provision by e-mobility

The survey results for the year 2025 highlight several key barriers impacting the provision of e-mobility services across the reviewed projects. Among the 15 projects surveyed in 2025, only 5 projects reported encountering barriers in the provision of e-mobility services. This represents a notable decrease compared to the 2024 survey, where 8 out of 14 projects identified barriers. This reduction may indicate progress in addressing the previously reported challenges, though persistent and emerging obstacles remain.

In 2025, **Coordination Between Stakeholders** emerged as the most reported challenge, cited by 60% of projects identifying barriers. Respondents noted the continued difficulty in aligning diverse actors such as DSOs, technology providers, and market participants, particularly in the context of integrating e-mobility with the electricity and heating sectors. Misaligned goals and delayed decision-making processes were seen as central hurdles to effective collaboration.

Network Regulations were identified by 40% of the projects, reflecting ongoing concerns regarding the lack of harmonised and updated regulatory frameworks (e.g. transposition of Directive 2018/2001, Directive 2019/944) to support the deployment of vehicle-to-grid (V2G) technologies. Projects highlighted uncertainties over compliance for bidirectional chargers and the need for more adaptable grid codes considering increasing EV participation in flexibility markets.

Data-related Barriers, namely **Data Interoperability** and **Data Access and Privacy**, were each reported by only 20% of projects in 2025, compared to 100% in 2024. This sharp decrease may point to advancements in standardising communication protocols and improving compliance with data privacy regulations. Nevertheless, respondents noted ongoing concerns over the cost of interoperable hardware and regulatory fragmentation.

Market Mechanisms also declined in perceived relevance, with only 20% of projects citing them as a barrier in 2025, compared to 63% in 2024. Feedback points to a continued lack of clarity in market structures and limited availability of dynamic pricing schemes. **Permitting Processes**, cited by 38% of projects in 2024, were not reported as a barrier in 2025, which may indicate procedural improvements or shifts in project focus.

When comparing 2024 and 2025 (Figure a; Figure b; Figure c), the overall decline in reported barriers suggests an improving policy and implementation landscape. However, **Coordination Between Stakeholders** remains a critical and stable concern (63% in 2024, 60% in 2025), underscoring the structural complexity of multi-actor collaboration in the evolving e-mobility ecosystem.

In conclusion, while there is a noticeable reduction in the share of projects reporting barriers, from 57% in 2024 to 33% in 2025, continued efforts are required to enhance collaborative governance, streamline regulatory frameworks, and strengthen enabling market mechanisms. The sustained emphasis on stakeholder coordination and regulatory clarity highlights their importance as prerequisites for the efficient and scalable deployment of e-mobility services.

Key Insights from Projects Surveyed:

- **FEDECOM:** Reported multiple regulatory challenges across Belgium, the Netherlands, and Switzerland. In Belgium, technological immaturity of V2X-capable EVs hinders pilot operations. The Netherlands faces a lack of regulatory frameworks for V2G activities, while Switzerland experiences regulatory gaps that limit V2G deployment to the energy community level only.
- **U2Demo:** Highlighted challenges related to Network Regulations and Coordination Between Stakeholders. The project reported that some of the tested services cannot be implemented under existing regulations, emphasising the need for updated frameworks to support EV-based services.
- **STREAM:** Reported difficulties with Market Mechanisms and Stakeholder Coordination. The lack of established local flexibility markets creates uncertainty regarding EV participation in flexibility services, necessitating clearer definitions of market roles and mechanisms.
- **ODEON:** Identified concerns with Data Interoperability, Stakeholder Coordination, and Data Access and Privacy. Privacy, legal, and ethical concerns about data sharing, coupled with interoperability issues from disparate standards, were highlighted as key obstacles to EV service provision.

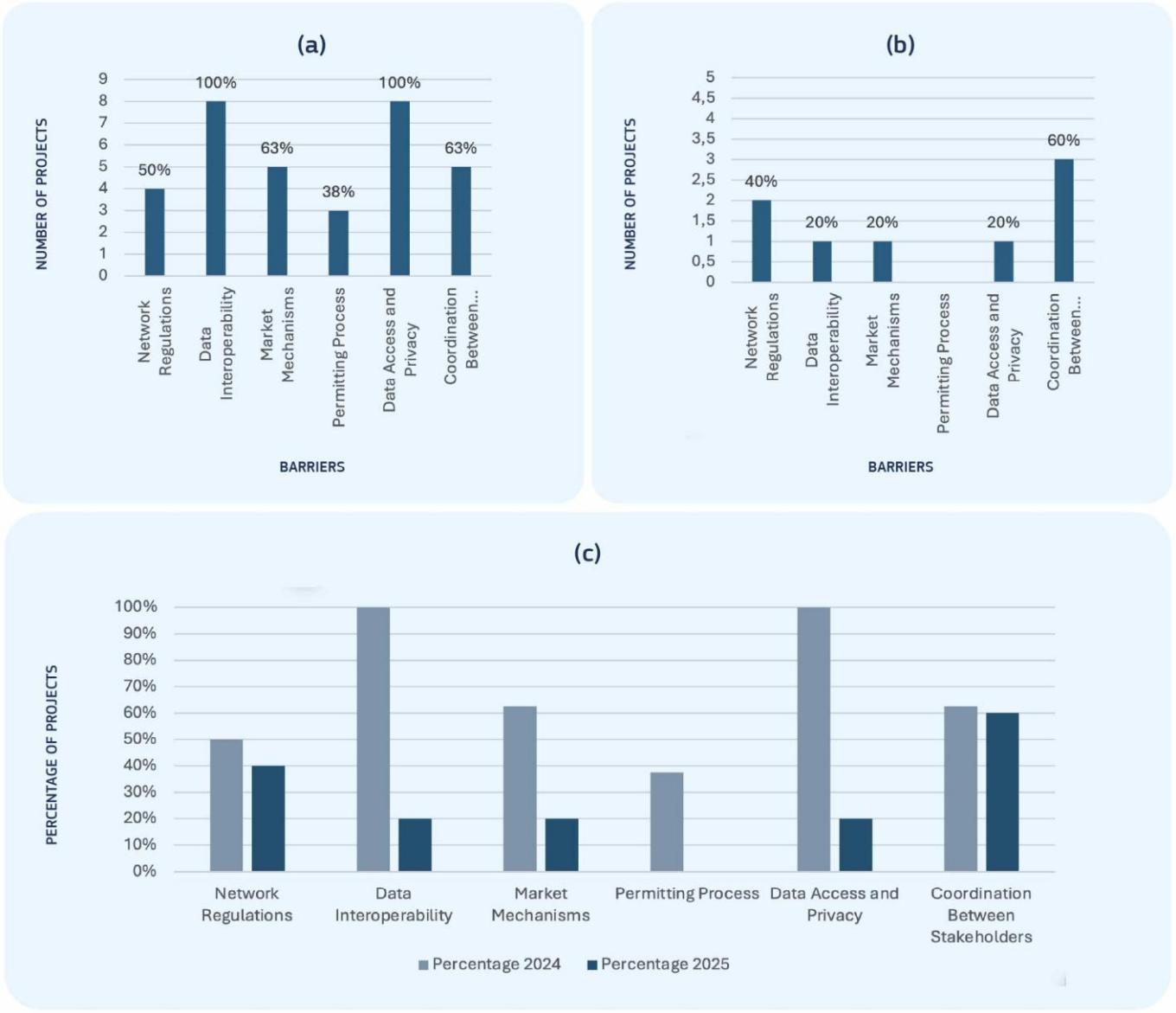


Figure 5. Overview of the barriers related to service provision by e-mobility in the reviewed projects. (a) Data reported for the 2023-2024 period, (b) data extracted from the survey conducted for the current 2024-2025 report. (c) The percentages represent the share of projects that identified barriers in the evaluated cross-sectoral analysis, based on the 2024 report (orange) and the 2025 report (blue).

4.2.2 Integration with heat

The survey results for 2025 highlight the key barriers encountered in the integration of heat across the projects. Out of the 15 projects surveyed in 2025, 10 projects (67%) reported encountering obstacles in their heat integration efforts. This indicates a slight reduction compared to 2024 (Figure 6 a), when 6 out of 14 projects (43%) identified barriers in this area.

Data Interoperability remains the most frequently cited barrier in 2025, reported by 60% of the projects. Despite a reduction from 83% in 2024, the issue persists as a critical obstacle. Respondents noted the complexity of integrating heterogeneous platforms and the lack of standardised communication protocols across systems and energy carriers. The financial burden associated with additional hardware to manage decentralised assets was also emphasised. Although there are indications of progress, interoperability challenges remain widespread and unresolved in many implementations.

Network Regulations were identified by 40% of the projects, a notable increase from just 17% in 2024. Feedback pointed to fragmented and inconsistent national regulatory frameworks, unclear guidance for integrating thermal systems, and a lack of defined responsibilities across electricity, gas, and heating sectors. These regulatory silos limit the scalability and replicability of cross-sectoral solutions, particularly in projects dealing with flexibility or distributed energy resources.

Market Mechanisms were also highlighted by 40% of respondents in 2025, compared to 50% in 2024. Key concerns include the absence of appropriate remuneration schemes, misaligned incentives between sectors, and limited access for aggregators and small actors. Several projects noted that flexibility services linked to thermal energy are not adequately supported under current market rules, hindering financial viability and replication potential.

Coordination Between Stakeholders was reported by 40% of the projects, down from 67% in 2024. Despite this decrease, the barrier remains significant. Projects expressed difficulty in aligning actors such as DSOs, TSOs, local governments, and technology providers—particularly in cases requiring integrated planning, co-investment, or shared governance models. The lack of institutional mechanisms to support multi-actor coordination continues to limit effective project deployment.

Data Access and Privacy was another recurring issue, mentioned by 40% of projects, slightly down from 50% in the previous year. Persistent concerns include citizen mistrust, legal uncertainty around data ownership, and insufficient frameworks to support secure and efficient data exchange across stakeholders. Although some progress was noted, data governance remains a relevant challenge, particularly for user-centric approaches.

Permitting Processes emerged as a barrier in 2025, identified by 20% of the surveyed projects. This issue had not been reported in 2024, suggesting a new layer of complexity as projects move from design to implementation. Respondents highlighted delays due to fragmented administrative procedures, overlapping jurisdictional requirements, and the lack of clear permitting pathways for integrated thermal energy systems.

In comparison with the 2024 results, several trends can be observed. Data Interoperability, while still the most cited barrier, has slightly decreased in prominence, possibly reflecting the impact of recent standardisation efforts. Network Regulations, conversely, have become significantly more relevant, revealing increased awareness of misalignments across policy domains. Market Mechanisms and Data Access and Privacy have remained relatively stable, indicating persistent structural limitations. Coordination Between Stakeholders, though less frequently mentioned than in 2024, continues to be a systemic issue. Lastly, the appearance of Permitting Processes as a new barrier in 2025 suggests that as projects progress towards implementation, new operational and administrative challenges are being revealed.

Overall, the findings indicate a gradual shift in the nature of barriers, from purely technical concerns towards systemic and institutional limitations. Advancing heat sector integration will require not only continued work on interoperability and data governance, but also a stronger focus on regulatory alignment, market reform, and coordinated permitting frameworks.

The 2025 detailed survey responses provide valuable context for the trends observed:

- **Thumbs Up**: Initially, no specific barriers were identified. However, the potential for selling energy from disaggregated buildings to the district heating network (DHN) is undergoing study (Task 5.4), and regulatory implications are still being assessed.
- **ECHO:** Explores integrating domestic heating and cooling systems with distributed micro-storage and DSO-operated local electricity networks. The project addresses challenges in regulation, data interoperability, and stakeholder coordination, testing new market schemes designed to incentivise the adoption of thermal energy storage (TES) at the residential level.
- **CEEGS:** Focuses primarily on technical and economy-related challenges tied to novel electrothermal technologies, alongside legislative barriers in various EU Member States. These factors complicate broader deployment and market acceptance.

- **PUSH-IT:** There are no special regulations for heat storage in the German state of Hesse. However, integrating heat storage into an existing district heating network is challenging without strong cooperation from the network operator. Additionally, PUSH-IT highlights that large-scale projects involving multiple stakeholders with divergent interests suffer from an unclear allocation of risks, costs, and benefits. Slow decision-making and extensive permitting requirements further delay project progress.
- **ENFLATE:** Identifies data interoperability as a key challenge: no standardised communication interface exists for controlling decentralised flexibility assets, necessitating additional hardware and driving up costs. Previous findings also noted market mechanism constraints in Switzerland, which hinder revenue stacking (DSO, BRP, TSO) and affect financial viability at the household level.
- **SCARLET:** Investigates the use of MgB2 cables cooled with liquid hydrogen, integrating energy transmission and thermal management. A principal barrier is the lack of infrastructure that simultaneously supports energy transport and effective thermal management, particularly in remote or offshore environments.
- **OMEGA-X**: Reported difficulties in navigating diverse regulatory frameworks, securing permits for energy communities, and ensuring data-sharing compliance. DSOs were also reported as reluctant to provide access to operational data.
- **SENERGY NETS**: Cited coordination failures among DSOs, TSOs, and market actors. Key market barriers included lack of remuneration for capacity, timing mismatches in procurement across sectors, and a lack of coherence in incentive structures. Also raised was the importance of interoperability across platforms managing multiple energy vectors.

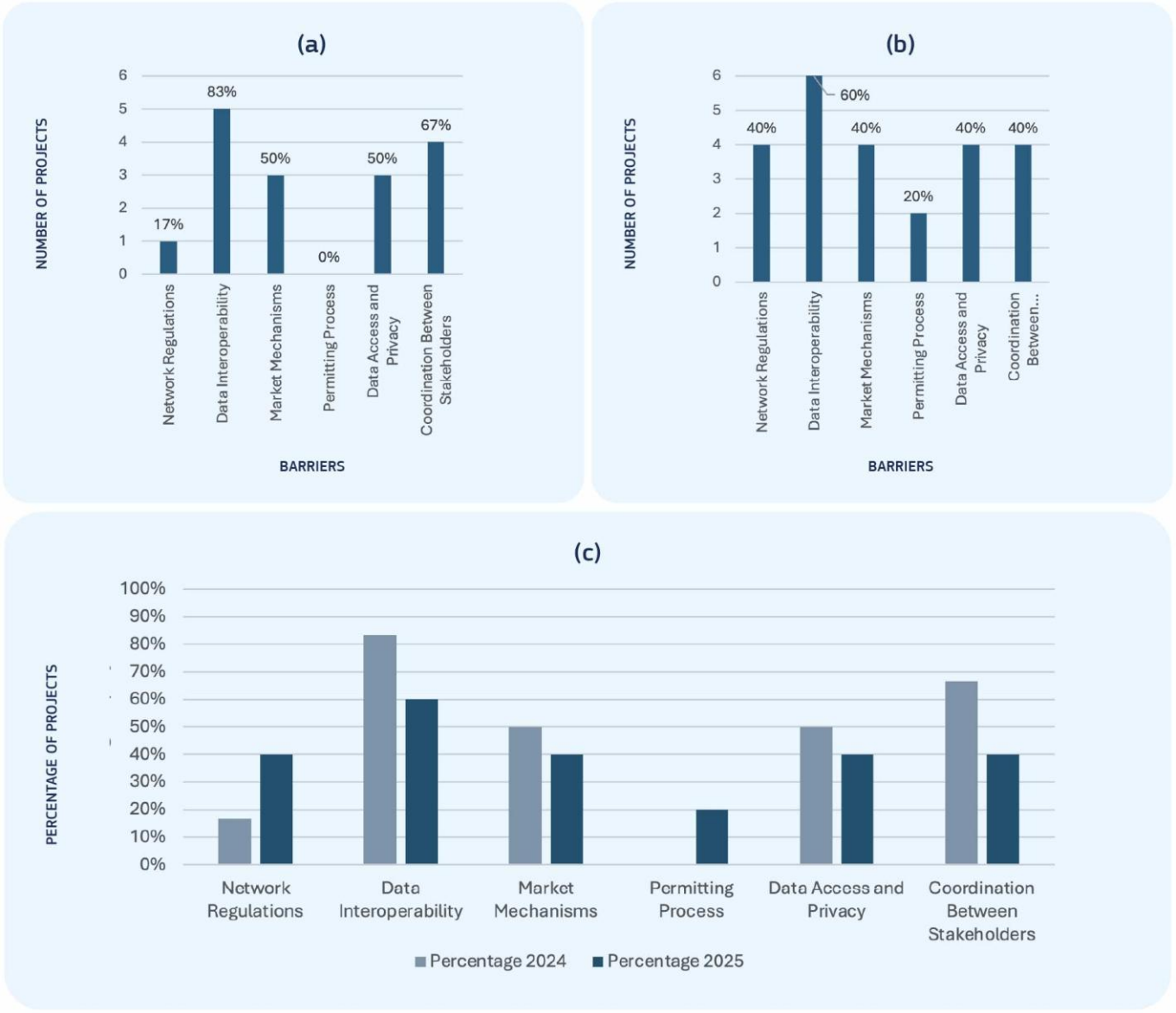


Figure 6. Overview of the barriers related to heat integration in the reviewed projects. (a) Data reported for the 2023-2024 period, (b) data extracted from the survey conducted for the current 2024-2025 report. (c) The percentages represent the share of projects that identified barriers in the evaluated cross-sectoral analysis, based on the 2024 report (orange) and the 2025 report (blue).

4.2.3 Sector integration at the household level

The 2025 survey results highlight the key barriers to sector integration at the household level across the respondent projects. Out of the 15 projects in 2025, 11 (73%) reported barriers related to household-level integration, reflecting a significant increase in reporting compared to 2024, when only 6 out of 11 projects (55%) identified such challenges. The findings confirm the increasing complexity of integrating decentralised energy services at the household level in the context of evolving regulatory, market, and technical frameworks.

The most frequently reported challenge in 2025 is **Data Interoperability**, reported by 64% of the projects, though slightly lower than the 83% reported in 2024. Projects emphasised ongoing issues with integrating various household devices such as heat pumps, smart meters, and energy storage systems. Respondents pointed to the lack of standardised protocols and the difficulties in achieving seamless data exchange across platforms and energy

carriers. This barrier continues to slow down implementation, particularly in multi-vendor or multi-vector environments.

Market Mechanisms were identified as a barrier by 45% of projects in 2025, slightly below the 50% reported in 2024, reflecting ongoing regulatory gaps that hinder prosumer participation in **observed** flexibility markets. These gaps prevent effective value stacking across different stakeholders, such as DSOs, BRPs, and TSOs. In Switzerland, for instance, regulations complicate energy-sharing schemes between commercial and residential users, limiting opportunities for innovation.

Data Access and Privacy reported by 45% of the projects in 2025, down from 67% in 2024. Remaining relevant, especially in the context of GDPR compliance, fragmented legal interpretations across Member States, and citizen mistrust in data sharing. Several projects, reported difficulties in accessing, managing, and securely exchanging user data while ensuring end-user confidence and consent.

Coordination Between Stakeholders highlighted by 45% of the projects, a sharp increase from 17% in 2024. Projects noted substantial challenges in aligning stakeholders such as DSOs, technology providers, aggregators, and local authorities. Integration at the household level requires coordinated planning, clear communication responsibilities, and consistent decision-making processes, which are often missing.

Network Regulations were reported by 27% of the projects, particularly in regions where grid rules have not adapted to the dynamic nature of household energy services. Restrictions on energy-sharing between geographically dispersed communities remain a key challenge, limiting participation in local flexibility markets.

Permitting Processes were also noted as a barrier by 18% of the projects similar to 2024. Respondents pointed out that permitting procedures remain slow and inconsistent across jurisdictions, creating bottlenecks for the deployment of new household-level energy solutions.

Compared to 2024, the 2025 results show several evolving trends. **Data Interoperability** remains the most cited barrier, although it decreased slightly from 83% to 64%, indicating modest progress in standardisation efforts. **Data Access and Privacy** concerns also declined, from 67% to 45%, which may reflect a broader adoption of privacy-compliant practices and improved data governance frameworks. In contrast, **Market Mechanisms** remained stable, confirming the structural and ongoing nature of this barrier in household-level integration. A notable shift was observed in **Coordination Between Stakeholders**, which increased significantly from 17% in 2024 to 45% in 2025, highlighting a growing recognition of the complexities involved in aligning actors across the energy value chain. Meanwhile, both **Network Regulations** and **Permitting Processes** showed little variation between years, underscoring the persistence of legal and administrative challenges that continue to hinder implementation.

The 2025 detailed survey responses provide valuable context for the trends observed:

- **Thumbs Up:** No major barriers identified. However, the developed thermal energy storage devices must comply with existing regulations and legislation governing domestic hot water systems, health and safety standards, and residential building requirements, each of which may vary depending on local contexts.
- **FEDECOM**
  - **Belgium:** Unable to establish an energy-sharing scheme between a commercial actor (the Brico retail store) and residential customers.
  - **Netherlands:** Data interoperability challenges in managing residential distributed energy resources (DERs).
  - **Switzerland:** Energy communities are restricted by the concept of geographical contiguity, prohibiting use of the public distribution grid unless the community takes full responsibility for its operation and maintenance. FEDECOM resolved this by involving the local DSO as the pilot site manager.

- **ECHO:** Continues to address issues related to regulation, data interoperability, and stakeholder coordination. Challenges persist around data ownership and information exchange, which hamper broader sector integration.
- **CEEGS:** Faces regulatory barriers and market mechanism challenges tied to novel electrothermal technologies. Although the primary targets are not households, residential users may eventually adopt the technology if clearer policies and frameworks are established.
- **ENFLATE:** Reports market mechanism constraints in Switzerland: current regulations prevent effective revenue stacking of DSO, BRP, and TSO income streams, undermining the financial viability of household-level energy solutions.
- **DEDALUS:** Notes multiple challenges, including network regulations, data interoperability, permitting processes, and data access/privacy concerns. These collectively slow project deployment and increase administrative overheads.
- **STREAM:** Encounters data interoperability, permitting, stakeholder coordination, and data access barriers. A key hurdle is determining responsibility for activation signal communications and whether a centralised device registry should be established to facilitate aggregator-level flexibility transfers.
- **ODEON:** Highlights privacy, legal, and ethical issues in data usage and sharing, noting that demand-side flexibility aggregators currently lack a clear regulatory framework to enter the market. Ongoing EU-level efforts aim to address these policy and regulatory obstacles.
- **OMEGA-X**: Reported issues with Data Interoperability, Coordination Between Stakeholders, and Data Privacy. Emphasised challenges in enabling seamless data exchange and ensuring stakeholder alignment in demand-side aggregation.
- **SENERGY NETS**: Identified Network Regulations, Stakeholder Coordination, and Data Privacy as key barriers. Highlighted customer reluctance to participate in heat demand response and the difficulty of achieving sufficient engagement for meaningful implementation.

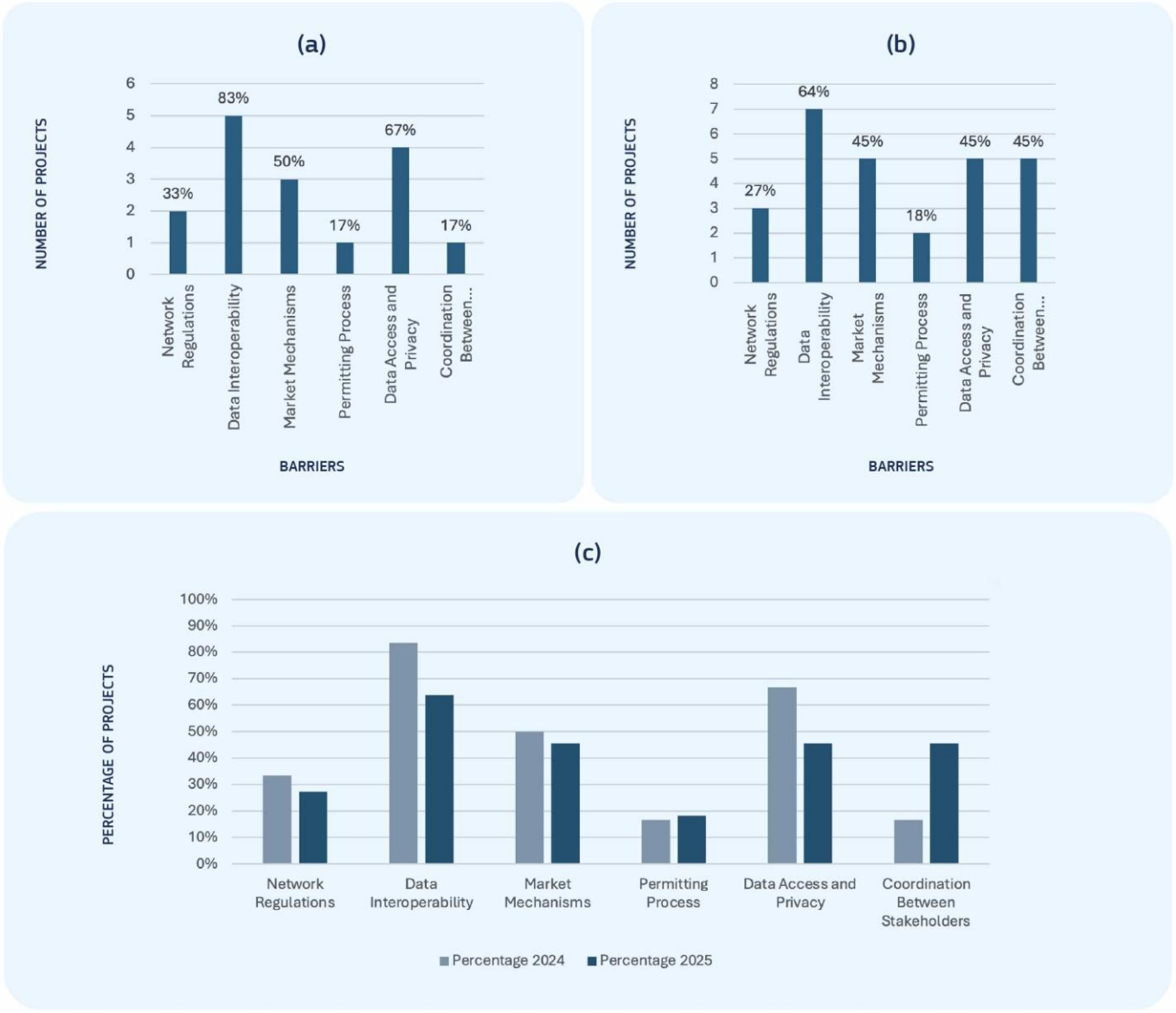


Figure 7. Overview of the barriers related to sector integration at the household level in the reviewed projects. (a) Data reported for the 2023-2024 period, (b) data extracted from the survey conducted for the current 2024-2025 report. (c) The percentages represent the share of projects that identified barriers in the evaluated cross-sectoral analysis, based on the 2024 report (orange) and the 2025 report (blue).

4.2.4 Other sector integration / sector coupling barriers

This section addresses barriers encountered in sector integration initiatives not covered under the e-mobility, heat integration, or household-level integration categories. These include cross-vector projects involving hydrogen, electrothermal storage, CO2-based systems, and other emerging solutions that require coordinated operation between electricity, gas, and thermal infrastructure. These projects often face unique regulatory, technical, and administrative challenges due to the novelty of the technologies and the lack of sector-specific frameworks.

The 2024 survey results (Figure 8 a) showed that **Data Access and Privacy** was the most reported barrier (50%), indicating widespread concern about the secure handling and sharing of information across sectors. Other significant challenges included **Network Regulations**, **Data Interoperability**, and **Market Mechanisms**, each reported by 25% of the projects. These results highlighted persistent difficulties in harmonising regulations, communication protocols, and economic incentives across Member States. Interestingly, **Permitting Processes** and

Coordination Between Stakeholders were not reported as barriers in 2024, suggesting limited implementation activity or early-stage project maturity.

In contrast, the 2025 survey revealed a shift in the type and prominence of barriers. **Network Regulations**, **Market Mechanisms**, and **Permitting Processes** each emerged as top barriers, identified by 67% of the participating projects. These findings reflect increased project maturity and deeper engagement with implementation, where administrative complexity and regulatory inconsistencies become more pronounced. The growing relevance of **Permitting Processes** points to procedural inefficiencies and jurisdictional fragmentation that hinder cross-sector deployment.

Strikingly, **Data Interoperability** and **Data Access and Privacy**—key concerns in 2024—were not reported as barriers in 2025. This could indicate project focus has shifted away from data-intensive components or that improvements in data governance and standards have started to take effect. Similarly, **Coordination Between Stakeholders** remained absent as a reported barrier, likely due to the specific nature of the technologies and stakeholders involved.

Project Insights:

- **FEDECOM**: Identified significant challenges related to hydrogen regulation. Legal and operational constraints were reported, particularly concerning the integration of hydrogen systems within energy communities. Financial risk and lack of technical guidance further hindered project execution.
- **CEEGS**: Emphasised barriers in permitting and regulatory adaptation for technologies beyond TRL 7. Public acceptance and complex approval processes slow down innovation deployment.
- **SCARLET**: Highlighted infrastructural and regulatory limitations in integrating hydrogen with electricity networks. The project called for clearer standards and a more harmonised regulatory landscape.

These findings confirm a growing trend: as projects mature and move from design to deployment, legal and procedural frameworks become the main bottlenecks. The emergence of **Permitting Processes** as a major barrier underscores the need for simplified and harmonised administrative pathways. At the same time, the prominence of **Market Mechanisms** and **Network Regulations** reflects the structural challenges of aligning economic signals and grid operation principles across sectors.

Overall, other sector coupling initiatives face increasingly complex institutional barriers, particularly when dealing with emerging technologies or multi-carrier integration. Policy support is required to streamline permitting, establish flexible regulatory frameworks, and ensure consistent market access for integrated energy systems.

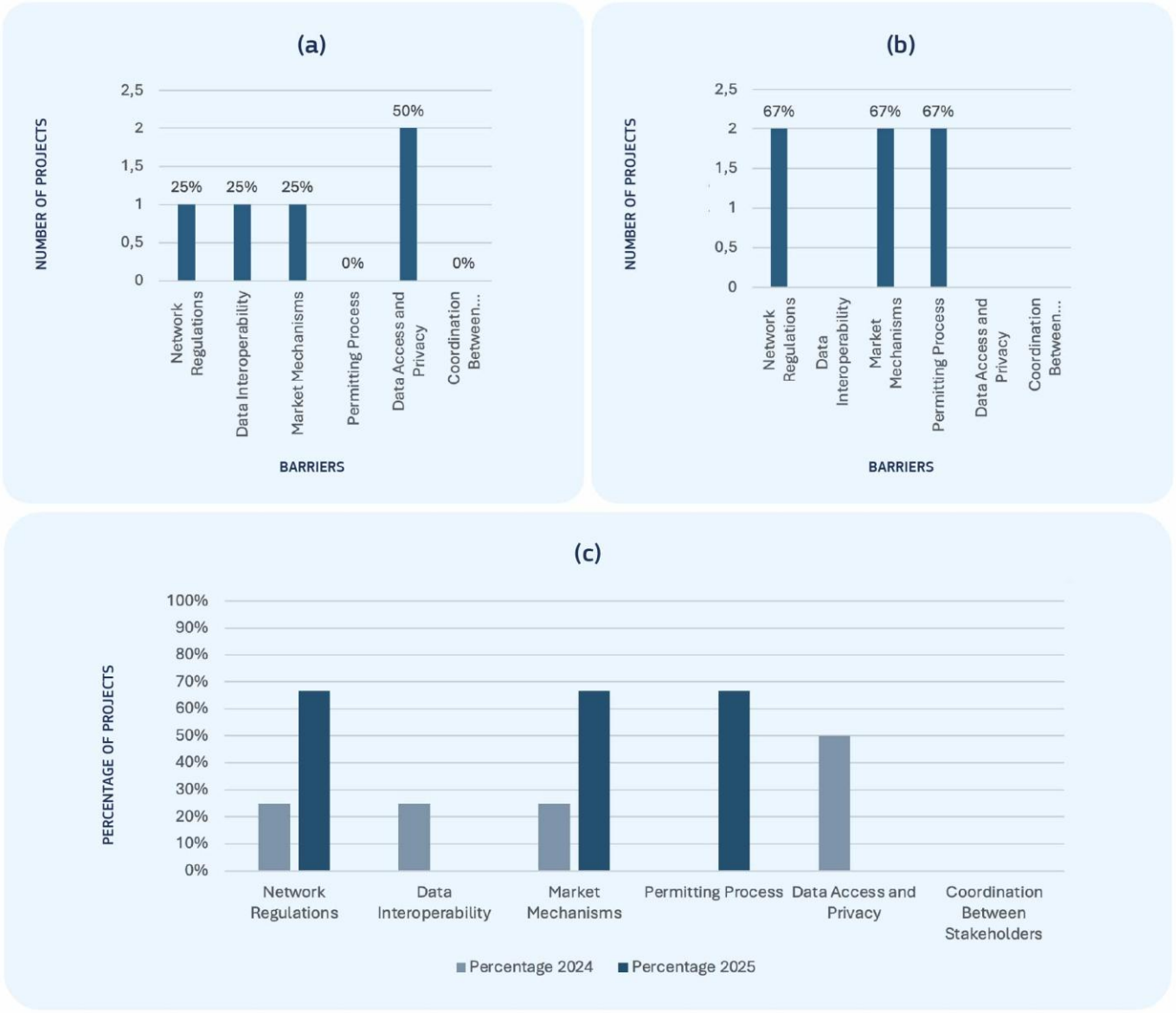


Figure 8. Overview of the barriers related to other barriers in the reviewed projects. (a) Data reported for the 2023-2024 period, (b) data extracted from the survey conducted for the current 2024-2025 report. (c) The percentages represent the share of projects that identified barriers in the evaluated cross-sectoral analysis, based on the 2024 report and the 2025 report.

4.2.5 Summary of Identified Barriers form the survey (2023–2025)

The comparative analysis of the Action 4 surveys from 2023–2024 and 2024–2025 reveals a shift in the nature of barriers to sector coupling. While technical issues like **data interoperability** and **data privacy** show moderate improvement, persistent **regulatory**, **market**, and **administrative** barriers are becoming more prominent as projects advance towards implementation.

In **e-mobility**, only 35% of projects reported barriers in 2025, down from 57% in 2024. **Coordination Between Stakeholders** remains the most cited challenge (60%), highlighting difficulties in aligning roles among DSOs, service providers, and aggregators. **Network Regulations** (40%) and **Market Mechanisms** (20%) still hinder V2G deployment. Data-related concerns decreased significantly (both falling from 100% to 20%), likely reflecting advances in standardisation and privacy compliance (Figure 5 c).

In **heat integration**, barriers were reported by 67% of projects in 2025, up from 43% in 2024. **Data Interoperability** (60%) continues to be the most reported issue, though down from 83% the previous year. **Network Regulations**, **Market Mechanisms**, and **Stakeholder Coordination** each affected 40% of projects, reflecting growing regulatory complexity in cross-sector applications. **Permitting Processes**, not cited in 2024, emerged in 2025 (20%), indicating new administrative challenges as projects move from planning to execution (Figure 6 c).

For **household-level integration**, 73% of projects reported barriers in 2025, compared to 55% in 2024. The most frequent issues include **Data Interoperability** (64%), **Data Access and Privacy**, **Market Mechanisms**, and **Stakeholder Coordination** (all 45%). These reflect ongoing concerns over device integration, data governance, and local coordination. **Network Regulations** (27%) and **Permitting Processes** (18%) remain stable year-on-year, pointing to slow progress in adapting local frameworks (Figure 7 c).

In **other sector coupling**—involving hydrogen, CO_2-based storage, and cross-vector systems—barriers shifted notably. In 2025, **Network Regulations**, **Market Mechanisms**, and **Permitting Processes** were each cited by 67% of projects, compared to just 25% or less in 2024. Previously dominant data-related barriers disappeared entirely. This reflects both improved data practices and deeper engagement with legal and operational barriers as projects reach deployment stages (Figure 8 *c*).

As summarised in Table 3, the dominant trend across all categories is a transition from technical to structural and institutional limitations. While data issues remain relevant, they are increasingly overshadowed by fragmented regulations, insufficient market incentives, and inconsistent permitting.

Addressing these barriers requires harmonised frameworks, streamlined procedures, and improved cross-sector coordination.

Table 3 - General results from the survey 2024 and 2025.

2024				
	service provision by EVs	sector integration with heat	Integration at the house level	other sectors integration
Network Regulations	50%	17%	33%	25%
Data Interoperability	100%	83%	83%	25%
Market Mechanisms	63%	50%	50%	25%
Permitting Process	38%	0%	17%	0%
Data Access and Privacy	100%	50%	67%	50%
Coordination Between Stakeholders	63%	67%	17%	0%
2025				
	service provision by EVs	sector integration with heat	Integration at the house level	other sectors integration
Network Regulations	40%	40%	27%	67%
Data Interoperability	20%	60%	64%	0%
Market Mechanisms	20%	40%	45%	67%
Permitting Process	0%	20%	18%	67%
Data Access and Privacy	20%	40%	45%	0%

Coordination Stakeholders	Between	60%	40%	45%	0%

4.2.6 Sector interaction analysis

The three matrices (Figure 9) provide a detailed view of how the interaction between the barriers on sector coupling and sector integration, as identified by the projects, has evolved between the 2023–2024 and 2024–2025 project cohorts across four key integration dimensions: Electric Vehicles (EVs), Heat, Household-level Integration, and Other Sector Coupling Barriers.

Percentage Interaction Matrices (2023–2024 and 2024–2025)

The analysis of the interaction matrices for the 2023–2024 (Figure 9 (a)) and 2024–2025 (Figure 9 (b)) project cohorts provides valuable insights into the evolution of sector coupling across four key dimensions: Electric Vehicles (EVs), Heat, Household-level Integration, and Other Sector Coupling Barriers. The percentage interaction matrices show the level of co-occurrence between sectors, calculated as the ratio of projects addressing both sectors simultaneously compared to the total number of projects that address at least one of them. In both years, the strongest interaction is observed between Heat and Household, confirming their relevance in integrated energy systems. In 2024–2025, EVs show a higher level of integration with both Household and Heat compared to the previous year, indicating a growing interest in linking mobility services with domestic and thermal energy systems. Meanwhile, the dimension "Other Sector Barriers" continues to show limited cross-sector engagement, suggesting that, although recognised, these barriers are not yet being consistently addressed alongside the core sectors.

Comparison Matrix (2024–2025 vs 2023–2024)

The comparison matrix (Figure 9 (c)), which reflects the change in integration levels between the two periods, reveals several key trends. Notably, the interaction between EVs and Household increased by over 15%, highlighting a shift towards more integrated approaches at the domestic level. The integration between EVs and Heat also experienced a significant rise, possibly due to the advancement of vehicle-to-grid and vehicle-to-heat technologies. On the other hand, the barriers to the integration between Household and Other sector slightly declined, which may indicate a shift in the projects' focus from addressing abstract or systemic barriers to implementing tangible, cross-sectoral solutions.

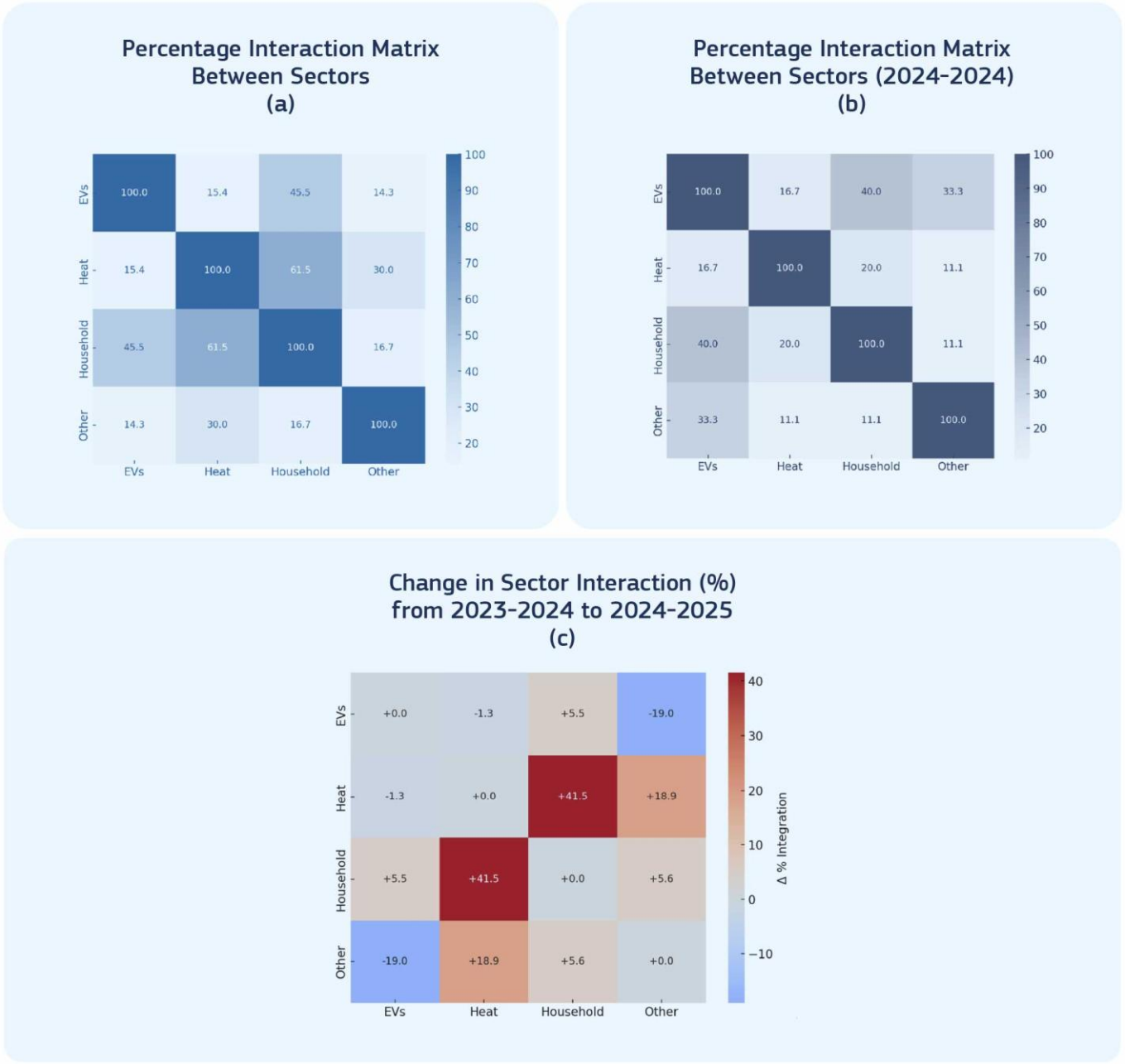


Figure 9. Sectorial integration analysis across projects (2023–2025); (a) Interaction matrix for 2024-2025 projects, showing the percentage of co-occurrence between sectoral integration indicators; (b) Interaction matrix for 2023–2024 projects, using the same methodology to ensure comparability; (c) Comparative matrix illustrating the change in integration percentages between the two periods. Positive values indicate increased interaction; negative values suggest reduced integration or decoupling trends.

In summary, this analysis reflects an overall maturation in the integration between sectors, especially around EVs, suggesting that the projects funded in 2024–2025 are more holistic in scope. While "Other" barriers are still underrepresented in combined approaches, the increased coupling between operational sectors hints at a shift towards systems-level implementation. These insights can inform strategic focus areas for upcoming funding calls and policy design.

5 BEST PRACTICES TO OVERCOME BARRIERS

In February 2025, the projects participating in Action 4 participated in a knowledge-sharing session to discuss the best practices and provide recommendations to overcome barriers to sector coupling. In the following lines, we provide an overview of the best practices to overcome the barriers identified on the integration of 3 main sectors:

5.1 Best practices to overcome barriers to the integration of the transport and electricity sectors.

To enable a seamless integration of smart charging, vehicle-to-grid (V2G), and broader e-mobility solutions, a combination of regulatory adaptations, technological developments, and stakeholder engagement is required. The following recommendations address the key barriers identified:

1. **Design of demand response programs able to include EVs:** implicit demand response (i.e. price signals), explicit Demand Response (ancillary services, see also #2), in order to encourage EV users to participate in flexibility provision.
2. **Inclusion of EVs in virtual power plant portfolios:** Enable aggregators to include EV batteries in VPPs, allowing them to provide flexibility services such as frequency regulation and peak shaving, and develop standardised grid interaction protocols to facilitate the participation of EV fleets in flexibility markets.
3. **Development of user-centric Interfaces for smart charging and V2G:** Co-design charging apps and dashboards with end users to improve attractiveness, accessibility and encourage participation.
4. **Establishment of an open V2X platform for charging point operators:** Develop an open-source V2X data-sharing platform to enhance interoperability and efficiency of smart charging. This framework should include the appropriate measures to protect consumers' data and with their consent. This is essential to ensure real-time coordination between charging point operators (CPOs), DSOs, and aggregators to optimise grid management.
5. **Decision-making tools to support municipalities:** Provide guidelines for municipalities on integrating EVs into their grid in a way that considers the needs and capacity constraints of the local network to ensure quicker connections and prevent congestion arising from the integration of EVs.
6. **Cost-effective charging solutions for condominiums and shared spaces:** Establishing community-based EV charging schemes is important to allow cost-sharing among apartment residents.
7. **Strengthening interaction with DSOs to address grid constraints in an interoperable way:** Establish standardised and appropriate data exchange frameworks between DSOs, CPOs, and EV aggregators to optimise grid operation and maintenance with a clear definition of which data is needed, from whom and for what, in order to prevent the production of unnecessary amounts of data.

5.2 Best practices to overcome barriers to the integration of the heating and electricity sectors.

Effective integration of the heating and electricity sectors is essential for achieving EU decarbonisation targets. Based on insights gathered from projects participating in Action 4, the following best practices have been proposed to address key barriers encountered:

1. **Standardisation of data and communication protocols** is crucial to facilitate seamless integration between heating systems, thermal storage units, and electrical grids. Adopting standardised communication protocols such as OpenADR and Modbus TCP/IP ensures compatibility among diverse

technology providers. Furthermore, joint initiatives involving DSOs, heating network operators, and technology providers should be encouraged to collaboratively define and implement interoperability standards. Utilising standardised ontologies, such as SAREF (Smart Appliances REFerence ontology) and BRICK schema, enhances semantic interoperability across systems, particularly at the building scale, and facilitates seamless data integration within a harmonised European context.

2. **The development of robust regulatory frameworks for heat storage integration at the building level** is vital. Clear, standardised procedures for connecting thermal storage systems to electricity and district heating networks across Europe should explicitly detail technical requirements, roles, responsibilities, and cost-sharing mechanisms among stakeholders. Additionally, implementing regulatory sandboxes to test innovative sector integration solutions, such as combined thermal-electric storage systems, allows policymakers to refine regulations based on practical experience, ensuring regulations are both effective and adaptable.
3. **Market mechanism reforms are necessary to support thermal flexibility.** This involves developing local and regional flexibility markets specifically tailored to thermal resources, recognising thermal energy storage as a key asset for (electricity) grid-balancing services. Some projects suggested the introduction of dynamic tariff schemes that reflect the real-time value of heat storage and flexible consumption can incentivise active participation by consumers and prosumers. Aggregators also play a crucial role, as they bundle and manage distributed thermal assets, enabling smaller-scale participants to effectively engage with flexibility markets.
4. **Enhanced stakeholder collaboration and coordination** are essential to overcome integration barriers. Structured multi-stakeholder platforms involving DSOs, district heating operators, technology providers, regulatory authorities, aggregators, and end-users can ensure transparent decision-making and alignment of objectives. Public-private partnerships can share risks, costs, and benefits, accelerating the deployment of integrated solutions and overcoming stakeholder divergences.
5. **Streamlined permitting processes are integral to successful integration**. Simplifying and standardising permitting procedures across jurisdictions for integrated heating-electricity technologies can reduce delays and uncertainties. Centralised digital permitting platforms should be implemented to streamline submission, review, and approval processes, increasing efficiency and transparency.
6. **Public and end-user engagement is essential to drive acceptance and adoption**. Targeted educational and awareness campaigns should highlight the benefits of integrated heating-electricity solutions, including cost savings, reduced carbon emissions, and enhanced energy security. Integrating user feedback into early design stages ensures that solutions align closely with consumer needs and preferences. Employing collaborative methodologies such as World Cafés, focus groups, and participatory workshops can gather diverse stakeholder insights, fostering active dialogue and collective problem-solving. Additionally, leveraging co-creation sessions, hackathons, and innovation hubs stimulates creative solutions and ensures robust community involvement throughout the transition process.

5.3 Best practices to overcome barriers to the integration of multi-energy systems and buildings to the grid.

The successful integration of multi-energy systems (MES) across Europe plays a vital role in decarbonising energy sectors. However, several barriers hinder the full potential of sector coupling, in particular at household level, where the building sector meets the electricity, heat and cooling sectors. To address the challenges, the following best practices are recommended:

1. **Enhancing market coordination and regulatory adaptation:** The coordination of electricity and gas day-ahead and intraday markets with flexibility markets requires new or adapted regulations to integrate

MESs and buildings effectively into the grid. Moreover, it is essential to adapt the regulation to incentivise demand-side flexibility. In this sense, it is recommended to introduce mechanisms that encourage MESs and buildings to offer flexibility services (e.g., dynamic pricing, capacity markets).

2. **Reforming multi-energy taxation**: The current taxation structure often discourages sector coupling and decentralised energy production. Policymakers should reconsider taxing energy flows at each step of the value chain to promote flexibility and energy sharing.
3. **Ensuring market liquidity for sector coupling:** Assessing market liquidity is essential to evaluate whether energy and flexibility markets have sufficient liquidity to support sector coupling. This includes analysing the volume of transactions, diversity of participants, and price stability in local energy markets. It is also recommended to support the growth of energy aggregators that can bundle smaller MESs and building-generated energy resources (e.g., rooftop solar, battery storage) to enhance liquidity and market participation as well as developing local flexibility markets. This is essential to strengthen regional and municipal energy trading platforms that allow MESs and buildings to interact with the grid more effectively.

Table 4- Cross-cutting best practices to address regulatory and social barriers affecting sector coupling across the EU. The table outlines parallel recommendations targeting institutional actors and end users, highlighting the importance of aligning regulatory frameworks with user-centric design, transparent data governance, and incentive-based engagement strategies

Overarching best practices to overcome barriers to regulatory and social challenges that hinder sector coupling across the EU:	
Regulatory barriers	**Social barriers**
Use regulatory sandboxes	Integrate the users' needs and feedback in the early stages of tools design
Develop frameworks and standards for seamless data integration and interoperability	Design simple and user-friendly interfaces for users
Engage NRAs and policy makers in the project activities	Be clear of what kind of data are collected and for what purpose in the users' onboarding process
	Incorporate the aspect of potential economic benefits as part of the user incentives

6 RECOMMENDATIONS TO FOSTER SECTOR INTEGRATION ACROSS THE EU

Achieving effective sector integration is fundamental to optimising Europe's energy transition and meeting climate neutrality objectives. Drawing upon empirical evidence from EU-funded pilot initiatives and the barriers identified in this report, the following recommendations outline strategic interventions to address regulatory, market, and technical challenges. These measures emphasise a coordinated approach across regulatory frameworks, market structures, and stakeholder engagement to unlock the full potential of sector coupling.

Strengthening **cross-market coordination** is essential to overcoming the fragmentation between electricity, gas, heating and cooling, mobility, and flexibility markets. National regulatory authorities must implement standardised frameworks to ensure interoperability between energy vectors, defining stakeholder roles, market participation

rules, and transactional platforms. Temporal misalignment between electricity, gas, and flexibility markets creates inefficiencies, and regulatory bodies should harmonise gate closure times, settlement periods, and clearing mechanisms to optimise cross-sector resource use. Additionally, the European Commission should expedite standardised mechanisms for cross-border flexibility trade to leverage regional variations in renewable generation and demand.

Establishing robust **regulatory frameworks** for flexibility remains a priority. The European Commission and national regulators should develop legal frameworks that support flexibility services across multiple energy carriers, particularly in district heating networks, renewable energy communities, and bidirectional vehicle-to-grid systems. Expanding regulatory sandboxes will allow real-world testing of innovative solutions, enabling stakeholders to refine business models and inform adaptive regulatory development. Technical specifications should be mandated for bidirectional electric vehicle chargers, thermal storage integration, and distributed flexibility resources to ensure compatibility and reliability.

Enhancing **data standardisation** and **interoperability** is crucial for seamless sector integration. Policymakers should enforce standardised communication protocols to reduce complexity and improve data exchange. Secure data governance structures must address privacy concerns while enabling analytics-driven optimisation. European funding should support the development of open-source platforms that facilitate secure and standardised data sharing, reducing reliance on proprietary solutions.

Streamlining **administrative and permitting procedures** is necessary to accelerate sector integration. Member States should simplify administrative processes across jurisdictions, and digitalised permitting workflows should be implemented to minimise project delays and transaction costs. A unified digital platform applying the “once-only principle” could enhance procedural efficiency, particularly for innovative cross-border projects. Capacity-building programmes for local authorities should equip them with the expertise to evaluate and facilitate sector integration initiatives.

Strengthening **multi-stakeholder engagement** is key to ensuring successful sector integration. Institutionalised forums should facilitate transparent collaboration among regulators, distribution system operators, district heating operators, technology providers, aggregators, and consumer advocacy groups. Projects should adopt user-centric design approaches that incorporate consumer perspectives from early conceptual stages to align solutions with actual user needs. Strategic communication emphasising economic, environmental, and energy security benefits will foster public acceptance and encourage adoption.

Reforming **fiscal and market mechanisms** is necessary to eliminate economic disincentives to sector integration. Policymakers must undertake multi-energy taxation reform to remove counterproductive tax structures that penalise energy conversions between carriers. Clear regulatory frameworks should support local flexibility markets and enable diverse energy resources, such as thermal storage, to participate in flexibility mechanisms. Policies should allow flexibility assets to monetise multiple services across different markets and timeframes, enhancing the financial viability of sector integration.

6.1 Sector-Specific Interventions

6.1.1 E-Mobility ntegration

To enable effective sector integration, the regulatory framework for electric mobility must evolve to support vehicle-grid integration and unlock the flexibility potential of electric vehicles within the broader energy system. Policymakers should mandate demand-side response programs, introducing dynamic tariff structures, time-of-use pricing, and real-time market participation mechanisms to incentivize grid-supportive charging behaviour. Harmonised grid connection codes and interoperability standards must be enforced to facilitate seamless vehicle-

to-grid and vehicle-to-building interactions, allowing electric vehicle fleets to operate as dispatchable flexibility assets.

Market-based mechanisms should integrate electric vehicles into wholesale electricity markets, including participation in capacity mechanisms and demand-side flexibility auctions. Cross-border harmonisation of electric vehicle regulation within the European Union Internal Electricity Market is crucial to ensuring interoperability of charging networks. The European Commission should accelerate the development of standardised contractual frameworks for peer-to-peer energy trading, allowing decentralised electric vehicle energy exchanges to be securely executed within blockchain-based market infrastructure.

6.1.2 Heat Integration

Thermal storage must be explicitly recognised as a strategic flexibility asset within regulatory and market frameworks. Policymakers should mandate the integration of thermal systems into demand-side response programs, capacity markets, and ancillary services, ensuring it contributes to grid stability and renewable energy integration. The transition from high-temperature district heating to low-temperature, decentralised systems should be accelerated, leveraging excess heat from industrial processes, data centres, and renewable sources.

Regulatory frameworks must facilitate the interoperability of heating networks with electricity grids by establishing standardised technical guidelines for integrating electrical and thermal systems within buildings. Harmonised rules should enable hybrid heating solutions that combine heat pumps, thermal storage, and cogeneration systems. Financial incentives and tariff structures should be adjusted to reflect the value of flexible thermal resources, ensuring that district heating operators and consumers benefit from optimised energy consumption and cost savings.

Municipal authorities should be empowered to oversee local heating strategies, using geospatial mapping, predictive analytics, and energy planning tools to optimise the deployment of thermal system solutions. Streamlined permitting and investment support mechanisms will be crucial to accelerating the deployment of sector-coupled heating systems.

6.1.3 Household-level Integration

Households must play a central role in sector integration through enhanced regulatory support for prosumer participation in energy markets. Interoperability standards should ensure seamless communication between household energy assets and market signals, enabling real-time optimisation of self-consumption and flexibility services. Smart meter rollouts should be mandated alongside dynamic pricing schemes, allowing consumers to respond to dynamic price signals and reduce peak demand stress on the grid.

Policymakers should strengthen the regulatory framework for energy communities, allowing households to aggregate small-scale flexibility resources for participation in broader energy markets. This should include enabling peer-to-peer trading, community self-consumption schemes, and collective demand-side response initiatives. Consumer protection frameworks must be reinforced to ensure fair compensation for flexibility services while safeguarding against potential exploitation from market asymmetries.

The development of integrated home energy management systems should be supported through incentives for smart home technologies, including bidirectional electric vehicle chargers, hybrid heating systems, and residential battery storage. These solutions should be interoperable across multiple energy carriers, allowing households to optimise energy use and contribute to grid balancing. Digital platforms should facilitate transparent market participation, ensuring consumers have access to reliable data, automated control mechanisms, and real-time energy market insights.

6.1.4 Final Remarks

Implementing these integrated policy recommendations will significantly enhance sector coupling across the European Union, optimising energy resource use and fostering a resilient, decarbonised, and economically efficient energy ecosystem. These findings are grounded in practical insights from real-world sector integration initiatives, offering actionable pathways to accelerate the European Green Deal objectives.

Achieving deep sector integration requires a paradigm shift in how energy systems are designed, regulated, and managed. The proposed measures are not isolated interventions but part of a comprehensive, systemic approach that addresses the interdependencies between electricity, gas, heat, mobility, and flexibility markets. By harmonising regulatory frameworks, fostering cross-market coordination, and eliminating economic barriers, policymakers can create an enabling environment where integrated energy solutions flourish.

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The Service Contract (n. CINEA/2023/OP/0001/SI2.901723) supports ETIP SNET activities, funded by the EU.