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ENTEC

Energy Transition Expertise Centre

Common European Energy Data Space

Full Report – Common European Energy Data Space

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Executive Summary

The energy transition towards renewables requires additional flexibility options in the electricity system, to coordinate resource-dependent generation and demand. The management and control of this flexibility needs an advanced digital ecosystem for the communication between organisations and devices. The Common European Energy Data Space will facilitate the participation by flexible energy resources as set forth by the EU action plan on digitalising the energy system.

This report, researched and written by the Energy Transition Expertise Centre (EnTEC) under the auspices of the European Union, develops a plan for the realisation of this Common European Energy Data Space. It provides an inventory of flexibility related actors and services on the European energy market or at high technological readiness levels in European research projects who may be future users and contributors to the data space. Flexibility provision has been analysed in three high level use cases: (i) virtual power plants and aggregation; (ii) price responsive charging and discharging and balancing services from electric vehicles and (iii) smart residential flexibilities.

To attract energy companies as participants to the data space, current challenges and pain points need to be addressed, together with the provision of clear benefits. Within this study pain points per high level use case have been identified in a stakeholder workshop and desk research.

Access to metering data as well as the corresponding control functionality of the flexibility assets was a key pain point mentioned across all use cases. Similarly, standardisation of data and communication processes were mentioned for all use cases. Access to device data from OEMs (original equipment manufacturers) was another challenge that was identified as relevant to the e-mobility and home energy management use case. For flexibility aggregation in VPPs (virtual power plants), a standardised and scalable process for onboarding assets is an enabler for the expected growth and a facilitator of market processes such as switching aggregators.

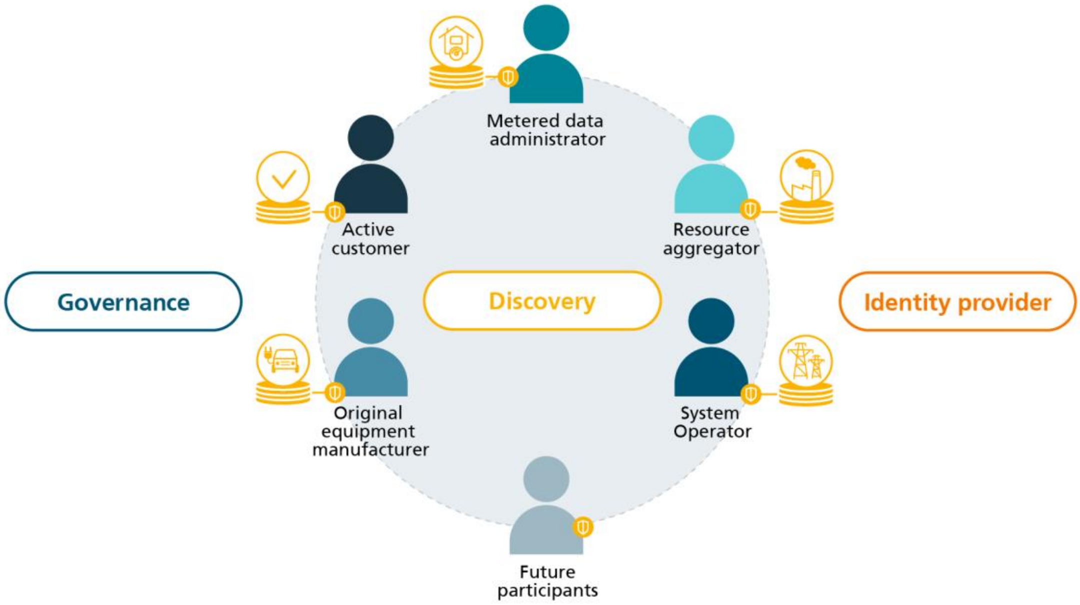
Data space technology offers technical solutions to the challenges regarding the technical access to metering, device, or other data, standardisation and data access control and discoverability. Data space connectors in combination with an identity provider as mature software components provide solutions for access control and secure data exchange. Metadata brokers facilitate discoverability of data assets and provide options to link assets to semantic models which supports the application of standards.

The Common European Energy Data Space can thus be developed starting from available software components. Figure 1 visualises the initial setup to proceed in a five-step action plan:

1) Define initial user stories and understand the business cases of key participants
2) Define and establish the Data Space framework and governance
3) Make data assets discoverable
4) Develop and provide processes to solve pain points in selected use cases
5) Extend data space features in an iterative process

Stakeholders in the initial ecosystem, with the mission to provide flexibility to the system, are transmission and distribution system operators, metered data administrators, original equipment manufacturers and resource aggregators. The active consumer as an operator of assets is also a data space participant, mainly in the role as a data owner who is controlling the use of data by consent to third parties.

Figure 1: Initial setup of the Common European Energy Data Space



Access to smart metering data assets available from the diverse set of European AMI (advanced metering infrastructure) concepts will be a valuable unique feature of the Common European Energy Data Space. It will provide a one-stop-shop to access metering data in a common format regardless of central or decentral metering structures in the different European energy markets.

Secondly, the data space will serve as a tool for OEMs to provide energy-related device data from their cloud back-ends, to enable digital services and respond to extended data usage rights of their customers as provisioned by the proposed Data Act and Renewable Energy Directive III. Reference implementations of key processes compliment the development of the data infrastructure in the data space. In addition to the access to metering data, a standard process for asset registration for flexible energy assets to VPPs will facilitate access to the market for smaller private asset operators.

The building of a Common European Energy Data Space is an ambitious endeavour, and its success relies on collaboration and cooperation of a large number of organisations. The regulated nature of the energy sector adds the regulatory environment on national levels as additional complexity. Given this and the dynamic nature of IT-development, the understanding of the Common Energy Data Space is based on a federated architecture where several instances of Energy Data Spaces will be operated. These data spaces should be linked by interoperability mechanisms that allow for data exchange including cross-sectoral purposes (e.g. with mobility, water, smart cities domains).

Governance principles and regulated structures will be key in the early stages of the data space creation, fostering the participants' trust in the ecosystem. Thus, transparent structures and clear communications have significant importance. On the technical side, future interoperability requirements will affect the choice of technologies. Further progresses and specific advancements on these requirements will help to avoid delays in architectural and investment decisions as well as the avoidance of vendor-lock-in situations

Altogether, the study outlines a path to the Common European Energy Data Space that will digitally enable additional flexibility, establish a data infrastructure for further services and become an indispensable part of the future energy system.

Table of Content

List of acronyms and abbreviations

Acronym	Full description
2G	Second Generation
aFRR	Automatic Frequency Restoration Reserve
ANRE	Romanian Energy Regulatory Authority
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
AS 4	Applicability Statement 4
B2B	Business to Business
B2C	Business to Customer
BDEW	Bundesverband der Energie und Wasserwirtschaft
BEMS	Building Energy Management System
BRP	Balance Responsible Party
BSI	Federal Office for Information Security (Germany)
BSP	Balancing Service Provider
BVDA	Big Data Value Association
CIS	Customer Information System
CPO	Charge Point Operator
DAM	Day-Ahead Market
DER	Distributed Energy Resource
DMS	Distribution Management System
DSO	Distribution System Operator
EDA	Energy Data Exchange (Austria)
EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
EIC	Energy Identification Codes
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCR	Frequency Containment Reserve
FRP	Flexibility Requesting Party
FSP	Flexibility Service Providers
G2V	Grid to Vehicle
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GW	Gigawatt
HAN	Home Area Network

Acronym	Full description
HEMS	Home Energy Management System
HEMRM	Harmonised Electricity Market Role Model
HLUC	High Level Use Cases
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communications Technology
ID	Standardised Identifiers
IoT	Internet of Things
LAN	Local Area Network
MaKo	Market Communication (Germany)
MDA	Metered Data Administrator
MDMS	Meter Date Management System
mFRR	Manual Frequency Restoration Reserve
MS	Member State
MVP	Minimum Viable Product
NAN	Neighbourhood Area Network
OEM	Original Equipment Manufacturer
OMS	Outage Management System
P2P	Peer-to-Peer
PCC	Point of Common Coupling
PtH	Power to Heat
PV	Photovoltaics
REC	Renewable Energy Community
SCADA	Supervisory Control and Data Acquisition
SLA	Service Level Agreement
SM	Smart Meter
SM-PKI	Smart Metering Public Key Infrastructure
SRL	System Readiness Level
SSI	Sistema Informativo Integrato
ToU	Time of Use
TRL	Technology Readiness Level
TSO	Transmission System Operator
V2G	Vehicle to Grid
VPP	Virtual Power Plant
WAN	Wide Area Network

1 Introduction

1.1 The common market and the internal energy market

The European strategy for a common, single market embodies the idea that goods, services, labour, and capital should be able to move freely across any internal European border. Citizens of one EU country can travel across one border to do business as if they were in their own country—this means not just being able to buy or sell goods and services, but also to invest and work.

A single market for energy has been pursued by the European Commission since 1996 with the introduction of the directive concerning common rules for an internal market in electricity (96/92/EC) (European Union 1996), which has been revised several times in the following decades, most recently in 2019 (2019/944) (European Union 2019). These directives obliged Member States to alter national legislation across the electricity sector, including for infrastructure (power plants and high-, medium-, and low-voltage networks) as well as for how markets themselves operate, such as how billing would work and the unbundling of supply chains, separating generation, transmission, distribution, and retail of energy. It also sets out how Member States, regulatory authorities, and transmission system operators (TSOs) should co-operate in an interconnected internal market for electricity, focussed on achieving security of supply while integrating renewable energy sources within a free and competitive market. To meet energy and climate targets, this means a focus on both new energy storage facilities (Papouis et al. 2023) and facilitating small end-users' access to energy markets via independent aggregators (European Commission et al. 2022).

1.2 The twin transition

The European Union's twin transition aims to simultaneously transform the economy to be both climate neutral and digital. Each component is meant to feed and reinforce the other, with digital technologies enabling the delivery of more environmentally friendly goods and services. This can include elements such as smart grids, which allow renewable energy—with variable power outputs—to be more easily integrated into the existing energy grid. It should also, as put forward by the 2019 Electricity Market Directive (European Union 2019), allow individuals or small communities producing on a small scale to participate in the market. This approach to enable renewables both helps to reduce the electricity market's overall environmental footprint, and transforms how it operates, increasing the number of players providing electricity (and increasing complexity).

Digitalisation drives not only energy efficiency by enabling smart energy systems that reduce unnecessary usage and optimise energy consumption, but also enables better integration of new, renewable sources of energy from a multitude of sources. Renewable energy creates large fluctuations in energy generation, which only a decentralised, digitally connected system of generation and consumption can accommodate. At the same time, it helps to incentivise individuals and smaller communities to adopt renewable energy sources, increasing the total amount of resources that can be used to transform the energy system. The European strategy for data calls for the development of the common single market for data and for data spaces in key industrial sectors, including energy (European Commission 2020).

1.3 Flexibility and its importance in the energy system

A strong and quick increase of renewable generation is expected by 2030 to fulfil the RePowerEU energy targets (European Commission 2022) and reach a greenhouse gas emissions reduction by at least 55% as set as a target in the Fit for 55 package (European Commission 2021a). Renewable energies with wind and solar as the main contributors should provide more than 60% of electricity production by 2030, which would be an increase of 23% compared to 2020 (European Commission 2023d). As mentioned earlier, large fluctuations of renewable power generation and the increased number of small producers lead to strong impacts on power markets and the power grid. Thus fossil-free flexibility will play an increasingly important role in the future to improve the efficiency of power markets, increase the use of energy infrastructures and avoid grid congestions (European Commission et al. 2023). The increase of flexibility options will also support the security of supply and make the energy sector more resilient against external and unforeseen impacts.

At the same time, the threat of targeted disruption increases with a large number of controllable generators and applications. A secure framework and trusted actors are therefore a necessity for the integration of more flexibility in the energy system.

1.4 Key issue of data sharing: requirements and benefits

Frictionless cross-company data sharing is key for an efficient electricity system which will be characterised by a wider variety of types of energy, providers, and users than the former system. However, data sharing is currently being driven by national standards and interests developed with a less diverse or restricted energy grid at the national level in mind. Companies in the European Union have faced several issues in sharing data, including:

- **Data formats:** energy data is often collected, stored, and shared using different formats, protocols, and semantics, making it difficult to integrate and share across systems, creating challenges for companies who need to exchange data with other companies or regulators.
- **Data access:** energy data is often owned by different parties, including energy providers, grid operators, manufacturers of various equipment and products, and regulators. This can make it difficult for some companies to access the data they need to operate their businesses effectively.
- **Data privacy:** metering data and further data on flexibility provision is often tied to an individual person as electricity consumer. Thus, it is personal data and as such governed by the EU data protection regulations, such as the General Data Protection Regulation (GDPR). This adds additional requirements and complexity to system architectures necessary to implement the GDPR regulations and manage consent from individuals.
- **Cyber security:** sharing data across different systems and organisations can increase the risk of cyber security breaches.

To address these issues, the EU has launched several initiatives to promote the sharing of energy data, such as the EU Action Plan on digitalising the energy system (Commission 2022), which supports the energy-related objectives of the European Green Deal (European Commission 2019) and includes a key action area to create a common European data space for energy. This initiative aims to facilitate the sharing of energy data across different organisations and systems along the energy value chain by promoting interoperability, standardisations, and data protection.

In addition, the European Union's digitalisation of the energy system action plan aims at using digital technologies to modernise and decarbonise the energy sector (Commission 2022). The plan includes an additional four key areas, which complement the one dedicated to data sharing: empowering consumers, boosting investments in smart energy systems, increasing energy efficiency of ICT systems, and enhancing cyber security.

The plan aims to give consumers greater control over their energy use by promoting smart meters and consumer-friendly energy management systems. It seeks to deploy more renewable energy sources, promote system flexibility (including demand-side management and energy storage solutions), and optimise existing infrastructure through digital technologies. Digital solutions should also help improve the performance of buildings and industrial processes. Finally, the plan aims to support research and development in key areas such as advanced energy storage, smart grids, and digital energy services.

1.5 Data spaces and their importance for data sharing

Data should drive Europe's digital single market, while at the same time helping to answer "societal challenges", which include easing the energy transition to carbon-free or neutral sources of energy. To achieve broader data sharing that would be key to bring forward this diversified electricity grid, new ways or concepts to facilitate and encourage data sharing are essential. As a part of the EU's strategy on data (European Commission 2020), the concept of a "data space" is being implemented. This could be a potential solution for some of the bottlenecks that the energy industry faces. These data spaces aim to protect data generated by European citizens and enterprises, while simultaneously intending to keep data accessible and open for innovative uses.

A data space is, in essence, an infrastructure for data sharing that consists of a set of systems of participants that agree to collaborate within an agreed upon structural and legal framework. It should encourage both interoperability as well as governance structures that help ensure that the relevant parties have better access to data for developing innovative energy services, while people's sensitive data is adequately protected. The consent of the data space users is necessary for accessing such data. While (sectoral) data spaces themselves should be interoperable as well, each data space can be tailored to meet the needs of its members to facilitate data exchanges that meet common goals. In the case of an energy data space, this would include ensuring that data can help facilitate flexibility in energy delivery as well as helping members to meet regulatory obligations.

1.6 Purpose of this report

This report is intended to inform the European Commission's Directorate-General for Energy about the areas where a Common European Energy Data Space can facilitate data sharing and what further steps may be taken for its development. Data spaces are not a "cure all" for data sharing needs, but if guided and implemented correctly, they can reduce burdens on industry and offer solutions to long-standing data sharing issues.

This document includes the results of a literature review on flexibility needs and potentials in the European electricity sector. It further presents an inventory of European flexibility initiatives per type of flexibility. Based on this research, generic models and processes in metering and aggregation services are described. Relevant high level use cases (HLUC) in the aggregation of assets within virtual power plants (VPP), in price-responsive charging and in smart residential flexibilities are presented with the current pain points (challenges or impediments) from the perspective of industry actors. Chapter 5 describes the role of the energy data space with the levels of interoperability to be considered and specific technological solutions to pain points. The work streams are then combined into an implementation plan that is suggested for the establishment of the Common European Energy Data Space in Chapter 6 and concluded with a summary and outlook in the final Chapter 0. Further information on the approach and methods for this study are available in Annex A.1.1.

Take away – What is the political setting for this study?

→ Common European markets for energy and data should help facilitate the energy transition.
→ Digital technologies and access to data are key to the integration of renewable energy sources to achieve the RePowerEU targets.
→ Data spaces shall facilitate data sharing by enabling collaboration and innovation, while protecting sensitive data and simplifying regulatory compliance.

2 Flexibility for the European energy system - needs and potentials

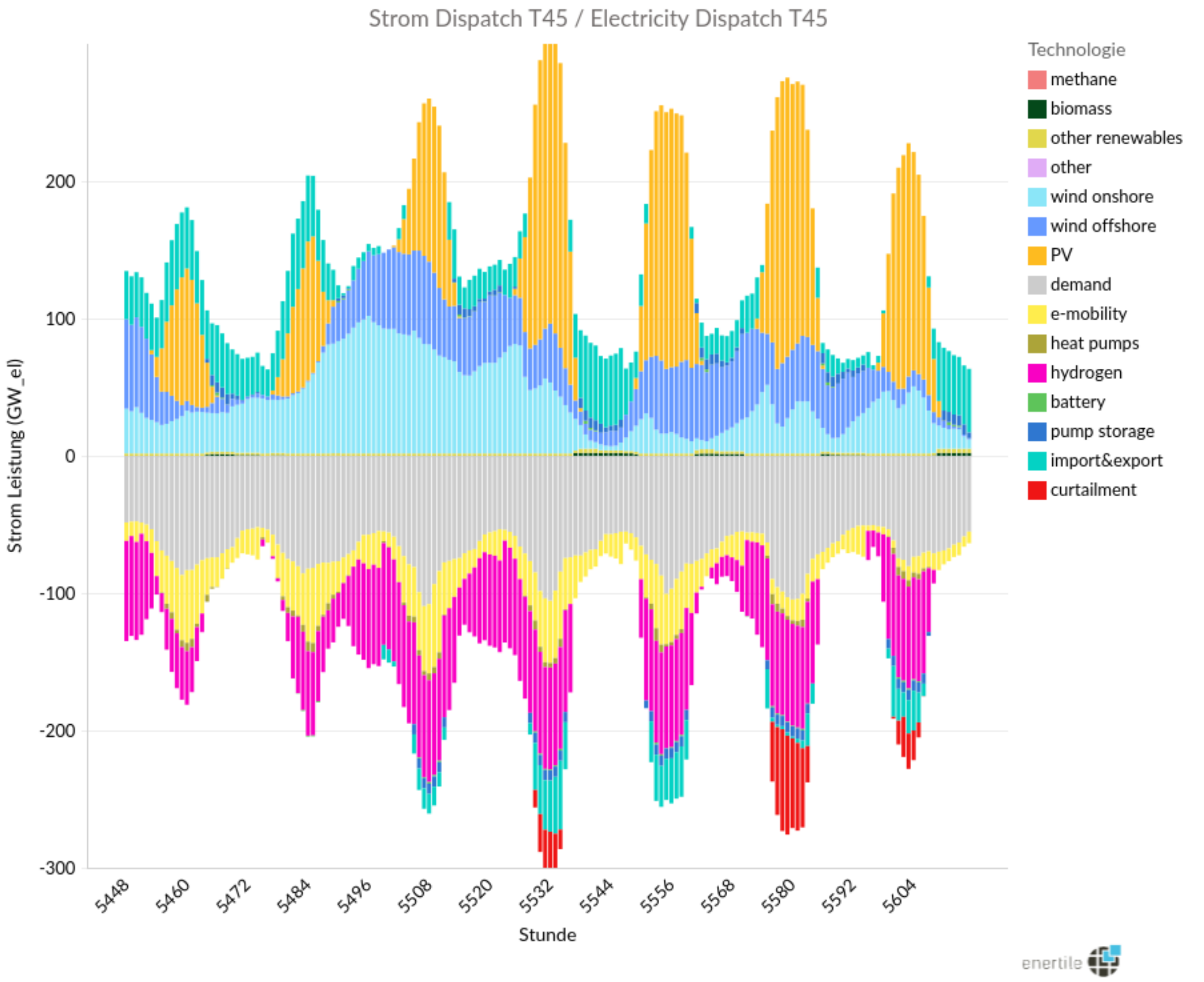
2.1 Role of flexibility in the energy sector

The EnTEC study "Digitalisation of Energy Flexibility" pinpoints key applications that can provide flexibility in future power systems if they are digitally enabled (Klobasa et al. 2022). Some of the most promising applications provide flexibility via electric vehicles, district heating and cooling, aggregation for virtual power plants and home energy management systems.

If existing barriers are overcome, several hundred gigawatts could be available from digital-enabled use cases until 2050. These use cases can extend or even replace existing flexibility systems that are mainly provided by gas-fired power plants and energy storage.

Current long-term scenario studies see flexibility for future power systems provided by gas-fired power plants that will use hydrogen in the long run with energy storage supplemented by electric cars and heat pumps (European Commission et al. 2023). The need for flexibility in this complex system presents a massive challenge, which can be seen in a study of the German power system that models how to achieve climate neutrality targets by 2045. Here, large, and variable supplies of wind and solar energy need to be aligned with a very strongly increasing flexible demand from electric cars and industry users (see Figure 2). In the model, further flexibility is provided by increased production of hydrogen and by exporting energy to neighbouring countries when supply outstrips local demand.

Figure 2: Flexibility of dispatch in power system operation - long-term scenario Germany in week 33 of 2045



Source: Enertile - long term scenario 2045 (Fraunhofer ISI 2021)

2.2 Sources of flexibility

An initial assessment of possible use cases in which data spaces as an infrastructure for data exchange could be an important enabler showed four main sources of flexibility:

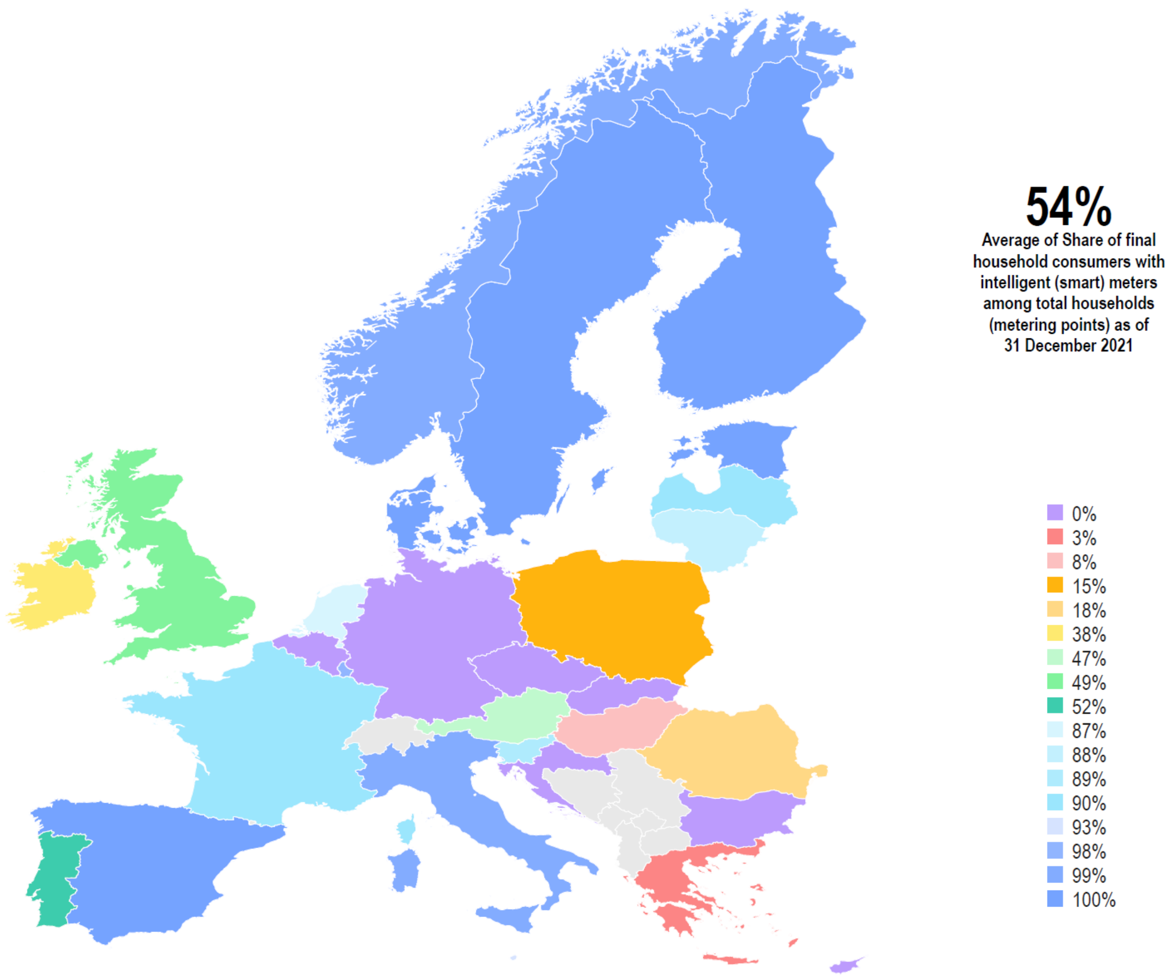
1) **individual consumption and metering**, which is included in most of the relevant use cases, especially related to flexibility enabled by home energy management systems;
2) **aggregators** that bundle renewable generators, storage and demand-side **response**;
3) the **electric mobility sector**; and (4) the **residential sector** via smart homes with heat pumps and rooftop PV-systems. The following sections explain the main flexibility provided by these four main sources.

2.2.1 Individual consumption and metering in the residential and service sector

Individual demand-side management and demand response in the residential sector are expected to provide a large source of flexibility. While individual appliances are small, their number is large, creating a large, aggregated pool. However, pre-requisite for providing flexibility is metering data that provides information on power usage over time.

Smart meters are rolling out across all EU Member States, though unevenly, (see Figure 3). To take advantage of this infrastructure, a standardised connection and metering approach is needed to avoid high connection costs. IT security is another important design criterion for a metering infrastructure that allows applications to operate flexibly. Energy data spaces can provide these building blocks.

Figure 3: Status of smart meter roll-out at the end of 2021 in Europe



Source: CEER 2022 (ACER / CEER 2022)

In the residential sector, flexibility can be provided by household appliances, such as heating and cooling technologies as well as battery storage systems. Aggregators already provide access to battery storage combined with electric vehicles or rooftop PV-systems, which can continue to be scaled up (see also Section 2.2.2).

The availability of metering and consumption data is also seen as a key facilitator for behavioural changes regarding energy demand and increased energy efficiency, especially if variable tariffs are in place. Studies show that consumers are sensitive to price and, as such, can drive flexibility in future power systems (Beermann et al. 2022).

2.2.2 Aggregation of generation and demand flexibility

Aggregators already provide flexibility on both the supply and demand sides of energy generation. In recent years, aggregators have pooled generation units and demand applications in power markets as well as ancillary service markets. On the generation side, they integrate renewable generators into virtual power plants, which also provide flexibility on the demand side. These virtual plants allow, for example, industrial demand-side actors like paper or cement mills to participate in ancillary service markets. For these plants to function, aggregators maintain data streams and platforms to control and monitor the different uses. Such services often integrate supervisory control and data acquisition (SCADA) systems of hardware manufacturers, such as wind or PV generators. In the past, applications that provide flexibility have been generation units that provide a minimum output of 100 kW, however in recent years, smaller units have also been integrated into virtual power plants, such as household battery systems. Currently, grid-system operators maintain EU-wide flexibility and data platforms to coordinate reserve capacities for the power grid (ENTSO-E 2023a, 2023b).

2.2.3 E-mobility

Decarbonisation of the mobility sector is driving electric mobility and could increase the flexibility of the power system substantially. Key applications that provide this flexibility would be smart charging and vehicle-to-grid concepts that allow the feed-in of electricity from electric vehicles back to the grid. The main sources of flexibility are the car batteries themselves and the related charging infrastructure, which can delay and shift the charging process according to overall demand. This flexibility could be particularly important with PV generation potentially generating a large portion of the energy required to charge EV batteries. In addition, the additional load of millions of charging vehicles could increase peak loads on the grid infrastructure, which can only be avoided or reduced when charging processes are coordinated. As such, EV flexibility could also reduce the need for new power generation and lower grid infrastructure costs (Meier et al. 2019).

2.2.4 Residential sector

Smart home applications and connected assets in the building sector can also provide additional flexibility. The decarbonisation of residential heating with heat pumps is one such source of flexibility, and this field is expected to grow markedly in the upcoming years. Massive installations of grid-connected solar/PVs with prosumption options can also contribute to grid flexibility. The building sector is expected to provide four types of energy flexibility, namely load shedding, shifting, generation, and modulation. These flexibilities can be created in many ways, but often require a digital interface (e.g., aggregation platforms, remote monitoring and control, communication protocols, etc.) so that they can be integrated into the smart grid.

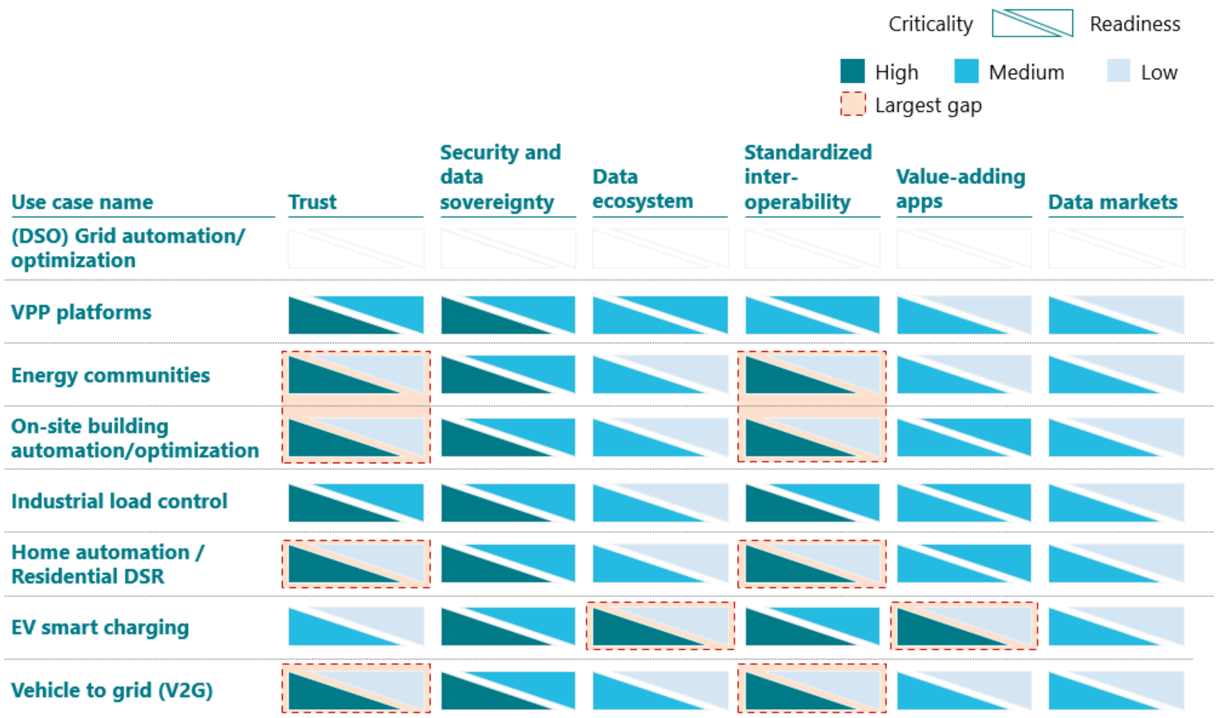
2.3 Flexibility requirements

Renewable energy sources shall provide 42.5 % of gross energy consumption in the EU by 2030 (Council of the European Union 2023b). The two largest sources of renewable energy, wind and PV, are non-dispatchable and will vary substantially given prevailing weather conditions, requiring an increase of other types of energy generation units as well as demand-side flexibility. While headlines have focussed on increasing power prices in European power markets, the increasing use of renewable energy has created additional volatility in the last two years, which is a challenge for grid integration.

The baseline for flexibility is mainly provided by installed renewable and fossil-fuel generation capacity, available internally and across borders, combined with hydrogen production to potentially store energy from renewable sources and the process of electrification of important demand sectors, which creates both flexibility and additional demand. Several flexibility options can fulfil short-term flexibility needs, while some options allow for a longer shift duration, especially in the heating and industrial sector. Shifting duration time, daily availability, and shift direction could fulfil most of the future requirements for flexibility in the energy system.

Examining the use cases specifically, the International Data Spaces Association identified a number of requirements, which are trust, security, data sovereignty, interoperability, data ecosystems, data markets and apps (Steinbuss 2022). These data ecosystems should also make data easy to find and access. Existing data sharing arrangements, however, are deficient, particularly in the area of interoperability and trust (see Figure 4). Smaller gaps are seen for virtual power plants platforms and industrial load control.

Figure 4: Evaluation of criticality and readiness of main data service requirements for flexibility in the use cases

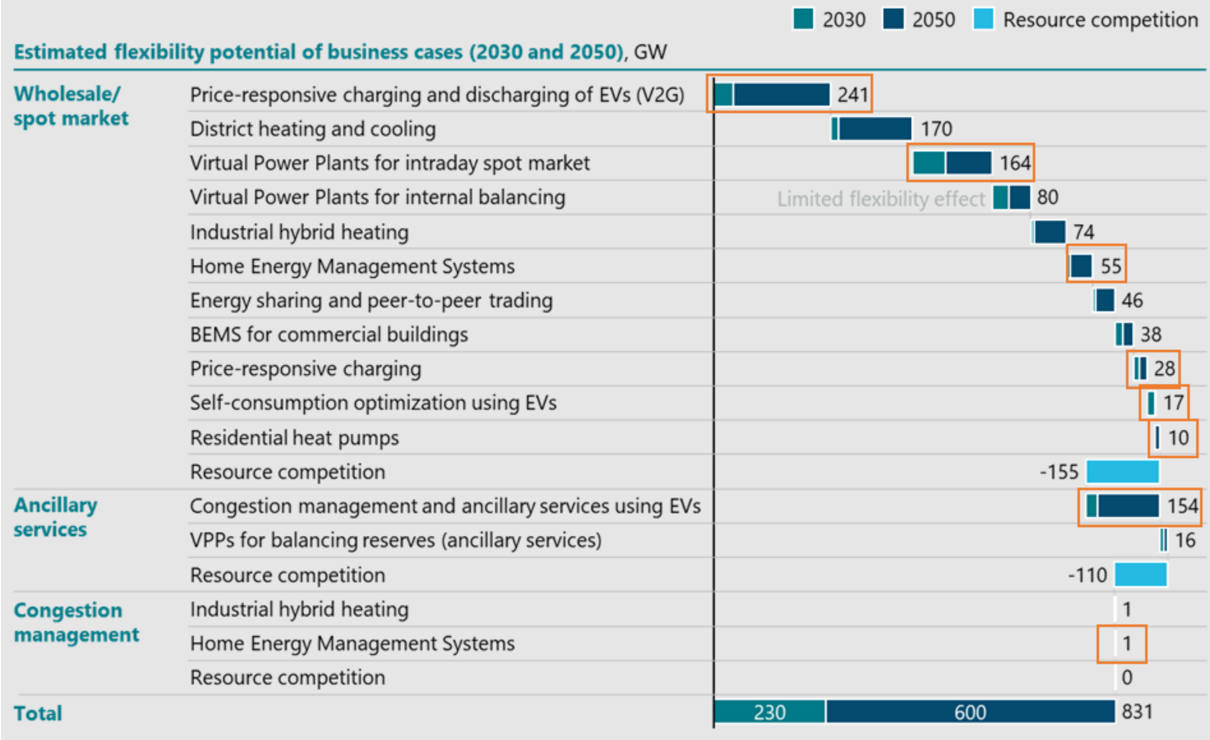


Source: (Klobasa et al. 2022)

2.4 Potential for more flexibility

Flexibility in energy systems is important for managing congestion, delivering ancillary services, and organising wholesale markets. Depending on how the grid infrastructure and the interconnection between Member States develop, flexibility needs are likely to be highest in wholesale markets. Flexibility needs for congestion management and ancillary services are expected to stay on a much lower level (Klobasa et al. 2022). Digitalisation is expected to provide the needed flexibility, especially for shifting shorter time periods. Use cases that show the most promise to create this flexibility are price-responsive charging and discharging of EVs, district heating and cooling, and virtual power plants (see Figure 5). Building-related use cases can also provide large amounts of flexibility through energy management systems for homes (HEMS) and buildings (BEMS) with these digital technologies integrating energy from battery storage.

Figure 5: Capacity of digital-enabled solutions by type of flexibility provided



Source: (Klobasa et al. 2022)

Based on these findings, three high-level use cases have been selected for further analysis in this study. These use cases will be described in further detail in Chapter 4:

1) virtual power plants & aggregation – detailed description see Section 4.1,
2) smart charging & vehicle to grid – see Section 4.2,
3) smart residential flexibilities – see Section 4.3.

Take away – needs and potentials for flexibility in the European energy system

- → Digitally enabled flexibility services need to provide a large share of flexibility to the future energy system.
- → Smart metering infrastructure is necessary to provide flexibility from the residential and service sector.
- → Aggregation of generation and demand in virtual power plants, smart charging including vehicle to grid capabilities and smart residential flexibilities are high level showcases for the application of a data space.

3 State-of-the-art of flexibility provision in the EU

3.1 Inventory of European flexibility initiatives

An inventory of digitally enabled flexibility initiatives will help to understand the state-of-the-art in different European markets considering wholesale electricity trading as well as the provision of services to system operators from different areas of interest.

The inventory was compiled using desk research as well as a survey. It includes private initiatives and organisations with ongoing market activities as well as research initiatives and projects with a technology readiness level (TRL) 7 and above. It is not intended to be an exhaustive list. Detailed information on the process and the full list of actors within the inventory are documented in Annex A.1.1.

Table 1: Current state of flexibility initiatives and actors in the EnTEC inventory

Type of flexibility	Wholesale market	Ancillary services	Congestion management	N/A	Total
Austria			2	5	7
Belgium	1		1	8	10
Denmark	1		2	3	6
Estonia		2	2		4
France	3	3	4	3	13
Germany	6	3	8	15	32
Ireland		2	3	3	8
Italy	1	3		4	8
Norway	1	1	1	1	4
Poland			1		1
Portugal	1		2		3
Romania	1		1		2
Slovenia	3		1		4
Spain		2	1	1	4
Sweden			1	1	2
The Netherlands	2	2	4	5	13
EU	15	9	14	27	65
Other	1	3		5	9
Total	**36**	**30**	**48**	**81**	**195**

Table 1 reports the type of flexibility that is associated with the initiatives of each country. For certain types of flexibility initiatives, wholesale market services and balancing services are mentioned most often while congestion management applications have been found to a slightly lesser extent. Ancillary services were addressed by at least nine R&D projects, which indicates that this area is subject to intense research, while wholesale market-oriented initiatives are already established in the market.

Within the inventory, the meter operators and metered data administrators are usually a branch of the main system operators within a Member State. There are also initiatives by original equipment manufacturers (OEMs) of heat pumps and EVs that provide service agreements for their products, including set rates for electricity combined with the ability to provide flexibility to the electricity grid.

Table 2: State of inventory per area of interest per 3 July 2023

Note: One initiative can be assigned to several areas of interest

	Country	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Main Scope	Austria	6		1	1
	Denmark	4			2
	Estonia	1	1	1	1
	France	2	9	5	3
	Germany	10	8	19	13
	Ireland	4	1	1	3
	Italy	4	1	2	2
	Poland	1			
	Romania	2			
	Slovenia	3	2	1	2
	Spain	1	2	1	
	Sweden	1	1	1	
	The Netherlands	4	4	4	2
Additional	EU	24	25	24	27
	Belgium	7		1	1
	Norway	1	2		1
	Portugal			1	2
	Other		1	3	5
	Sub-Total	**75**	**57**	**65**	**65**
	Total		**262**		

Table 2 shows the distribution of initiatives in the inventory across the areas of interest. As initiatives can be relevant to several areas, the number of areas exceeds the number of initiatives shown in Table 1. The metering and consumption column includes various distribution service operator (DSO) companies with their metered data administrator (MDA) function and data hub initiatives. The mobility column covers many industrial and commercial EV manufacturers and charge point operators (CPOs). The smart building column includes OEMs for domestic batteries and PV inverters.

To assess the relevant ecosystem of potential actors within a data space, it is important to note that energy service companies usually partner with specialised software developers. While decisions are made by the energy companies, their IT partners will also be key to implementing data space solutions.

In an additional survey, further information on the business model was collected from the initiatives. The findings below are based on 17 responses to the survey, seven of which came from private initiatives and ten from European research projects. The responses can be used to illustrate some insights on potential business models as described in the business model navigator (Gassmann et al. 2013) that are relevant to the flexibility service (cf. Figure 7).

Figure 6: Survey result on generic business model types

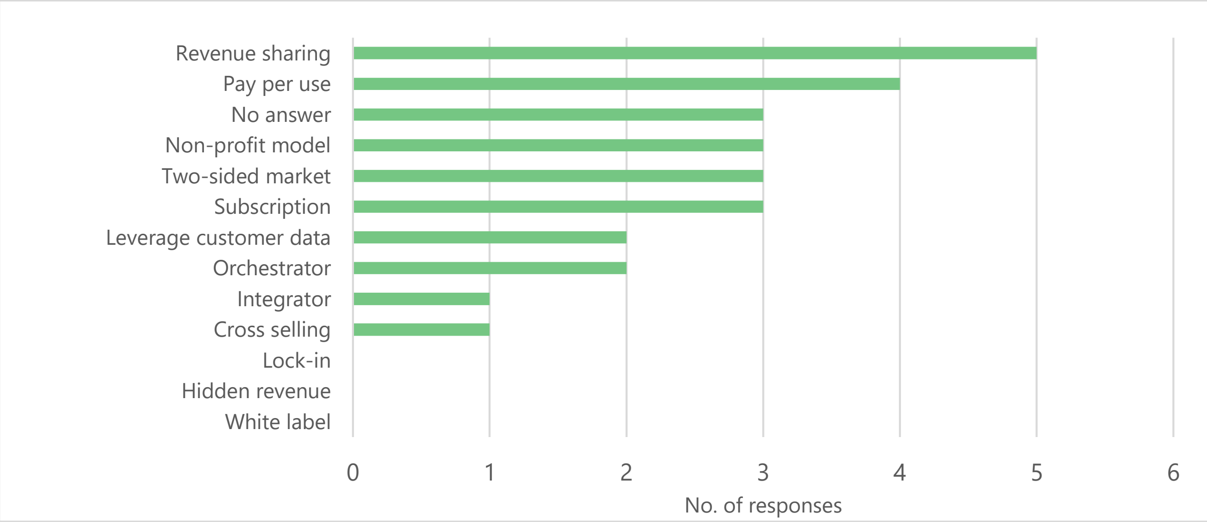
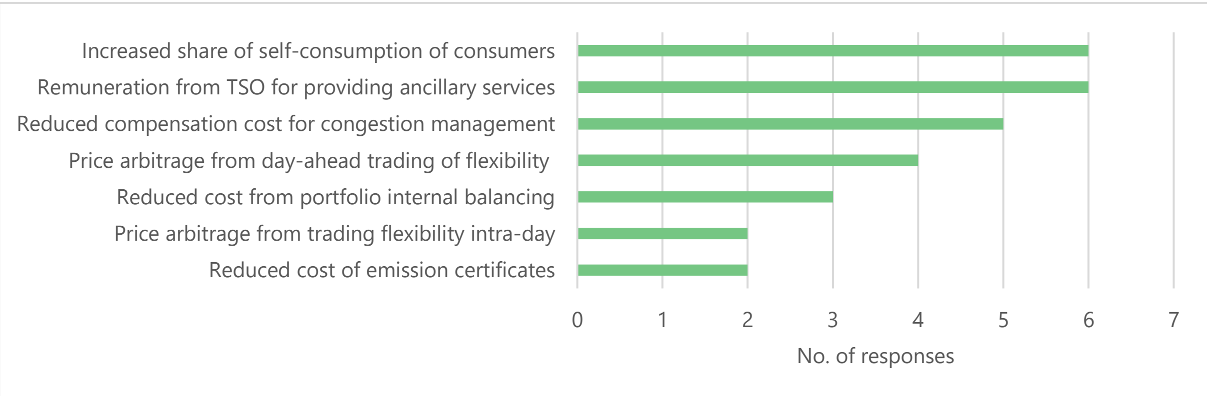


Figure 7: Survey result on expected revenue sources



The business model most often identified by respondents as relevant for their business was revenue sharing. This might indicate that further research and discussion on revenue sharing along digital value chains will remain very relevant for the development of viable business cases in a digital network of partners.

Remuneration from the TSO for ancillary services was also well represented in the survey. This may be related to the high number of European research projects participating in the survey.

Reduced compensation costs was also highly rated and again likely of special importance from a system operator's perspective. On the revenue assessment of survey participants, it seems that intraday trading is underrated compared to its potential and growth rate.

With regard to data space features, the pay-per-use model might benefit from a clearing house or logging function. If consumers provide consent that allows for multi-sided data usage, usage policies may be applied to define the extent and scope of other stream and leverage models between the data provider and consumer.

The survey also asked about technical and organisational barriers to implement flexibility services: Technical compliance requirements and adapting data pre-processing were consistently ranked first and second. In terms of organisational priorities, legal contractual agreements and organisational compliance requirements were identified as the largest barriers. Furthermore, respondents also cited staff training and change management as high priorities for enacting commercial initiatives.

Furthermore, the responses describe a range of state-of-the-art solutions available on the energy market. Recent commercial initiatives have implemented a near real-time resolution of 4 seconds, though stakeholder engagement in the first workshop of this study indicated that some short-term, AI-based services may even require multiple measurement values per second. Other services may not require near real-time resolution, but 5-15 minutes steps may be necessary to increase short-term trading and activation on the intraday market. Technology choices on software components need to consider time resolution as a requirement.

3.2 Consumption and metering

In general, metering in the electricity sector is divided into two categories as defined in *Directive (EU) 2019/944 on common rules of for the internal market for electricity* (IEM-D) (European Union 2019):

- Conventional meter – analogue or electronic meter without the possibility to send and receive data,
- Smart meter (SM) / smart metering system – allows remote capabilities to send and receive data for information, monitoring and controlling activities.

While the introduction of most recent smart meter systems at Member State level according to the IEM-D (Article 19 – 21 & Annex II) is required to fulfil minimum standards, some Member States had already introduced smart meters according to the initial EU smart meter rollout regulation *Directive 2009/72/EC* (The European Parliament and the Council of the European Union 2009; Vitiello et al. 2022). However, these systems are limited in their operational lifetime until 4 July 2031 if they do not fulfil current requirements (defined in IEM-D Article 20 & Annex II (European Union 2019)).

Another category of meters, relevant for the study's scope, has been recently introduced by the European Commission in the process of amending the IEM-D (European Commission 2023e). Its amendment proposal defines a so-called *dedicated metering device*. Such devices are embedded in or attached to (behind-the-meter) *distributed energy resources* (DERs) to provide data for demand response purposes (including storage). In order for them to be used for monitoring or settlement in cases of such a provision of flexibility, requirements need to be defined at the Member State level and then fulfilled by these devices. Only then will TSOs or DSOs be allowed to use them under the condition that current smart meter systems are not available or not able to provide the required data at DER level (e.g., no electrical sub-meters exist at the required location).

Table 3: Categories of metering devices according to current / planned EU regulation

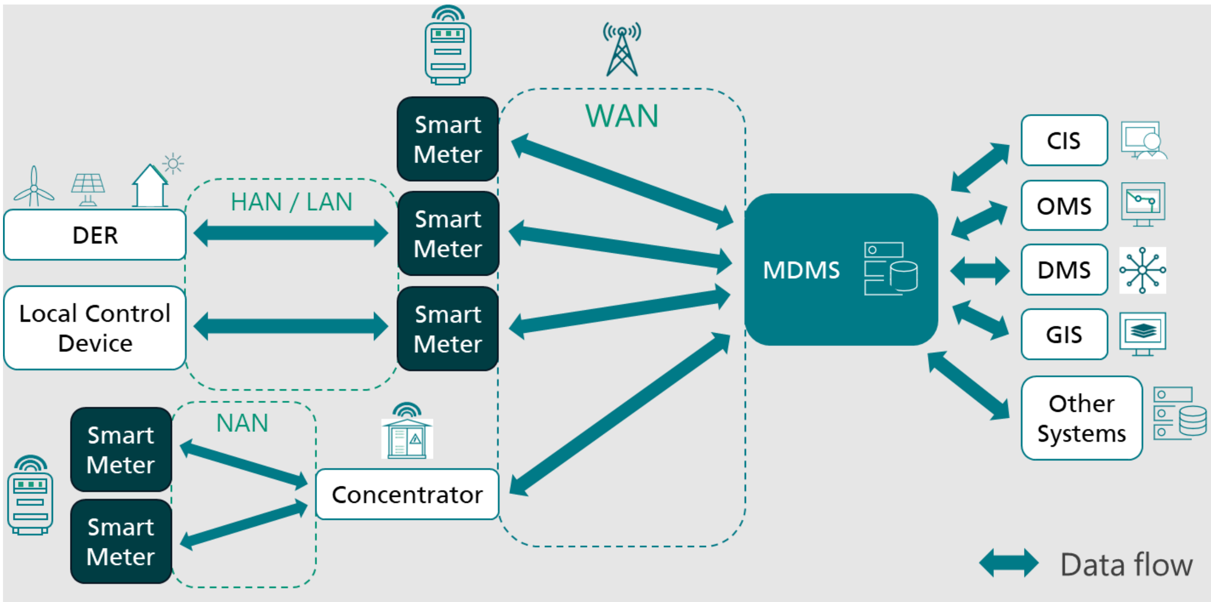
	Conventional meter	Smart metering system / SM	Dedicated metering device
Send data	Analogue: X Electronic: ✓	✓	✓
Receive data	X	✓	✓
Legal use for settlement	✓	✓	X (EC proposal)
DER embedded	X	X	(✓)
Comments		Operational SMs that only fulfil requirements according to (The European Parliament and the Council of the European Union 2009): End of operation: 04/07/2031	Limited to demand response usage with the following prerequisites: 1) Current SMs cannot provide required data 2) MS defines technical requirements

Source: derived from (European Commission 2023e; European Union 2019; The European Parliament and the Council of the European Union 2009)

Since the introduction of smart metering systems in Europe, a general infrastructure has been developed to fulfil the newest requirements, such as a bidirectional link to the premises of (active) customers. This is typically known as *advanced metering infrastructure* (AMI) (Ghosal et al. 2019; Uribe-Pérez et al. 2016). A core principle of current AMIs is a centralised approach to storing and distributing relevant metering data.

At the centre of the general data communication lies the *meter data management system* (MDMS) which offers centralised data storage, data management and data analytics (cf. Figure 8). Connected systems like a *consumer information system* (CIS), *outage management system* (OMS), *distribution management system* (DMS) or a *geographic information system* (GIS) can be linked to meter data for their specific functions (e.g., directly or in an aggregated form). Other systems might access the data as well for various purposes. (Ghosal et al. 2019)

Figure 8: Simplified overview of current advanced metering infrastructure (AMI) features



Source: Own illustration (derived from Fig. 1 – 3 in (Ghosal et al. 2019)). Note: CIS: consumer information system, DER: distributed energy resources, DMS: distribution management system, GIS: geographic information system, HAN: home area network, LAN: local area network, MDMS: meter data management system, NAN: neighbourhood area network, OMS: outage management system, WAN: wide area network.

Different technologies can communicate on-site metering data to the MDMS. In general, two connection types are used:

1) a direct connection to a specific smart meter via a *wide area network* (WAN), or
2) an on-site connection to a local concentrator in a *neighbourhood area network* (NAN). In the latter case, the concentrator is also connected to a WAN.

Beside the uplink to the central MDMS, an AMI can consist of local components in the so-called *home / local area network* (HAN/LAN). At this level, a smart meter can be connected to a local control device or directly to a DER to support flexibility services such as demand response (Ghosal et al. 2019).

As the specifics of each AMI implementation in the different Member States vary in detail, the minimum requirements must be fulfilled in accordance with the IEM-D (Article 20)[1]:

- accurate measurement of current electricity consumption with a live interface for customers;
- validated historical consumption data needs to be available in a way that is simple, secure, and free of charge;
- close to real-time,non-validated data must be available on site via a standardised interface or by a remote access point without any associated costs and obstacles to allow energy management, including flexibility services such as demand response;
- balance between highest security and associated efforts for fulfilment;
- data protection and privacy according to EU regulations;
- ability to measure the amount of electricity that (active) customers generate and feed back into the grid;

[1] Please note that additional minimum functional requirements have been provided by the European Commission in (European Commission 2012) (as enforced by IEM-D Annex II).

- (active)) customers, or a party authorised to act for them, should have access to data regarding electricity that they have fed into the grid in an easily understandable and comparable format via remote access or a standardised communication interface without any charges;
- possibility to measure and settle (active) customers in accordance with the imbalance settlement period of a Member State.

As previously highlighted, Member States implement AMIs in different ways. Within the geographic scope of this study, four major development paths have been identified (which are briefly described in Table 4):

1) single / major central AMI,
2) multiple central AMIs,
3) central data hub / registry,
4) common decentralised data exchange.

In general, all of the initiatives that were analysed for this study on operational AMI implementations have adopted a central AMI approach. In a few of the Member States analysed, a single or major market leader drives smart meter development. As a result, other market actors generally interact with this single AMI to receive metering and other data.

Table 4: Overview of different European AMI implementations with possible add-ons

	Single / Major central AMI	**Multiple central AMIs**	**Central data hub / registry**	**Common decentralised data exchange**
Main actor(s) for SM development / AMI add-ons purpose	Single or strong market leader drives smart meter development	Multiple active actors drive the smart meter development in a Member State	*AMI add-on:* AMIs connect with a central data hub / data registry	*AMI add-on:* AMIs provide a standard interface
AMI interaction	Market actors interact with the central system (e.g. for ToU tariffs or remotely-controlled demand response)	Individual interaction of market actors with these systems (e.g. for dynamic pricing, remote control)	Central platform for market actor interaction (e.g. market communication)	Decentralised and standardised smart, meter-related data communication in a Member State
AMI (add-on) operator	Single / major operator: e.g. DSO (IE) or DSO network (FR, IT)	Multiple operators in a Member State: e.g. DSO-related meter operator or an independent meter operator (DE), or DSOs as meter operators (like AT, ES, NL, PL, RO, SE, SI)	Single operator: e.g. TSO (DK, EE, PL *(in development)*), or DSOs-owned organisation (ES, NL), or DSO organised (IE), or state-owned organisation (IT)	Shared services operator: e.g. in AT a TSO/DSO owned organisation, or in DE the BSI as well as an energy industry association owned organisation

Source: based on inventory covering 13 EU member states

One example comes from Ireland with the settlement of energy suppliers' time-of-use (ToU) tariffs (CRU 2023; ESB Networks DAC 2022). In Ireland, only one DSO is responsible for the ongoing, nation-wide deployment of AMI (CRU 2023; Pollitt et al. 2021). By comparison, France and Italy have more than one active DSO However, in all three countries, the dominant DSO[2] has driven smart meter development in cooperation with smaller, local DSOs (Enedis 2022; Gridspertise S.r.l. 2022; L'Académie des technologies 2019; Pelletier et al. 2017; Pollitt et al. 2021; Ramboell 2022).

In contrast to these three Member States, all other countries investigated show a more diverse landscape concerning DSO-driven smart meter development[3]. Without a single point of contact, co-ordinating data exchanges with multiple parties becomes a major challenge. Consequently, most of the Member States analysed have established data hubs with a central metering database combined with a registry of relationships between market actors. Specifically, they may store validated metering data, aggregated data or master data of (active) customers, providing access to this data to other market actors, such as balance responsible parties (BRPs) or energy suppliers. This kind of data could be used, for example, by customers looking to switch energy suppliers. Moreover, consumers can typically view or request metering data via a web portal of the data hub. (Acquirente Unico S.p.A.; Acquirente Unico S.p.A.; Diputación de Granada 2021; Energinet 2018; ESB Networks DAC; Platform Datadis CB; van Aubel et al. 2019)

Another general approach differing from the common AMI add-on of a central platform, can be found in these Member States:

- Austria: Energiewirtschaftlicher Datenaustausch / Energy Data Exchange (EDA),
- Germany: Marktkommunikation / market communication (MaKo),
- Sweden: svenska Elmarknadshandboken / Swedish Electricity Market Handbook and
- Romania: Regulated data format defined by Autoritatea Naţională de Reglementare în domeniul Energiei / Romanian Energy Regulatory Authority (ANRE) (ANRE 2023; Beschlusskammer 6 2022; EDA GmbH 2023a, 2023b; Energiföretagen Sverige et al. 2022; Merz 2021; PONTON GmbH 2020).

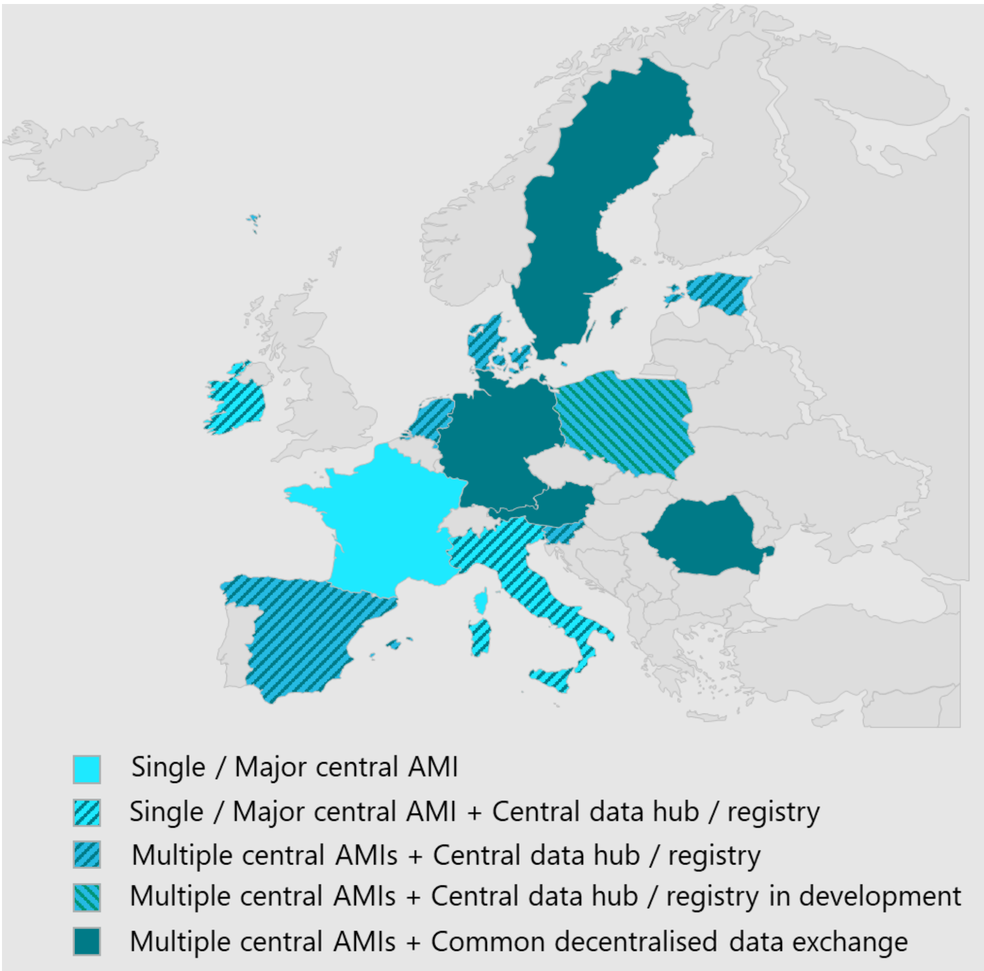
The activities described earlier require common, decentralised data exchange processes so that energy market actors such as BRPs, balancing service providers (BSPs), energy suppliers, metered data aggregators and energy communities can interact. These data exchanges can be a critical component of shared services. One example is a cooperation between Austrian TSOs and DSOs to provide an energy data exchange (EDA) using a peer-to-peer (P2P) carrier network to electricity market participants (Merz 2021; PONTON GmbH 2020). Another example, though less well-integrated, exists in Germany with the MaKo approach (Beschlusskammer 6 2022). From an infrastructure point-of-view, the German *Federal Office for Information Security* (BSI) supports the upcoming *Applicability Statement 4* (AS 4) web service as a part of the mandatory requirement of applying a *smart metering public key infrastructure* (SM-PKI). The BSI has allowed participants to also use their managed SM-PKI root certificates from the AMI in the overall MaKo communications (BSI 2023). Another shared service within the German MaKo is provided by the *Energie Codes & Services GmbH,* which is owned by the German energy industry association *Bundesverband der Energie und Wasserwirtschaft e.V.* (BDEW) (Energie Codes & Services GmbH 2023). Their role is known as that of a *local issuing office*, and they provide market participants with standardised identifiers (IDs) like the European *energy identification codes* (EICs) as well as national ones.

[2] > 80 % of all distributed power according to (Pollitt et al. 2021).

[3] In Germany the role of a metering point operator exists (Kroener et al. 2020). Such a party can be independent or related to a DSO (Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen 2022).

While some similarities exist, current European AMIs and their specific functionalities and implementations might differ from each other. Nevertheless, comparing Member States provides a chance to identify possible connecting points in the development of a future joint European energy data space. Figure 9 depicts in which permutations these possible AMI implementation options can be found in Europe.

Figure 9: Geographical overview of analysed EU Member States' AMI implementations[4]



Source: Own illustration (based on inventory covering 13 EU Member States)

From a theoretical perspective all these AMI implementations might cover different purposes in the context of flexibility provision. According to Wang et al. (2019) four can be named:

- **flexibility analytics** – the potential or demand for flexibility provision can be calculated based on historic or current (active) consumer profiles as well as historic or current power grid data received from smart meters;
- **local optimisation** – smart meter functionalities such as the local provision of current power data that provide customers with price incentives to reduce consumption at key times (such as ToU tariffs or dynamic pricing schemes) provided by the *point of common coupling* (PCC);

[4] It should be noted that in the Scandinavian countries (DK, FI, NO and SE) another platform exists, mainly for centralised imbalance settlement, which is partly based on smart metering data (eSett Oy 2022). Their solution is called *eSett* and is provided by a company owned by their national TSOs.

- **remote-control access** of single or aggregated DERs, potentially via the PCC on a smart meter;
- **settlement process** of validated smart meter data to calculate imbalances from a customer's responsible BRPs of (active) customers;

A more in-depth explanation of exemplary AMI implementations at Member State level can be found in Annex A.1.3 for the following countries: Italy, Estonia, Germany, and Austria.

To facilitate the development of a single internal market for electricity in the context of smart metering, the European Commission has recently adopted a *Commission Implementing Regulation (EU) on interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data (European Commission 2023g)*. This regulation will be the first of a set of upcoming regulations to fulfil Article 24 of the current IEM-D. Its core idea is to facilitate fully interoperable energy services within the EU. Within this context, access to validated as well as non-validated near-real time smart metering data from consumers should be made available more easily to market participants. With regard to flexibility provisions, this includes aggregators, energy service companies, and balancing service providers. This data should also be available to consumers themselves as active participants in the energy market. This is particularly relevant for home energy management systems in the case of near-real time measurements. It should be noted that corresponding data flows will only be accessible for new smart meters that have been in operation since 5 July 2019.

Under these general conditions, the core instrument of this implementation regulation is a reference model. This model should foster interoperable data exchanges between Member States by defining reference processes for various data access procedures and exchanges with defined market roles. The metered data administrator, metering point administrator, data access provider as well as the permission administrator would all have major roles. Every role must then be mapped transparently at a national level to the responsible national actors. Within all of these processes, the (active) consumer must always clearly understand the way that the energy market works to avoid any information asymmetries, so that consumers can find the best service for their needs. Each Member State is obliged to establish its first national version of the European reference model by 7 December 2025 and, if already available, publish their documentation in a common public repository.

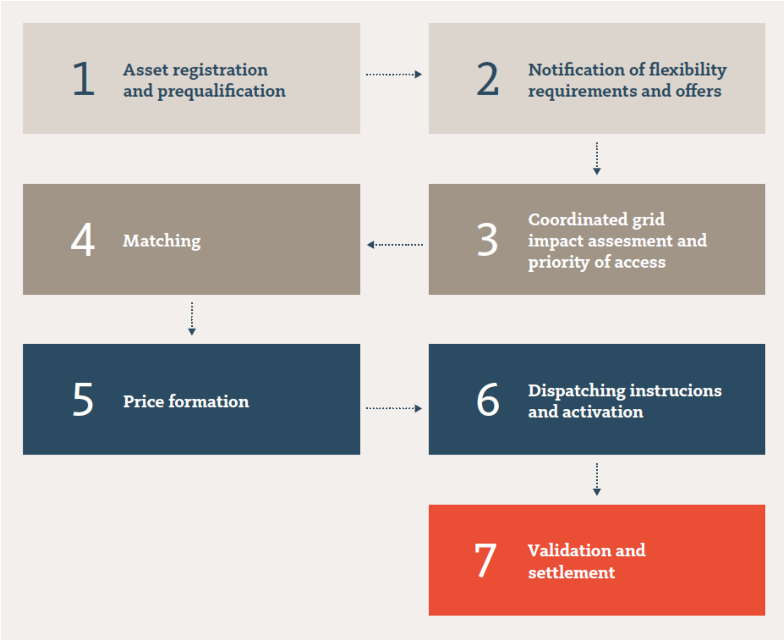
Moreover, the regulation enforces standardised interfaces for smart meters in the case of non-validated, near-real time data (H1 – H3 according to CEN/CENELEC/ETSI TR 50572:2011). In the annex of the regulation, a non-exhaustive list provides the following entries: *EN 50491-11 – EN, 62056 series – DLMS/COSEM, EN 13757 series – Wired and Wireless M-bus* and *EN 16836 - Zigbee SEP 1.1* (European Commission 2023f). The resulting transparency should then facilitate interoperable data exchanges within and across Member States.

3.3 Aggregation

Aggregators are entities on the electricity market which cluster a large number of (small) electricity generating and consuming units to offer flexibility services. The type of flexibility offered by aggregators can vary across all relevant categories, such as congestion management, adequacy, wholesale and balancing services (Heer et al. 2021). As described in Section 2.2.2, the ability of aggregators to provide flexibility services to power markets requires the ability to control and monitor a large number of appliances while also managing the underlying data streams between different market actors. Data stream management typically occurs via flexibility platforms, which can be self-contained marketplaces or provided via intermediaries to wholesale and balancing markets. Flexibility platforms may be owned and operated by, system operators, aggregators, or other independent participants in the energy market. TSOs and DSOs are prominent actors in this area, and they play different roles, such as being customers for flexibility providers or platform operators.

As described in the review of flexibility platforms (ENTSO-E 2021), the end-to-end process to provide flexibility can be subdivided into seven distinct steps, as illustrated below.

Figure 4: 7 steps in the end-to-end process for the provision of flexibility services



Source: Review of flexibility platforms (Frontier Economics, ENTSO-E, 2021) (ENTSO-E 2021)

Step 1 - asset registration and prequalification: this step entails the collection of basic asset information (location, voltage, available capacity, ramping time, etc.) and may also involve physical testing to validate an asset's characteristics. Stakeholders requiring prequalification can be flexibility requesting parties (FRPs) or aggregators, for example.

Step 2 - notification of flexibility requirements and offers: this step relates to the bidding process. Information about flexibility requirements and availability are accessible via digital communication interfaces between stakeholders, which facilitates the tendering process.

Step 3 - coordinated grid impact assessment and priority of access: this step is typically outside the direct scope of the aggregator and aims at TSO/DSO coordination to avoid orders that cause grid congestion and to ensure network optimisation across all voltage levels.

Step 4 - matching: during this step, the flexibility needs of the TSOs, and DSOs are matched with offers from flexibility service providers (FSPs), taking into account various criteria, such as the ability of the asset to satisfy the flexibility need, the opportunity cost of the FSP and TSO/DSO, and the negative effects of activated energy in other areas of the grid.

Step 5 - price formation: during this step, auctions are carried out to determine the price for electricity. The auctions can have different formats, such as closed auctions (which may include caps on bids) or continuously clearing markets.

Step 6 - dispatching instruction and activation: in this step (when a bid has resulted in a trade), the FSP is committed to changing the assets' set points. This requires a reliable communication infrastructure to send dispatching instructions (e.g. concerning the amount and time of power modulation, etc.) and, in some cases, directly issue activation signals.

Step 7 - validation and settlement: this step relates to the measurement (baseline and activation profiles) and remuneration of flexibility services. It potentially requires a very large amount of data due to the large number of individual assets in the aggregator's portfolio. A (less complex) alternative to individual billing would be for FSPs to provide fixed rewards or reduced tariffs to asset owners.

Take away – state-of-the-art of flexibility provision

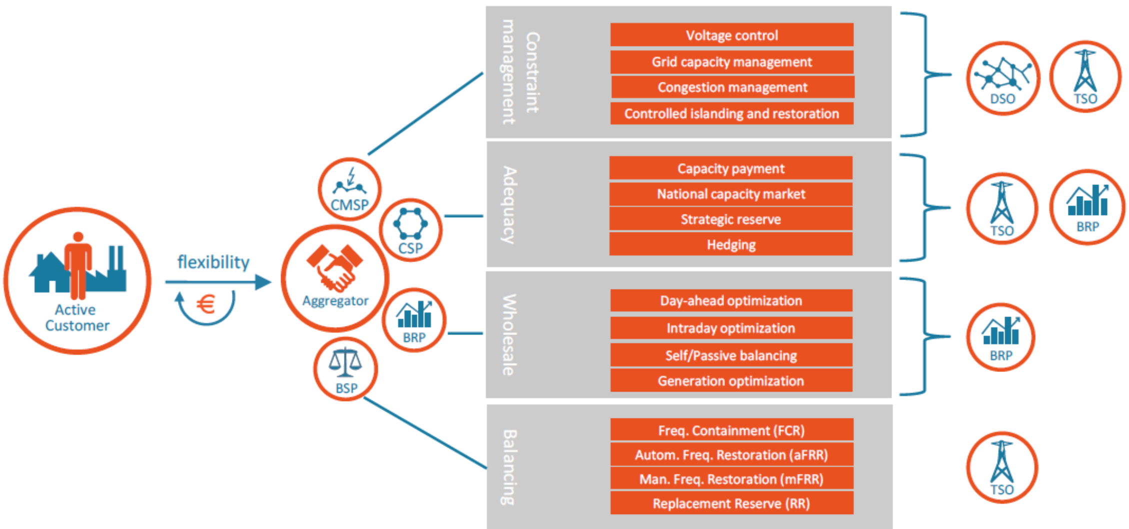
- → A total of 195 initiatives related to flexibility services have been identified in the inventory and are listed with further detail in the Annex.
- → Advanced metering infrastructure across Europe differs in its organisational setup and follows centralised and/or decentralised approaches.
- → Some steps of the process for flexibility provision through aggregators are generic.

4 Characteristics of high-level use cases for providing flexibility services

4.1 Virtual power plants and aggregation

VPPs account for very large pools of renewable energy generating assets and mature marketing processes. Prior to the emergence of DERs grid management generally meant adapting the supply side of the electricity grid (generators) to changes on the demand side. Today, with the ever-growing shares of fluctuating solar and wind power on the supply side, this paradigm is no longer suitable for balancing the grid. So, adaptions on the demand side are also needed. This is called demand-side management, meaning the active control of flexibility by, for example, an aggregator or supplier. There is a significant range of potential "flexibility products" for demand-side management services. They can be clustered into four categories: services for constraint management, adequacy, wholesale, and balancing (Heer et al. 2021),. Specific products in these categories are depicted in Figure 10, which also shows the various actors.

Figure 10: Different types of flexibility products for demand-side management services



Source: Report USEF – The framework explained (USEF, 2021) (Heer et al. 2021)

Within the seven steps of flexibility provision described in Section 3.3, our analysis across a range of flexibility products currently emerging within the geographical scope of this study has revealed the following four common activities:

- asset registration (part of step 1 "asset registration and prequalification"),
- prequalification (part of step 1 "asset registration and prequalification"),
- baseline registration (part of step 7, "validation and settlement"),
- registration of planned activation (part of step 6 "dispatching instructions and activation).

The following sections describe each of these four common activities.

4.1.1 HLUC description

A. Asset registration & prequalification (part of step 1 "asset registration and prequalification")

In the context of flexibility provisioning, the asset registration and prequalification activity plays a crucial role in assessing the technical capabilities and eligibility of flexible resources to participate in the market. Here are the different steps involved in the prequalification process, along with the key data exchanges between the various actors:

1) Asset registration

Owners provide comprehensive asset information to the aggregator, including specifications, capacity, location, and technical capabilities. Eligibility assessment and documentation preparation are also completed.

2) Technical assessment

The aggregator conducts a detailed evaluation of registered assets, considering factors such as specifications, response time, ramping capabilities, and grid compatibility. Additional data may be requested from owners. The aggregator forwards the collected information to the FRP, which conducts its own detailed evaluation.

3) Eligibility confirmation

Upon successful assessment, the FRP and then the aggregator confirm asset eligibility for the flexibility market. This "approval" initiates contractual agreements, metering, data reporting, and integration procedures. Testing and commissioning are performed to validate asset readiness.

In the above short description, the following high-level pains were identified. These pain points are described further in Section 4.1.4:

- data access control and discoverability,
- data quality,
- data security,
- standardisation.

B. Baseline registration (part of step 7, "validation and settlement")

When providing flexibility, baseline registration plays a crucial role in establishing the baseline calculations for registered assets. Here are the different steps involved in baseline registration, along with the key data exchanges between the various actors:

1) Baseline determination
2) Defining a methodology for determining baselines with parameters such as energy consumption, demand response capabilities, and renewable energy generation.
3) Baseline calculation and validation:
   - Applying the defined methodology to calculate baselines for registered assets, ensuring accuracy and compliance with regulatory requirements.
4) Baseline registration:
   - Submitting baseline calculation results and documentation to the market operator or regulatory authority and also providing transparency and supporting documentation.
5) Baseline adjustments and updates:

- Monitoring and assessing registered asset performance against baselines, making necessary adjustments based on changes in capabilities, conditions, or market rules.
- Compliance monitoring and reporting

Regularly monitoring registered assets to ensure compliance with baseline requirements, maintaining accurate records, and reporting baseline-related information to the market operator or regulatory authority.

In the short description above, the following high level pain points were identified. These pain points are described further in Section 4.1.4:

- baseline calculation,
- data access control and discoverability,
- data quality,
- standardisation.

C. Registration of planned activation (part of step 6 "dispatching instructions and activation)

When provisioning flexibility, registering planned activation activities plays a crucial role in coordinating and activating resources. Here are the different steps involved, along with the key data exchanges between the various actors:

1) Activation planning

The flexibility requesting party registers the planned activation, providing essential details such as activation date and time along with the required flexibility quantity, duration, and constraints. The aggregator verifies the registration information for accuracy and completeness.

2) Activation coordination:

The aggregator coordinates planned activations from multiple parties to optimise flexible resource usage. Flexibility resource owners receive notifications or requests for activation coordination from the aggregator, outlining activation details.

3) Confirmation and acceptance:

Flexibility resource owners confirm their availability and acceptance of the planned activation, providing consent and acknowledging the schedule. This ensures their participation in the activation. The aggregator receives the confirmation and updates the activation status.

4) Communication and alignment:

Grid operators receive notifications or updates about planned activations, facilitating coordination with grid operation and stability requirements. Balancing responsible parties (BRPs) may also receive information for accurate grid supply and demand balancing.

In the above short description, the following high level pain points were identified. These pain points are described further in Section 4.1.4:

- data access control and discoverability,
- data quality,
- standardisation
- access to metering data.

D. Maturity level

In some countries, such as Germany and the Netherlands, VPPs and aggregation have reached a relatively advanced stage of development and implementation. These countries have supportive regulatory frameworks like the Renewable Energy Act in Germany or the Energy Agreement for Sustainable Growth in the Netherlands. Market players actively participate, and VPP projects have been successfully deployed, such as WindNODE in Germany or EnergieKoplopers and GOPACS in the Netherlands. The level of market integration and the number of operational VPPs have increased, demonstrating a high maturity level.

Other European countries may still be in the early stages of exploring and implementing VPP and aggregation concepts. This might include ongoing pilot projects, regulatory adjustments, and stakeholder engagement to establish a solid foundation for VPP and aggregation market participation.

4.1.2 Data management

Data requirements for VPPs and aggregators vary depending on the specific use case, but commonly needed data includes real-time energy production/consumption data, grid conditions, weather forecasts, market prices, and customer preferences. Additionally, operational data such as device statuses, voltage levels, and power quality parameters may be required for effective control and optimisation.

The standards for data used in VPPs and aggregators are continuously evolving, and several initiatives promote industry-wide collaboration and standardisation. For example, communication protocols like Modbus and IEC 61850 are widely adopted for data exchange between devices and systems. Data exchange standards such as IEC 61970 and IEC 62325 are gaining prominence in order to facilitate interoperability and market communication. However, the availability and implementation of these standards across the industry has not yet been fully implemented or universally adopted.

To address these challenges, ongoing initiatives and industry collaborations focus on promoting the interoperability and harmonisation of data standards. For instance, organisations like the International Smart Grid Action Network (ISGAN) and the BRIDGE initiative are working to develop frameworks and guidelines for data standardisation. These efforts aim at ensuring seamless integration of VPPs and aggregators into energy systems by facilitating efficient data exchange, promoting transparency, and enabling interoperability between different market participants.

4.1.3 Business models

The dominating business models for VPP operators and aggregators of decentralised energy resources are based on energy trading on various European power exchanges. They use the wholesale market, and in particular the associated spot market, as an essential revenue stream: this involves taking advantage of day-ahead and intraday price spreads until five minutes before delivery. The market potential of intraday trading is estimated to be 180-220 million euros till 2030.

Furthermore, imbalances between consumption and generation are compensated by TSOs through their balancing reserve mechanisms. Aggregators can offer short-term flexibility from their assets as ancillary services on the balancing market to system operators, which can address manual frequency restoration reserve (mFRR) and automatic frequency restoration reserve (aFRR) with activation times of less than 30 seconds. The market potential till 2030 is significantly lower compared to the spot market and is estimated to be 22-25 million euros (Klobasa et al. 2022).

Countries with market-oriented congestion management schemes can provide additional flexibility and revenue. Last but not least, direct power purchase agreements (PPA) with electricity-intensive companies can be a part of a VPP operator’s business model.

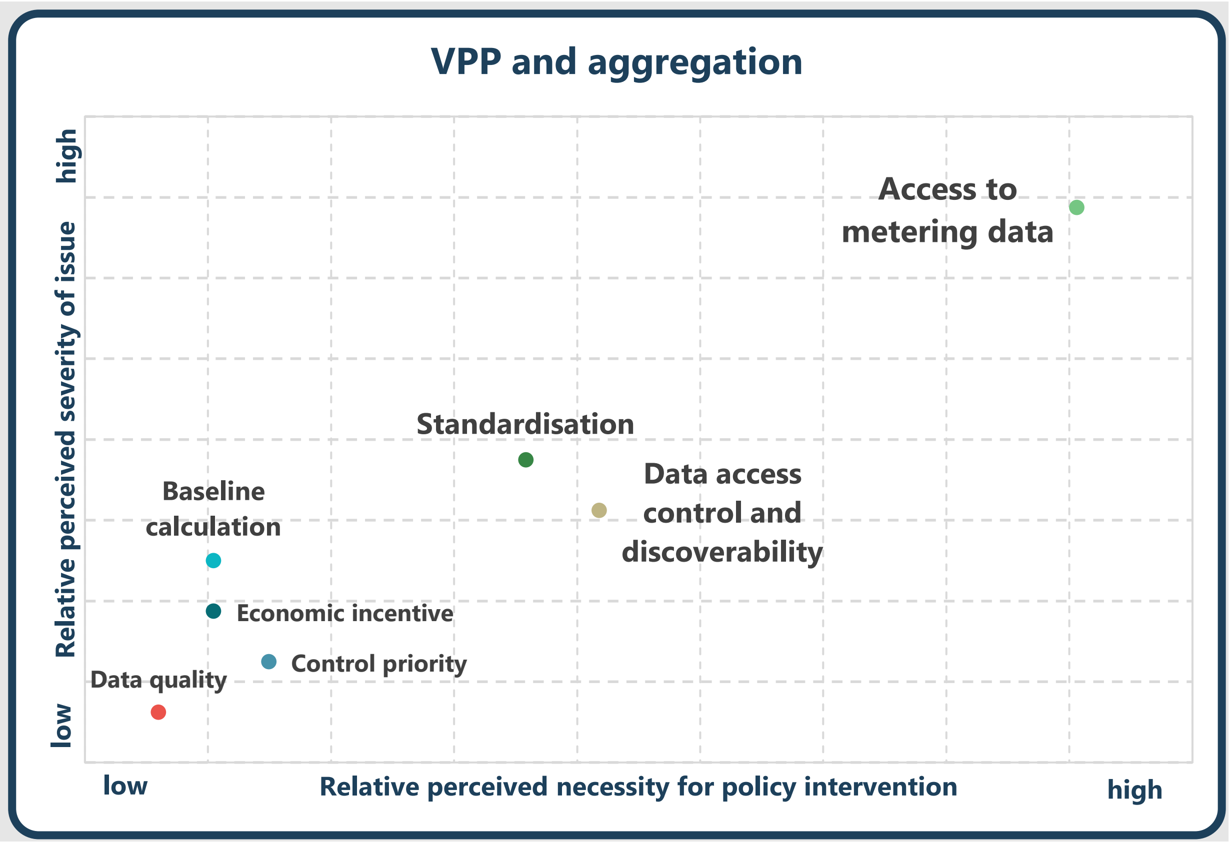
Supplementary services that an aggregator can provide include balancing group and portfolio management as well as offering their virtual power plant-as-a-service solutions to enable other market parties to aggregate and control their assets.

4.1.4 Pain points and gap analysis

The key pain points for data sharing identified as a part of this study are the access to metering data as well as the corresponding control functionality of the flexibility assets. Furthermore, issues that policymakers could address include the need for standards to smoothen onboarding and data exchange processes. Aspects such as baseline calculations and the economic incentive to offer flexibility are also important, although here the role of policymakers is less crucial.

Figure 11 shows the result from the workshop discussion on the severity of topics and the need for policy intervention. Participants evaluated the issues through scoring methods. The figure shows the relative positioning of issues among each other (see Chapter A.1.1 for details).

Figure 11: Pain points based on workshop results for the HLUC VPP and aggregation



For the identified issues a gap analysis has been performed to outline the desired state and gaps that have been identified:

Gap Analysis

Issue	Current state	Desired state	Gap
Access to metering data	Limited access and availability	Seamless access and usage	Availability and authorisation
Standardisation	Lack of common standards hindering interoperability and consistency	Standardised frameworks	Gap in standardisation, affecting interoperability and consistency
Data access control and discoverability	Limited access control; inconsistent data discoverability	Robust access control; standardised data discoverability for authorised stakeholders	Gap in comprehensive access control; standardised data discoverability protocols
Baseline calculation	Lacks standardised implementation, harmonisation, and clear validation processes	Clear principles for calculation, validation, and data exchange, ensuring replicability, transparency, and accuracy	Implementation, harmonisation, and clarity in baseline calculation methods, validation processes, and data exchange
Economic incentive	Inconsistent, fragmented incentive structures to provide flexibility services	Harmonised, transparent incentives for fair compensation	Lack of harmonisation and transparency in economic incentives
Control priority	Lack of clear rules, challenges in coordinating flexible resources	Well-defined priority rules based on system needs	Absence of clear control priority rules for effective resource coordination
Data quality	Inconsistent standards, varying data accuracy, completeness, and reliability	Defined standards, robust monitoring, and validation for high-quality data	Inadequate data quality standards, monitoring, and validation
Data security	Risks to data confidentiality, integrity, and availability	Robust security measures, encryption, access controls, and cyber security protocols	Inadequate data security measures and vulnerability to breaches

4.2 Price-responsive charging and discharging and balancing services from EVs

The e-mobility sector is growing rapidly and potentially adds great flexibility to the energy system via EV batteries. Together with the development of a European charging infrastructure, advanced, data-intensive solutions can provide flexibility, including relevant contributions to balancing services to the grid.

4.2.1 HLUC description

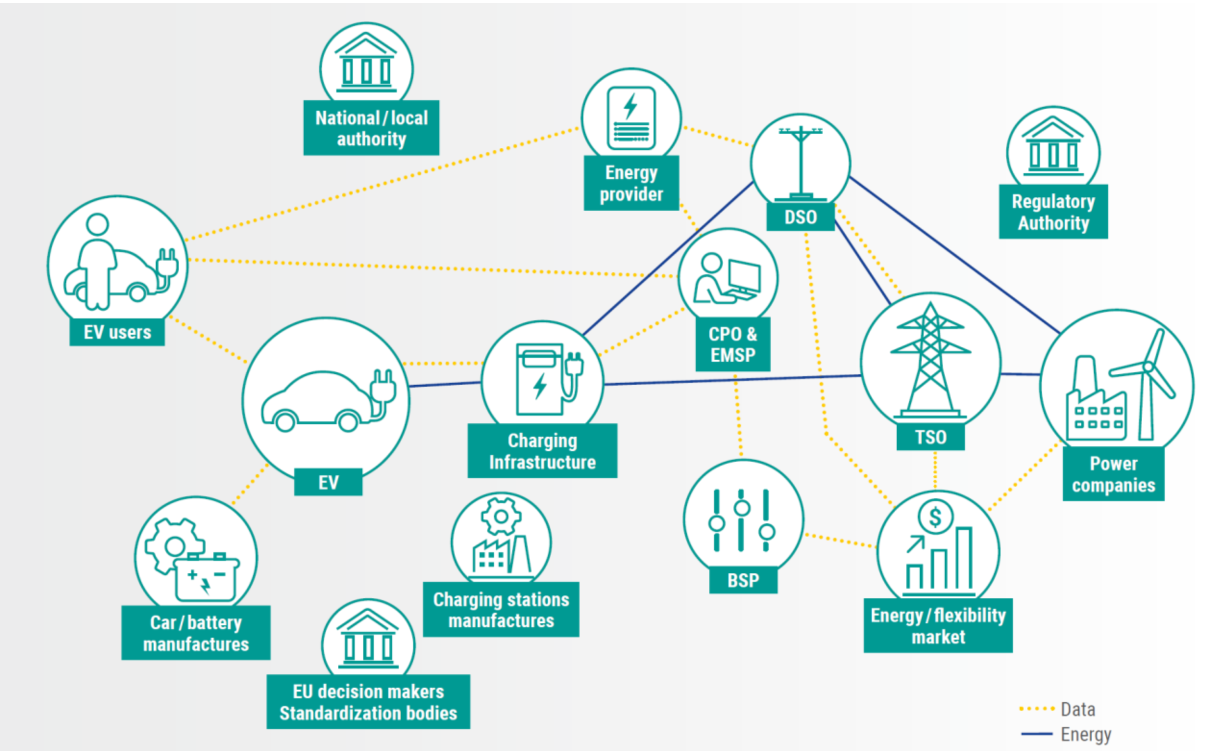
This high-level flexibility use case (HLUC) covers flexibility provided by charging infrastructure and goes beyond flexibility provided by wall boxes at residential locations (see Section 4.3 for a discussion of residential charging).

Key initiatives to implement this use case are driven by car manufactures (e.g. charging services branches or ventures of the car manufacturers like Elli, IONITY), energy companies (e.g. EnBW, Shell, Total) and charging infrastructure providers (e.g. The Mobility House, Virta). Relevant players are typically located in countries with a strong demand for electric vehicles, like Germany, the Netherlands, and France, though some initiatives are also driven by service providers located in other Member States.

The main use cases for this source of flexibility are optimisation of self-consumption (charging of self-generated electricity) and price-responsive smart charging that could also include bidirectional charging. Control requirements and data needs for the use cases in ancillary and grid services from electric vehicles are more demanding but could generate higher revenues.

Key stakeholders are users of electric vehicles, car manufacturers, charging-point operators, energy suppliers, and grid operators. The implementation of these flexibility services requires data exchanges between several of these stakeholders. Typically, service providers are included for billing purposes or to control the charging process and its duration. Further data flows are needed for grid operators on transmission and distribution levels for secure and safe grid operations (see Figure 12).

Figure 12: Data and energy flow between stakeholders in the e-mobility ecosystem



Source: ENTSO-E 2021

Maturity level

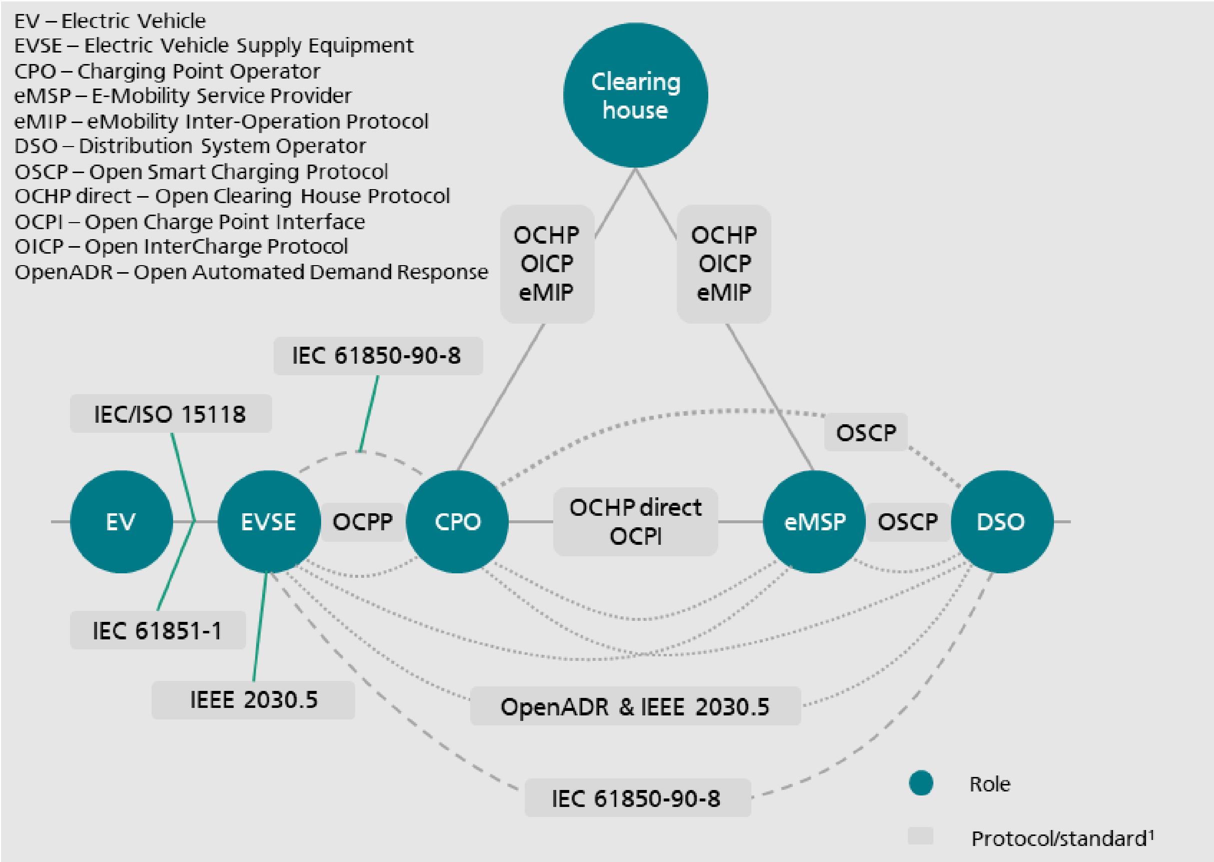
Ongoing initiatives have already reached a high level of maturity. Several platforms and apps exist that allow customers to use different charge point operators and pay them from one account, for example. Nevertheless, transparency and encouraging competition can still be improved, which could be a key advantage of an energy data space that includes data from several service providers. Solutions for the optimisation of self-consumption and price-responsive charging are already commercially mature. However, only a few existing technologies allow bidirectional charging (e.g. from (EVTEC 2023) or (Wallbox UK 2023)) and costs are higher compared to unidirectional charging units. Furthermore, only a few car manufacturers allow or are able to provide bidirectional charging capabilities to end users (e.g. Ford, Hyundai, Kia, Nissan, and Mitsubishi). Several European manufacturers provide or have announced bidirectional charging capabilities of some of their cars. Solutions are driven by large car manufacturers (OEMs) and by energy utilities, which are supported by service providers and manufactures for charging infrastructure.

4.2.2 Data management

Data management structures are established for charging and billing services by commercial stakeholders. The integration of third-party services is currently agreed on a bilateral basis between car, battery, or charge point manufactures and service providers that develop software solutions for services like billing. Providing price-responsive charging and grid services require more data and higher time resolution with some of the first commercial products being available (e.g. (Gridio 2023) or (Gridio 2023; Hive Power SA 2023)). The data required from electric vehicles to implement such solutions concern the battery's health, charge level, power set point, and capacity. The data held by charge point operators and car manufacturers could be made available to third parties if bilateral agreements are set up.

Data standards and protocols have already been defined to exchange data between several stakeholders (see Figure 13). For the communication between the electric vehicle and a charge point, IEC/ISO 15118 and IEC 61851-1 are the most relevant. Between the charge point and the charge point operator, the Open Charge Point Protocol (OCPP) has been taken up by a large number of stakeholders (including ISO/IEC). Data exchanges between a charge point and other service providers and grid operators are defined in the OpenADR standards and have been taken up by standardisation organisations like IEEE. The ISO 15118-20 standard that was agreed on in 2022 supports bidirectional charging. Beyond technical data standards, semantic models are also available for price-responsive charging and other flexibility services from electric vehicles (e.g. SAREF4AUTO by (ETSI 2023)).

Figure 13: Existing protocols and standards for charging and other services for electric vehicles



Source: based on (Living Lab Smart Charging 2017)

4.2.3 Business models

The main use cases for flexibility in the mobility sector are price-responsive charging and feed-in into the grid if bidirectional charging is feasible. Flexibility can also be provided in combination with residential electricity generation, through roof-top solar energy systems. Revenues are generated by avoiding more expensive electricity purchase in hours with higher electricity prices. This has to be linked with variable electricity prices to benefit from shifting charging times. Another revenue stream can be generated by avoiding purchases from the grid and increasing residential energy consumption, (see the section on HLUC for more information on smart residential flexibility).

For public charging infrastructure, different stakeholders are already engaged in commercial activities:

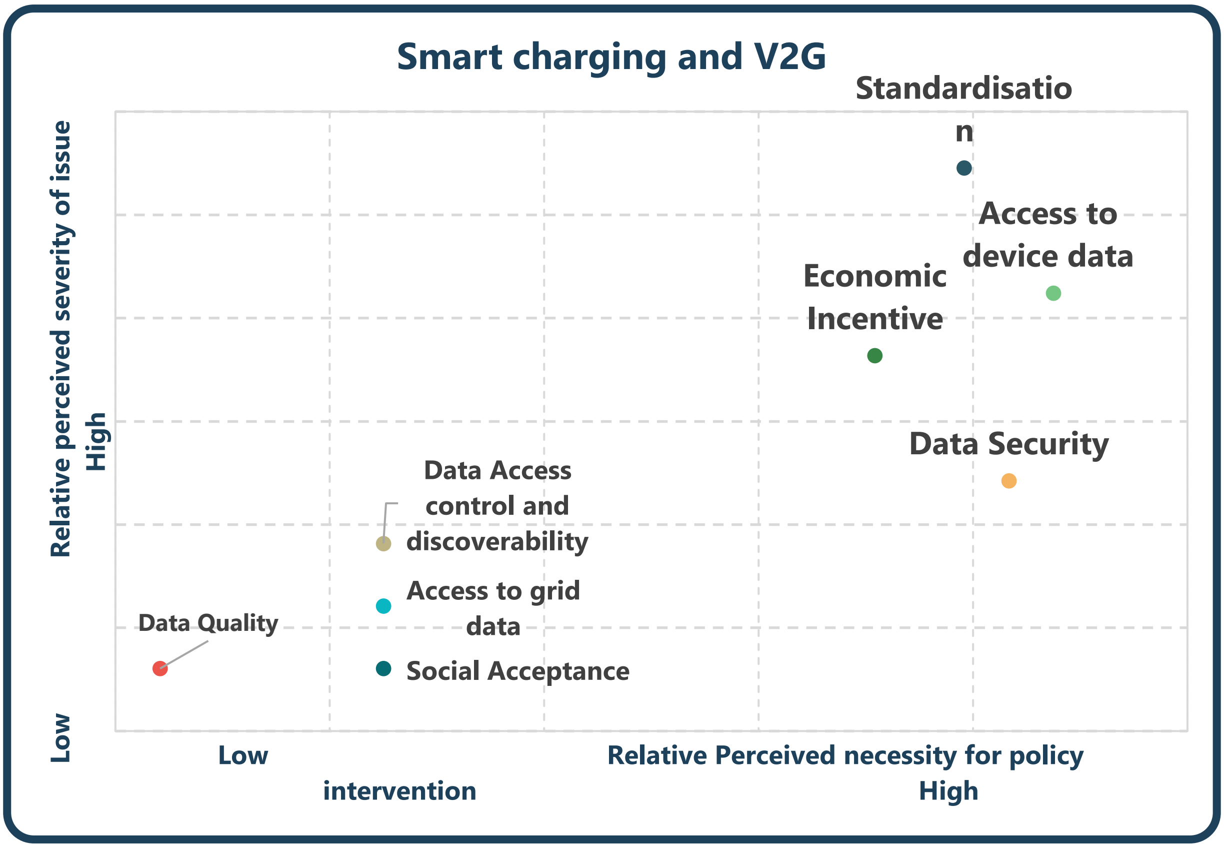
- car manufacturers on a company level (e.g. VW with Elli) and collaboratively in the automotive sector (e.g. IONITY),
- energy companies (e.g. EnBW with mobility+ app or Enel X – JuiceNet Enterprise),
- specialised service provider on charging infrastructure and operation (e.g. The Mobility House, ChargePoint),
- software providers for charging solutions (e.g. Octopus Energy, grid.io, gridX, Jedlix).

The main focus of data sharing in this use case is to provide roaming services for public charging infrastructure so that customers can easily use charging points from different companies. For charging at home, the key use case is the supply of electricity, which can be combined with variable tariffs. Use cases that allow the feed-in of electricity back into the grid are not commercially available so far and have only been tested in demonstration projects. A limited number of electric vehicles have also been prequalified for grid ancillary services, but diffusion of this approach is slow.

4.2.4 Pain points and gap analysis

Key obstacles to implement price-responsive charging and V2G services have been collected from existing studies and discussed with stakeholders in a workshop. A pain point often mentioned is the availability of and access to relevant data. This is also strongly linked with possible metering concepts (especially in the case of residential charging at home). Pain points related to residential flexibility are also discussed under Section 4.3 below. Standardised access to data and a harmonised format to exchange data are further pain points. The problem of dealing with different data formats and interfaces is especially relevant if third parties want access to data with the consent of the electric vehicle owners.

Figure 14: Pain points based on workshop results for the 2. HLUC price-responsive charging and V2G services



Gap Analysis

Issue	Current state	Desired state	Gap
Access to device data	Mainly hosted and used by car manufacturers and charge point operators	Access and findability by EV users and third party service providers; easy interoperability with other users	Access, findability, and interoperability not clearly defined
Standardisation of data exchange	Bilateral agreements between stakeholders; some harmonisation approaches ongoing	Easy access and exchange of data	Definition of requirements to allow access and exchange with user consent
Incentives to share and provide data	No incentives and requirements to share or provide data to third parties	Relevant data is provided by key stakeholders	Missing incentives and requirements
Data access control and facilitation	Closed solutions exist from commercial actors for service providers and end customers. No active facilitation ongoing	Open solutions and active facilitation	Definition of relevant actors and governance for data access and facilitation
Data security	Out of scope for this study, but still an important issue		

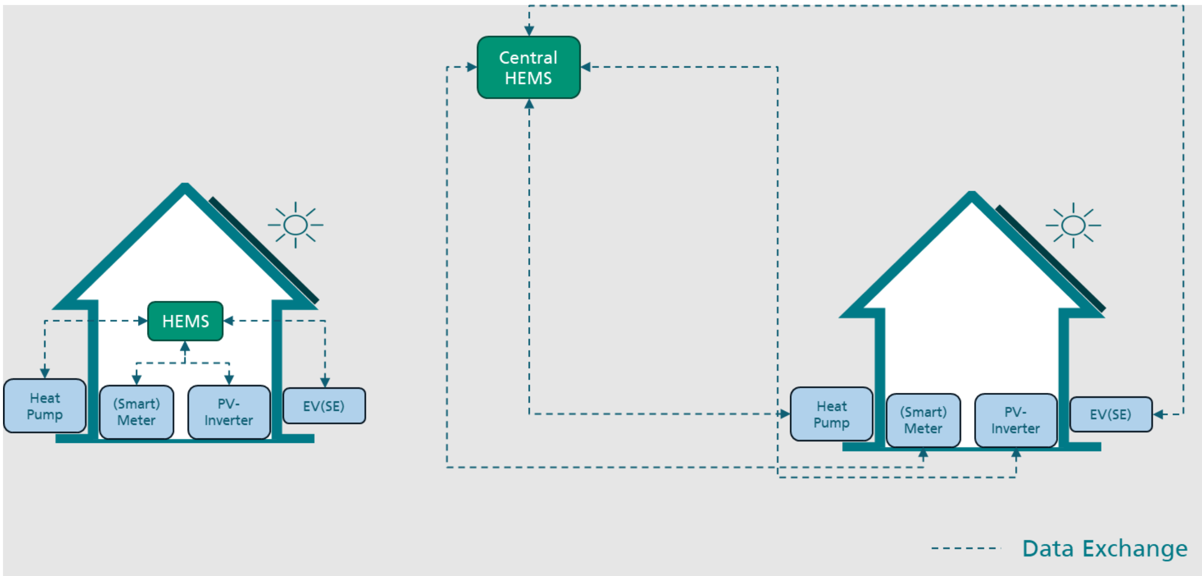
4.3 Smart residential flexibilities

The electrification and increasing interaction between the heat, mobility, and electricity sectors will be noticeable at the household level, where new devices will be integrated and managed by home energy management systems (HEMS). These HEMS will address the need for flexibility, specifically to alleviate grid congestion. HEMS are supposed to be designed to provide financial incentives to trade flexibility on the wholesale market, while serving households that produce their own energy or within an energy community. Thus, HEMS will have to serve all purposes. As personal data is used, a space for sharing data also needs to take privacy into account.

4.3.1 HLUC description

The third and last high-level use case, smart residential flexibilities, focuses on front-of-the-meter applications for deploying flexibility for congestion management as well as spot market optimisation. From a technology point of view, HEMSs are key enablers to utilise the flexibility. Such systems can integrate many flexible devices such as heat pumps, stationary home battery systems, electric vehicle supply equipment (EVSE), air-conditioning units, controllable thermostats, and others. As is depicted in Figure 15, a HEMS can be centralised or decentralised. A decentralised HEMS has no remote connection to devices outside of the building during its day-to-day operation. All data collected from and transmitted to the device is processed and stored locally. On the other hand, the centralised HEMS usually uses the cloud to store all data. In such a system, no additional hardware is installed in the building as all devices are managed by a central system. Both designs are possible, but current state-of-the-art systems typically combine both. This approach can take advantage of the potential benefits of a higher control quality as well as the aggregation capabilities of a local system with the advantages of using additional central data sources and storage capabilities. In addition, central systems can facilitate central access to the OEM clouds of flexible assets, such as electric vehicles or heat pumps. Moreover, central systems facilitate interaction with central energy markets. (Papaioannou et al. 2022; Wargers et al. 2022a).

Figure 15: General approaches of HEMS architecture: decentral vs. central (simplified)



Source: Own illustration (derived from Wargers et al. 2022b)

In general, HEMS might support demand-side management, allowing an external party, such as a resource aggregator or system operator, to directly control a household's energy flows at the PCC or of specific devices (e.g. maximum power in-/output or specific power flows). However, in the case of demand response, the HEMS might consider price signals like real-time pricing, day-ahead market prices, or variable grid fees in its optimisation algorithms. In both operation modes, a HEMS can still incorporate other objectives, such as maximising local consumption of PV-produced and home battery energy, or individual user preferences. Examples for the later can be a minimum charging level of an EV at a given time or a pre-defined temperature range in a house.

Maturity level

As the commercial initiatives in the inventory show, the generic technology of HEMS is available and operational across Europe. This ranges from solution providers such as Voltalis SA, which aggregates remote electric heating thermostats with a central cloud system in France to sonnen GmbH, a German OEM with a digital ecosystem around its core hardware product, a battery storage system. Devices such as a PV inverter, a heat pump, or an EV charger can be connected to the ecosystem on-site. In addition to local optimisation, their system allows local components to be centrally connected in a VPP to provide ancillary services and energy trading (sonnen GmbH; VOLTALIS SA 2023).

From a general perspective, it should be noted that energy communities, especially renewable energy communities (RECs), can be integrated into a HEMS solution if a central component organises their overall interaction. For example, the HEMS's edge device receives forecasts of in-front-of-meter REC's generation assets to increase its consumption behind-the-meter. However, not all Member States have implemented favourable national legislation to encourage such an approach. An exemplary solution provider with edge and cloud components is Cleanwatts S.A., situated in Italy and Portugal (Cleanwatts S.A. 2023).

4.3.2 Data management

Depending on the business model and technical approach, the required data sets for these use cases may vary significantly. If a service provider uses the energy management functionalities of an OEM to control single assets, e.g. for a ToU tariff, it might be sufficient to receive lower resolution data (in the range of a few minutes) together with the settlement period data of smart meters via the AMI (typically 15 minutes).

If on the other hand, an aggregator engages in more sophisticated market approaches like intraday-market optimisation or ancillary services with higher quality requirements, additional data requirements might be necessary. In these cases, market actors usually apply central components with additional data demands (up to second-based data with low latencies). At a local level, an even more granular data resolution might be required to follow, for example, control signals at the PCC or on single devices (under one second). The same applies to the primary use case of maximising local household consumption, when high-resolution metering data, typically at the PCC, might be used for the local control algorithms of a HEMS. The same can apply to local grid congestion management, such as when a power limit at the PCC is given. Finally, a HEMS controls local devices to achieve its specific optimisation objectives. The primary data points required in these types of data exchanges are the current power flow of a device, as well as the exchange of set-points or comparable mechanisms to adjust the power uptake responsible for the feed-in of relevant devices. However, there can be additional data points that support further features for improved control quality, user comfort, etc. (Papaioannou et al. 2022)

In practice, multiple interfaces might be used to exchange data with or within a HEMS as the following list of current low- and high-level protocols shows. Furthermore, proprietary interfaces, such as those based on local hardware or application programming interfaces (APIs) of OEM clouds, might be used in practice.

Table 5: Low- and high-level protocols for data exchange with or within a home energy management system

Protocol	Open source implementation	Licence required	Level of semantic implementation
BACnet	Yes	No	
ECHONET Lite	Yes	No	
EEBUS (EN 50631, VDE AR-E 2829-6	No	No	
IEC 61850	No	No	
IEEE 2030.5 Smart Energy Profile (SEP) Application Protocol / Zigbee	Yes	No	
KNX	Yes	Yes	
LonWorks (ISO/IEC 14908)	No	Yes	
Modbus	Yes	No	
OCF Framework	Yes	No	
OCPP	Yes	No	
Open Automated Demand Response (OpenADR)	Yes	No	
OpenTherm	Yes	No	

Protocol	Open source implementation	Licence required	Level of semantic implementation
Project Haystack	Yes	No	High-level protocol
Sigfox	No	Yes	Low-level protocol
SunSpec	Yes	No	High-level protocol
Energy Flexibility Interface (EFI)	Yes	No	Low-level protocol
Thread	Yes	Yes	Low-level protocol
Z-Wave	Partially open	Yes	Low-level protocol
IEC 63380	Under development	Under development	

Low-level protocol High-level protocol

Sources: (Coote 2022; Flexiblepower Alliance Network and LCP Delta 2023; Hilpert et al. 2023; Papaioannou et al. 2022; Project Haystack Corporation 2023; SunSpec Alliance 2023; Thread Group, Inc. 2023; WAGO Corporation 2023; Wargers et al. 2020).

4.3.3 Business models

If a HEMS should receive direct or indirect control signals, it would normally require at least one remote connection to an external party. This might be via an on-site link to a smart meter with, for example, power limits or price signals, or an external link, like a cloud connection. If this connection cannot be established easily by existing communication networks, e.g. the EV's on-board sim card or a consumer's private network, additional independent information and communications technology (ICT) solutions may need to be installed on-site by their own work force or with the help of qualified service contractors.

An aggregator can earn revenues through arbitrage trading on the energy market or via the ancillary service markets of service operators (SOs). While a final customer, as the target of HEMS-based services, could receive part of the revenue, another way to organise the market would be to aggregate customers into a balancing group with compensation for deferred consumption and additional production distributed across that group. This allows the customers to reduce their energy costs while the service provider might keep part of the savings achieved through the reduced balancing costs. Both options follow a revenue-sharing model. In addition, a HEMS service provider might also deliver cross-selling services, such as additional smart home devices with no strong link to flexibility provision, or leasing options for EV or PV units.

The benefits provided by these kinds of services are that they could incentivise energy production at a community level (also increasing competition), while also increasing flexibility in the system, which is critical to the energy transition. Another benefit arises in the context of the typical, primary use case of HEMSs, which is to maximise self-consumption of behind-the-meter generation assets, like PV generators. HEMS providers usually offer better electricity rates compared to normal operation without smart integration. Moreover, the customer can benefit from an easier to use system with a single point of access to all assets, which can meet a customer's preferences better. In the specific case of demand-side management on the spot market, an aggregator typically covers all relevant roles and responsibilities, such as resource aggregation, energy supplier, BRP, energy trader, etc. This might be performed by a single party or in cooperation with other market players.

While sophisticated models can provide multiple benefits, simpler models — like demand response with a ToU tariff for the entire household or a single asset — can still be a starting point to foster flexibility. A comparable level of simplicity might be feasible for local grid congestion schemes, such as when a defined power limit is provided. Here, a HEMS can optimise energy use within a pre-set boundary. However, if this limit needs to vary according to the grid situation, then usually more parties are involved. The same applies if the flexibility is to be provided in a more attractive market segment, such as centrally organised congestion markets with stricter quality requirements, where aggregators' participation is crucial.

A common element for these flexibility provisions are smart meters or, if these provide insufficient data granularity, an additional meter that can receive the necessary data for near-real time control actions. Nevertheless, access to the AMI is still required to perform at least settlement activities for individual consumers by accessing the validated data from a metered data administrator. For purposes such as these, market actors use energy data management systems to handle the data exchanges. In particular, trading systems are used to interact with the nominated power market systems of the market operators. They also provide services via ancillary service systems such as the platform Equigy, possibly in combination with the different ERP systems (Equigy B.V. 2023).

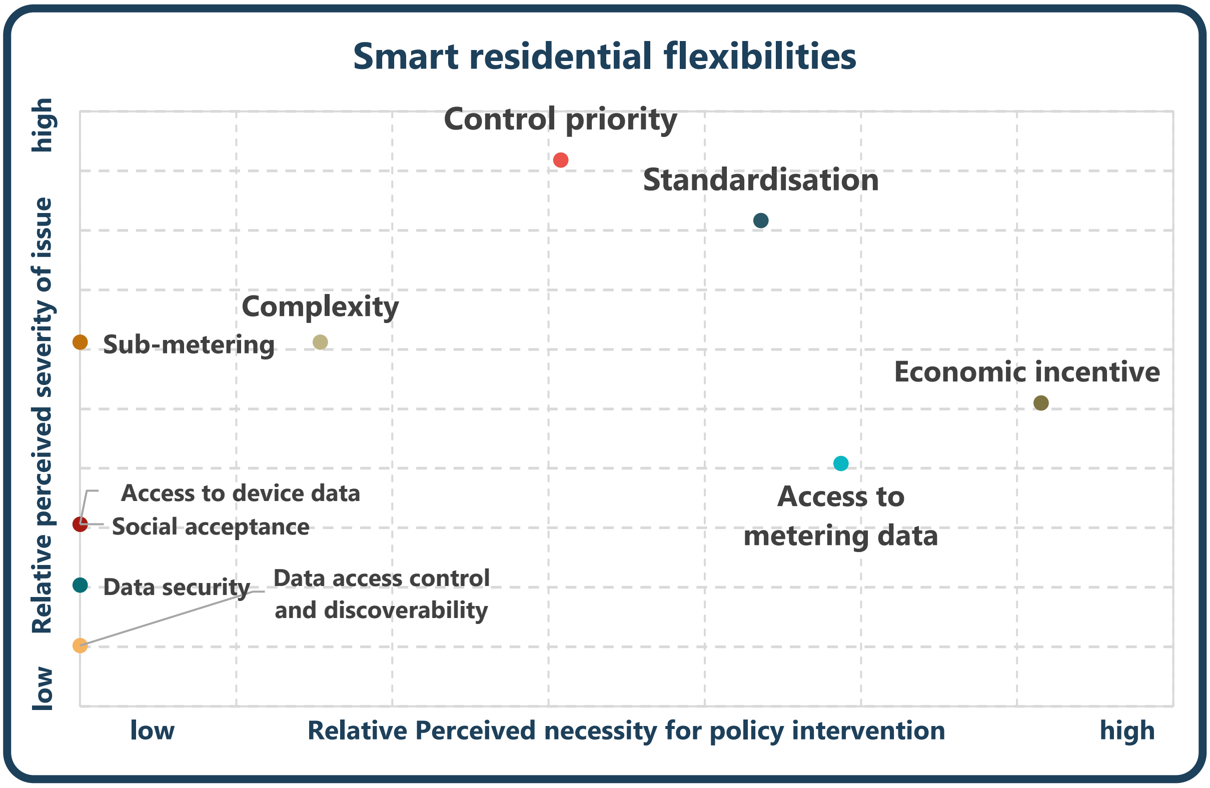
With individual homeowners as the main target group for HEMS-related business models, various IT systems can be deployed to interact in an efficient and streamlined manner (e.g. online customer portals or smartphone applications), avoiding the need for direct contact via on-site or remote service personnel. Their involvement is particularly required during the planning, commissioning, or in case of faulty operations of a HEMS. And last, but not least, the HEMS itself, its hardware and software components, must be designed and developed by the service provider itself with or by other involved parties.

4.3.4 Pain points and gap analysis

Similar to the previous HLUCs, obstacles to data exchanges have been identified in a stakeholder workshop as a part of this study. The results can be found in Figure 16. Due to the large number of stakeholder inputs, only the most relevant pain points were integrated into the final round of voting for possible policy intervention (in the given time of the workshop)[5].

[5] It was also only possible to discuss selected contributions. This made it partially necessary to draft an interpretation by the authors of the given sticky notes, which might lack specificity or contradict the intended contribution of a workshop participant. These limitations should be considered when analysing the following results.

Figure 16: Pain points based on workshop results for HLUC Smart residential flexibilities



Note: Policy interventions have not been voted on for all pain point categories

Gap Analysis

Issue	Current state	Desired state	Gap
Economic incentive (to participate in flexibility provision with residential flexibilities)	*Out of scope for the purpose of this study (but still very important)*		
Standardisation	Generally, this HLUC suffers from the challenge of integrating devices from many different OEMs in order to integrate all available flexibility on-site. Typically, only proprietary interfaces or low-level standards like Modbus, as well as single (device) standards are available at Member State level. Moreover, as a typical two-side-business	On the one side, all devices, (smart) meters and flexible assets provide open and standardised interfaces in a plug-and-play manner regardless of the access point (on-site, OEM-cloud, etc.). On the other side, market access via energy suppliers and energy traders, or the trading platforms themselves, are fully transparent and non-discriminatory. This is supported	Current proprietary or low-level interfaces still dominate the market. As a consequence new on-site OEM independent, integrating interfaces like EEBUS (EEBus Initiative e.V. 2023) or S2 (Konsman et al. 2022) have developed; however, their maturity and adoption rate still have a large potential, especially at EU level.

Issue	Current state	Desired state	Gap
	model, service providers must not only deal with the consumers' on-site devices, but also with the energy market systems. Here issues might occur due to the lack of uniform access and registration processes.	by open APIs that apply standardised data formats.	On the market side, NEMOs foster the development of standardised, open APIs; however, the technically more sophisticated actors typically use individual systems with their own APIs. With ancillary service provision, new uniform market access systems like Equigy (Equigy B.V. 2022) have appeared, but only in some Member States and for chosen ancillary market products.
Access to metering data	Limited access and availability (like HLUC 1)	*Seamless access and usage (like HLUC 1)* Near real-time values, with a high granularity of under one second (around 2 Hz) for sophisticated AI algorithms at the edge of HEMS with low latency values (around 750 ms)	*Availability and authorisation (like HLUC 1)* [6]
Control priority	A building as well as single devices might receive control signals from one actor or energy management system via a device or an OEM cloud.	*Well-defined priority rules based on system needs (like HLUC 1)* Clear control options for consumers so that they can set the primary controller.	*Absence of clear control priority rules for effective resource coordination (like HLUC 1)* Today, consumers are responsible for avoiding conflicts between separate, conflicting systems. These conflicts must be solved at a technological level if different ecosystems are deployed.

[6] New beneficial developments can be expected with the recently adopted Commission Implementing Regulation (EU) on interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data (European Commission 2023g).

Issue	Current state	Desired state	Gap
Complexity	The general complexity of HEMS increases, such as with new billing options (at device level), different sub-metering data (cross-sectoral), the number of actors (OEMs, energy market actors, installation personnel), and the number of systems installed.	If new complexity arises, the required development should be as transparent and clear as possible to all relevant parties. Possible issues with higher adoption rates should be analysed upfront.	European and national regulation in digital and energy policy is quite dynamic, influencing business models and technological choices. At the same time, a multitude of actors and devices add complexity and uncertainty, especially for SMEs. Moreover, policies might not always address cross-sectoral dimensions, which can lead to challenges in HEMS operation when not only the electricity sector is involved. Separating electricity and gas regulation from the heating/cooling and water sector can cause issues.
Sub-metering	The access and reliability of sub-meters is in question.	In each relevant sector, sub-meters fulfil standardised minimal reliability criteria. Moreover, access to meters must be granted via open interfaces, and these are ideally highly standardised (like the cross-sectoral open metering system standard (OMS-Group e. V. 2023))	Sub-meter's capabilities might vary substantially between sectors within a Member State or within a sector across different Member States. If a sub-meter supports an interface, low-level standards like Modbus are usually applied.
Access to device data	HEMS solutions might not receive access to device data required for flexibility provision.	Each OEM provides a transparent, simple, and interoperable access to the devices of a consumer by request.	Not all connectable devices have an open, standardised API to allow a low-cost control access for HEMSs. Consumers may suffer vendor lock-in. [7]

[7] EnTEC-team: Future improvement might be able with the up-coming European *Code of Conduct on energy management related interoperability of Energy Smart Appliances* for OEMs (European Commission 2023c).

Issue	Current state	Desired state	Gap
Social acceptance	Consumers might not want their devices to be used to offer flexibility services because they do not trust the way that flexibility will work, face unclear incentives or have insufficient knowledge of the data exchanges.	Transparent and clear information concerning associated risks, costs, and payment possibilities are available to the customers (from independent sources and from service providers). Moreover, market actors should provide simple and understandable data access and analytic tools to help consumers.	The application of HEMSs can be very complex. Therefore, it might not always be easy to communicate the implications of flexibility provision to consumers. This is especially challenging when there are multiple ecosystems.
Data security	Increased cyber security threats also affect HEMSs, and as a result, IT-security must keep consumer's data safe while protecting the power grid from unintended HEMS operation.	Cyber security must be strictly coordinated over the entire supply chain for a HEMS ecosystem.	A diverse landscape of HEMS solution providers and different-sized OEMs can reduce resilience against cyber-attacks if this multi-supplier network is uncoordinated.
Data access control & discoverability	*Limited access control; inconsistent data discoverability (like HLUC 1)*	*Robust access control; standardised data discoverability for authorised stakeholders (like HLUC 1)*	*Gap in comprehensive access control; standardised data discoverability protocols (like HLUC 1)*
Data quality	*Inconsistent standards; varying data accuracy; completeness; reliability (like HLUC 1)*	*Defined standards; robust monitoring; validation for high-quality data (like HLUC 1)*	*Inadequate data quality, format, standards, monitoring, and validation (like HLUC 1)*
Baseline calculation	Missing standardised baseline calculations to uphold quality control and accurate settlement.	Transparent, clear, and non-discriminatory baseline calculations must be developed at Member State level and in the long-term at EU level to avoid competitive issues and reduce transaction costs. The first step in this direction is the *Framework Guideline on Demand Response* from ACER 2022.	Baseline calculations vary by Member State and for different market products like balancing services and spot market trading. It is also possible that no clear regulations exist if two independent parties must interact with each other (e.g. resource aggregator and energy supplier).

Take away – characteristics of high-level use cases for providing flexibility services

- → Access to metering data is an enabler for flexibility services as well as a prominent pain point across all use cases.
- → Access to standardised device and battery data from the automotive and heat sector will facilitate and improve flexibility services.
- → A smooth onboarding process to aggregation services will support the uptake of flexibility services and empower owners and operators to switch between aggregators easily, thus enabling competitive market conditions.

5 The role of data spaces

Data spaces are designed to share data in a secure, efficient and controlled way using standard building blocks for interoperability, accounting for data sovereignty, ensuring legal compliance and other legal, technical or operational aspects. The Open DEI initiative defines a data space as "a data ecosystem, defined by a sector or application, whereby decentralised qualitative and quantitative infrastructure enables trustworthy data sharing with commonly agreed capabilities (data sovereignty and roles) (Nagel et al. 2021).

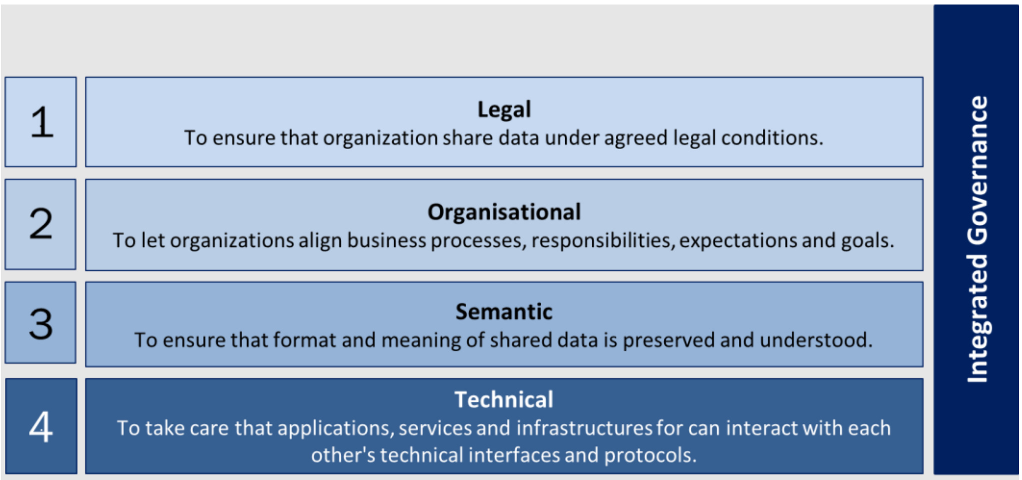
This chapter contains a brief overview of the architectural components of data spaces, the data space role model, and introduces its technical building blocks. Given that the data spaces blueprint is still being defined by the Data Space Support Centre (DSSC 2023b), we build this analysis using the concepts as defined in the Open DEI Design Principles for Data Spaces and the Reference Guide for Intra Data Space Interoperability (NL AI Coalition 2023).

Section 5.1 introduces four interoperability levels for data spaces; Section 5.2 elaborates on the data space role model, and Section 5.3 provides a set of generic data space building blocks. The concluding Section 5.4 combines and applies these data space concepts to explain how they can address the pain points in the use cases discussed in the previous chapter.

5.1 Interoperability framework

A system of categorising the aspects of interoperability is provided by the new European Interoperability Framework (EIF) (European Commission 2017). Data space interoperability is more than technical interoperability: the EIF distinguishes four interoperability levels under an overarching integrated governance approach.

Figure 17: European Interoperability Framework



Source: (European Commission 2017)

5.1.1 Legal interoperability

Legal interoperability encompasses an accession agreement, which is a contract between all participants and the owner of the data space, along with legal agreements for each transaction, known as "data service transaction agreements."

When a party signs an accession agreement, it becomes a participant in the data space and must comply with the overarching legal agreements associated with the scheme. The accession agreement may refer to terms-of-use that outline the rights and responsibilities of each participant and the scheme owner. These terms specify the requirements that participants must adhere to, ensuring the data space and its scheme function properly.

Legal matters are primarily addressed by predefining these multilateral legal requirements when accessing the data space. Alternatively, international architecture initiatives for federative data sharing, such as IDSA and Gaia-X, provide the ability to negotiate legally binding agreements for each data sharing transaction. An architecture is being developed to facilitate the negotiation of such agreements and enforce usage policies. However, the technical and market viability of these developments for large-scale deployment still needs to be demonstrated.

5.1.2 Organisational interoperability

Organisational interoperability pertains to the alignment, monitoring, and management of agreements, processes, and expectations on shared objectives for controlled data sharing within a network of data sharing organisations. This means establishing processes for onboarding and certification as well as adhering to commonly accepted criteria. It also includes defining service level agreements to meet overarching expectations and ensure quality control, as well as aligning operations and customer processes to enhance operational efficiency and improve the customer experience.

5.1.3 Semantic interoperability

Data spaces may use existing (generic) data space information models and require domain-specific information models. Typically, these domain-specific information models are supplied by specialised vocabulary providers (outlined in the role model below). Adopting a shared semantic model that is used by both data service providers and data consumers offers significant benefits in reducing complexity for interconnection and collaboration. Therefore, data spaces include semantic management. This can be achieved through a vocabulary hub, responsible for managing, registering, and publishing vocabularies (such as ontologies, reference data models, or metadata elements) as well as employing semantic transformation applications that facilitate user-friendly mappings between semantic models.

5.1.4 Technical interoperability

Technical interoperability encompasses the software and hardware components necessary for secure, controlled, and sovereign data sharing. It requires appropriate governance and includes the following aspects:

Secure connectivity: this involves establishing secure peer-to-peer connections to facilitate data sharing between participants in a protected manner.

Identity authentication and authorisation (IAA): IAA ensures that participants' identities are verified and authorised appropriately, maintaining the security of the data exchange.

Generic data space information model: this model serves as the foundational semantic framework for communication among data space participants. It defines the semantics used for modelling metadata, enabling effective data understanding and exchange.

Security gateway: technical interoperability enables the use of a security gateway, which ensures controlled and secure data sharing with other participants' security gateways. It also allows the security gateway to describe and publish the provided data service in a metadata broker using self-description capabilities.

Metadata brokering: this involves managing, registering, and publishing resources within a data space, such as data sets, data services, algorithms, and computing capabilities. The metadata broker makes these resources searchable and accessible both within and across data spaces. By federating multiple metadata brokers, they can collectively act as a comprehensive broker across various data space instances.

App enabling: this refers to facilitating the easy deployment of third-party data apps within the data space. It involves providing an application container environment (ACE) and capabilities for automated deployment of data apps, streamlining the process.

5.2 Data space roles

The advent of data spaces signifies a transformative shift in data governance. This shift, elaborated on in prior discussions, entails a comprehensive interoperability framework, encompassing legal, organisational, semantic, and technical facets. Beyond addressing technicalities, this approach engenders diverse responsibilities. Data spaces introduce new roles and corresponding obligations, redefining how entities engage in collaborative data sharing. This segment delves into these emerging responsibilities, laying the foundation of the data space framework.

The business role model for data spaces (NL AI Coalition 2023) builds and extends upon the work of the EU Open DEI initiative, which further elaborated the ambition as expressed in the EU Data Strategy. This business role model fulfils a primary (business) activity for data sharing.

The model distinguishes four categories of business roles for data spaces:

- core roles,
- intermediary roles,
- software and services roles, and
- governance roles.

5.2.1 Core roles

Organisations that fulfil a core role are required every time data is shared or an algorithm used in the data space.

Core roles are subdivided into seven sub-roles:

Beneficiary: the beneficiary is interested in a result of the interaction. The beneficiary receives the results that are requested from an orchestrator.

Orchestrator: the orchestrator manages the intended interaction and ensures that the algorithm yields the intended results for the beneficiary. The orchestrator manages the policies for what it orchestrates. The orchestrator understands what core modules are required and is responsible for properly assessing policies that are relevant for the intended result. It is the single point-of-contact for the beneficiary.

Operator: the operator is responsible for providing an environment for executing algorithms on the data. As such, it provides a capability (building block) that is referred to as the 'application container environment (ACE)' in which the security gateway and the algorithms are executed with the required data to produce the intended results. The operator is also responsible for properly assessing policies that are relevant during the execution.

Data services provider: data services providers hold data in the data spaces and make the data available in a controlled manner. The data services provider manages policies for the data it is holding. For example, it manages and enforces access and usage policies and provides additional policies to the operator. The data services provider also manages the quality and availability of data on behalf of data entitled parties.

Data entitled party: data entitled parties have one or more entitlements, such as having control over or being the subject of the data as provided by a data services provider. The data entitled party has the right to define the terms and conditions of use for data to which it is entitled.

Algorithm provider: algorithm providers hold the algorithms that are used in the data spaces. The algorithm provider manages and enforces policies for the algorithms it holds, such as for access and usage. It shares the policies with the operator. The algorithm provider also manages the quality and availability of algorithms on behalf of algorithm entitled parties.

Algorithm entitled party: algorithm entitled parties have one or more entitlements to the algorithm as provided by an algorithm provider. The algorithm entitled party has the right to define terms and conditions of use for the algorithm to which it is entitled.

5.2.2 Intermediary roles

The data space intermediary roles enables interaction between organisations fulfilling core roles by providing metadata, support services, and establishing trust.

Broker services provider: provides the ability to register, manage, and reveal information about the resources available in a data space, such as data services, algorithms, and computing resources. Moreover it can support the offering of data resources and services under defined terms and conditions.

Data usage accounting provider: provides and manages the basis for accounting access to and usage of resources (e.g. data, algorithms) by participants. It includes registering data transactions that have taken place, also for clearing, billing, and conflict resolution.

Data exchange facilitation provider: this role facilitates commercial relationships for data sharing between multiple data holders and users using a data app and cloud service for storing and sharing data points. It ensures that the technical, legal, and ethical aspects of data exchanges are adhered to while respecting the rights of the parties involved. Services include establishing agreements between parties, registering and managing data resources, and enforcing terms and conditions for usage.

5.2.3 Software and services roles

The data space software and service roles are fulfilled by IT companies providing software and services (e.g., in a software-as-a service model) to the participants of the data space.

App store provider: provides data apps which contain applications (e.g. algorithms) that may be deployed within the secure processing environments of the data space, such as in a participant's security gateway or the application container environment (ACE) and related execution environment of an operator. The data apps facilitate data processing workflows. The app store provider is responsible for managing metadata on the data apps it provides.

Semantic services provider: provides services to manage semantics within the data space, including a registry of vocabularies (i.e., ontologies, reference data models, or metadata elements) and semantic mappings that can be used to annotate, describe, and transform data sets. Moreover, the transformation of data sets can be provided as a separate service.

5.2.4 Governance roles

The data space governance roles coordinate the set of commonly agreed upon principles within a data space and manage the compliance of data space participants to these principles. The data space governance roles provide the capacity to enforce the 'agreement framework', which is sometimes also referred to as the 'trust framework'.

Data space authority: responsible for the (legal and operational) agreements within a data space and for certifying participants and components in the data space. Data spaces, consisting of the previously described roles, may potentially grow very large. In these larger data space environments, in which not all participants may directly know each other, capabilities are needed to ensure that data sharing transactions between participants are executed according to an agreed upon protocol and approach that can be trusted.

Data space identity provider: the data space identity provider offers a service to create, manage, maintain, monitor, and validate identity information of participants and components in a data space. This is required for the data space to operate securely and to avoid unauthorised access to data.

5.3 Building block architecture

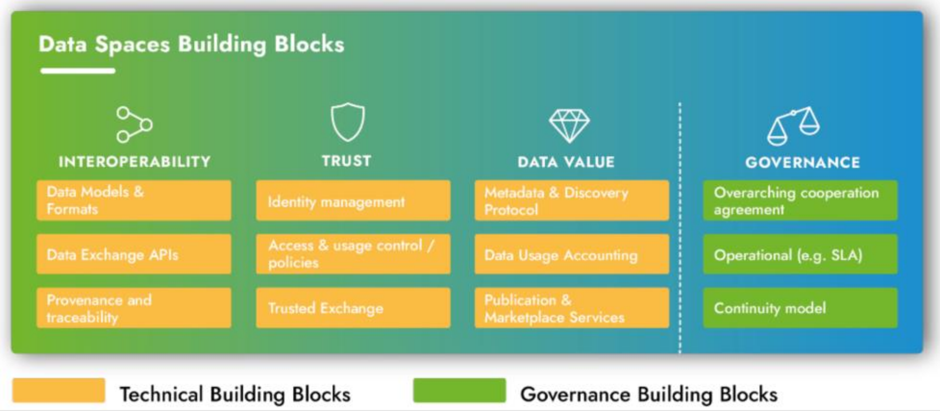
The building block architecture offers a breakdown of the data space architecture into logical and technical building blocks, jointly implementing the capabilities for realising the collaboration models and the business role model.

The following building blocks exist:

- data platforms, providing support for effective data sharing and exchange as well as for engineering and deploying data interoperability and processing capabilities;
- data marketplaces, where data-service providers can offer data and data-service consumers can request data — each can also process data for applications;
- data sovereignty, such as the ability of stakeholders to control their own data, deciding how digital processes, infrastructures, and flows of data are structured, built, and managed.

Together, these building blocks, owned by organisations in the energy ecosystem, would make up the underlying data sharing infrastructure. A commonly used building block taxonomy is the one defined by the Open DEI Design Principles for Data Spaces (Nagel et al. 2021). The taxonomy contains twelve building blocks categorised in four pillars as shown and described below. An updated version of the building block taxonomy is expected to result from the Data Spaces Support Centre project (DSSC 2023b) as part of the Data Space Blueprint. This section summarises these building blocks.

Figure 18: Data space building blocks



Source: (DSSC 2023a)

This report will now go into more details for each building block as detailed in the Open DEI Design Principles for Data Spaces position paper (Nagel et al. 2021).

5.3.1 Building blocks for data interoperability

Each data provider can ensure that any published data can be used by any data consumer with appropriate rights, while each data consumer can be sure they are able to access and use any data made available by any data provider selected.

The following building blocks belong to this category:

Data models and formats: this building block creates a common format to specify the data model specifications and represent data in data-exchange payloads. Combined with the data exchange APIs building block, this ensures that data is fully interoperable for participants. An example is the *vocabulary hub*.

Data exchange APIs: this component facilitates sharing and exchanging data between participants, encompassing both data provision and consumption. An example of a data interoperability component that offers a standardised data exchange API is the *connector*.

Data provenance and traceability: this building block offers tracing and tracking throughout the data provision and consumption process. As a result, it establishes the foundation for various crucial functions, including identifying the lineage of data and creating audit-proof transaction logs. Moreover, it allows the implementation of diverse tracking use cases at the application level, such as in the domain of monitoring energy transport.

5.3.2 Building blocks for trust and sovereignty

I. *Identity management (IM)*: facilitates the identification, authentication, and authorisation of stakeholders who operate within a data space. Its primary purpose is to ensure that organisations, individuals, machines, and other actors possess recognised identities, and that these identities can be authenticated, verified, and enriched with supplementary information. This additional information plays a crucial role in enabling access and usage control through authorisation mechanisms. An example of an IM building block is the dynamic attribute provisioning service (DAPS).

II. *Access and usage control/policies:* this building block aims to strictly enforce data access and usage policies according to established terms and conditions, to publish applications (refer to the 'publication and marketplace services ' building block below), or negotiate agreements between data providers and consumers. Data providers typically implement data access control mechanisms to prevent misuse of resources, while data consumers implement data usage control mechanisms to prevent misuse of data. In more intricate data value chains, prosumers may combine both mechanisms.

III. *Trusted exchange:* enables trusted data exchange among participants and reassures all parties in a data exchange transaction. This building block ensures that participants can validate and trust the identities of the other participants. Additionally, it verifies their adherence to the data exchange's rules and agreements. This establishment of trust is essential for fostering secure and reliable data sharing within the data space.

5.3.3 Building blocks for data value

Metadata and discovery protocol: this building block allows providers to publish and discover data and services with standardised descriptions of resources, services, and participants. These descriptions can apply generally or to specific domains. The implementation relies on semantic web technologies and incorporates linked-data principles.

Data usage accounting: this element enables tracking and accounting data access and usage by users. It facilitates essential functions like clearing, payment, and billing, even for data sharing transactions that do not involve data marketplaces.

Publication and marketplace services: offering data resources and services with clearly defined terms and conditions requires marketplaces. This building block supports the publication of these offerings and manages processes related to creating and monitoring smart contracts. These contracts comprehensively describe the rights and obligations for data and service usage, ensuring secure access to data and services.

5.3.4 Building blocks for governance

Overarching cooperation agreement: a business process framework for data spaces offers several potential benefits. Firstly, it provides an organised and comprehensive overview of all the capabilities required for data sharing. This overview serves as a guide for developing a logical and modular IT architecture for data sharing. It defines the specific capabilities that each role within the data space should possess and identifies the constituent building blocks necessary for supporting those capabilities. Secondly, a business process framework lays the foundation for interoperability by requiring Application Programming Interfaces (APIs) that expose the functionalities of each building block within the data spaces. These APIs reduce the costs associated with integration efforts, streamlining the process of connecting and coordinating components within the data space. An aligned data space-process framework significantly facilitates and promotes the adoption of data sharing. It provides clarity, guidance, and completeness in identifying capabilities, supporting the development of a modular IT architecture, and reducing integration costs.

Service level agreement (SLA) service components: these components define the business relationship and responsibilities of actors, overseeing the exchange and sharing of data.

The continuity model describes the processes for managing changes, versions, and releases for standards and agreements. This also includes the governance body for decision-making and conflict resolution.

5.4 Address the pain points identified in Chapter 4

From the identified gaps and pain points in the use cases, three stand out that specifically relate to data space building blocks:

1) technical access to metering, device or other data,
2) standardisation and,
3) data access control and discoverability.

In the following sections, these are discussed for all use cases.

5.4.1 Access to metering data

The main challenges are posed in the following areas:

- Legal interoperability: the use of metering data is currently limited to consumers and utility companies, and grid operators for specific use cases with explicit consent. Privacy and people's trust regarding the sharing of data are of utmost importance.
- Technical interoperability: the physical and data space infrastructure must be ready; smart meters, - part of the physical infrastructure necessary - are not yet widely available in all EU countries.

Generic data space building blocks to address access to metering data exist; pilot projects are being executed; solutions need to be implemented and made ready to scale.

- Required data space solutions for access to data exist. These are part of the "minimal viable data space" components, including a data space connector, identity provider, and metadata broker implementations.
- Convergence in data space architectures and technical specifications is slowly taking place (e.g. by DSSC (DSSC 2023b) and DSBA (Data Space Business Alliance 2022)).
- Privacy preserving technologies and data services for metering data are developed and evaluated in HEU projects (e.g. by BD4NRG and ENERSHARE).

Data space roles that are key to properly address the challenge to access metering data are, for example, an app store provider, a data provider and the data space authority.

5.4.2 Standardisation

The main challenges are encountered in the following areas:

- Semantic data interoperability and standardisation is needed for IT systems to understand each other. This includes the data models and metadata.
- Technical interoperability between different (software) implementations is needed within a data space and also interoperability across data spaces for inter-energy or cross-domain use cases. Currently, many different architectures are in development, all addressing more or less the same building blocks. Convergence is needed.

Data space building blocks to address data interoperability are:

- For the energy domain, there are already a couple of recognised organisations that provide (standardised) data models and data-exchange specifications. These include the BRIDGE Data Management group, CEN-CENELEC, and ETSI.
- Convergence in data space architectures and technical specifications is slowly taking place (for example, by DSSC and DSBA).

Data space roles that address data interoperability are the semantic services provider and the orchestrator

5.4.3 Data access control and discoverability

The main challenge is faced in the following area:

- Semantic and technical interoperability: data consumers need to be able to easily find the data sets and services they need. Data providers need to be able to publish, market, and control access to data. It requires a marketplace as well as access and usage control functionalities from a data space.

Although the maturity level of domain-specific data models (such as to manage electrical grid measurements and parameters) is already advanced, formalised mechanisms to introduce metadata are still lacking adoption and require development. The next step would be to identify the commonly required metadata sets from which the data models and ontologies have to be derived.8 The domain-agnostic part of metadata sets can be covered by existing standards, such as the Dublin Core Metadata Element Set (DCMES) (DCMI 2012), whereas the domain-specific parts would still need further development.

Data space building blocks to address access control and discoverability vary in level of maturity:

- The building block metadata and discovery protocol is part of the "minimal viable data space" component. It is a mature building block and applied in practice in different domains (IDSA). Data usage accounting enables tracking, clearing, paying, and billing for data access and usage.
- The building block of access and usage control is mature. Development of usage control policies and enforcement components are progressing, but not yet widely adopted.
- The concept of a data space marketplace is in full motion and part of the research activities in several HEU projects.

Data space roles that address the challenge of data access control are the orchestrator and the semantic services provider.

Take away – the role of data spaces

→ Interoperability has to be dealt with not only at the technical but also at the legal, organisational and semantic level.
→ Data space technology can address pain points from HLUC with trusted data exchange and access control as well as for standardisation with semantic services.
→ Required key software components are publicly available as open source software and sufficiently mature for non-critical applications.

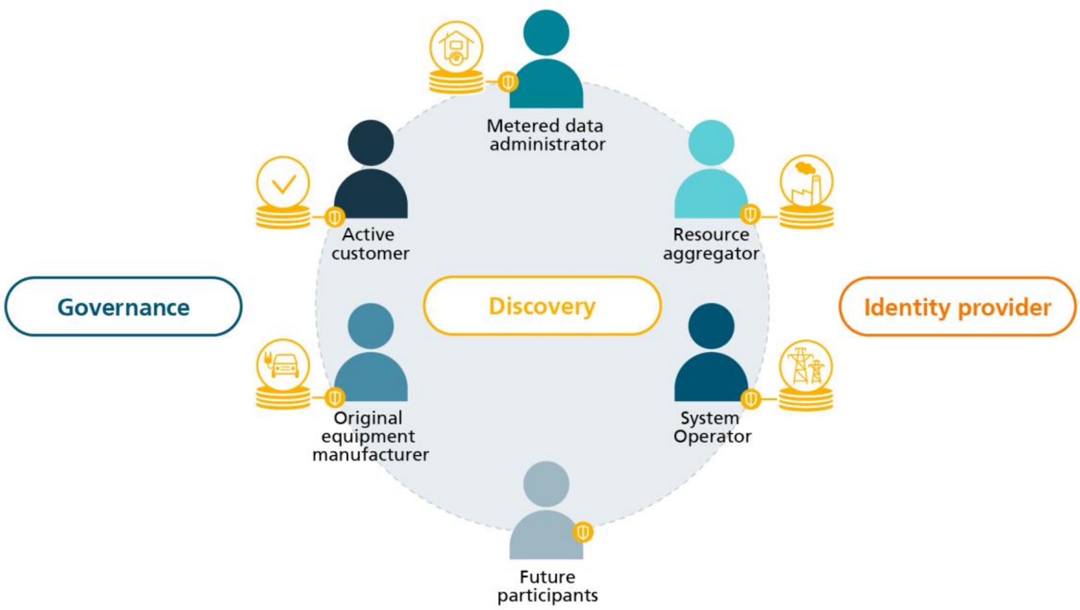
[8] The metadata should provide information about the data owner/provider and data value and accounting. It would also provide relevant information about the size of the data and the available variables. Finally, it would offer some example or aggregated values.

6 Implementation plan for data space development

The Common European Energy Data Space is to serve as the digital ecosystem for the energy sector in an integrated European energy market. It ought to provide the infrastructure for energy-related data and software services and enable flexibility provided by distributed devices from other sectors, especially from e-mobility and heating. At the same time, the ecosystem should foster digital sovereignty by empowering data owners to control access to and usage of their respective data in a secure environment.

While this vision can be realised in many ways, given the very dynamic environment and challenges in the energy sector, the following plan lays out a realistic scenario that can lead to the required data infrastructure based on European data space technology. A major objective of this infrastructure would be interoperability between data spaces of different sectors but also between different federated data spaces within the energy sector.

Figure 19: Initial setup of the Common European Energy Data Space



Source: Own illustration

The guiding principle for this implementation plan is that the data space needs to address existing challenges in the energy sector and solve pain points that have been identified in Chapter 4 so that it can provide benefits and gain acceptance with future participants. This ensures that the data space will contribute to existing business cases and create value for its participants.

Furthermore, working with a data space means adopting additional technology components, and initial efforts and investments for companies need to be reasonable with a promise of future financial benefits. Assuring and focussing on trust will be another key success factor and applies to the overall governance of the data space, the actors, and the maturity of software components at the time of rollout.

For the development of a Common European Energy Data Space, the following steps need to be taken:

1) define initial user stories and understand the business cases of key participants;
2) define and establish the Data Space framework and governance;
3) make data assets discoverable;
4) develop and provide processes to solve pain points in selected use cases.
    a) make metering data assets accessible from European AMI concepts;
    b) focus on OEM clouds and standardisation;
    c) reference implementation of a standard asset registration process for VPP;
5) extend data space features in an iterative process.

For each step, the plan identifies different groups that would be responsible for certain activities. Based on the inventory from Chapter 3, a list of organisations within these groups is available in the Annex in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**. As the inventory is not exhaustive, neither is the list of organisations.

Besides the specific actions needed to implement the data space, further pain points need to be addressed from the regulatory side. These points include the network code for demand-side flexibility based on the framework guideline (ACER 2022) including the regulation of methods for baseline calculations for flexibility services and the definition and clarifications on control priority of assets. Economic incentives for flexibility services also need to be addressed. The design of any future electricity market will have significant implications (European Commission 2023e) on this issue. As the data space is meant to act as an enabler of flexibility services through aggregation, regulations for critical entities (Council of the European Union 2022) and its implementations on the national level become relevant. Additional relevant legislation may be expected in the mid-term from implementing acts on data for demand response (European Commission 2023a) and data for customers switching electricity supplier (European Commission 2023b).

These action items have been identified within the workshops and research work conducted for this study but are not within the scope for the development of the energy data space.

6.1 Define initial user stories and understand business motivation of key participants

Figure 20: Step 1 - User stories for flexibility use case in data space

Finding shared interests in the identified use cases is key to motivate stakeholders to collaborate on the development of the data space. This ecosystem in the early stages of development (seed ecosystem) needs to be able to sustain itself financially and attract additional users. Through the research and workshops conducted, we identified four key user groups for a data space:

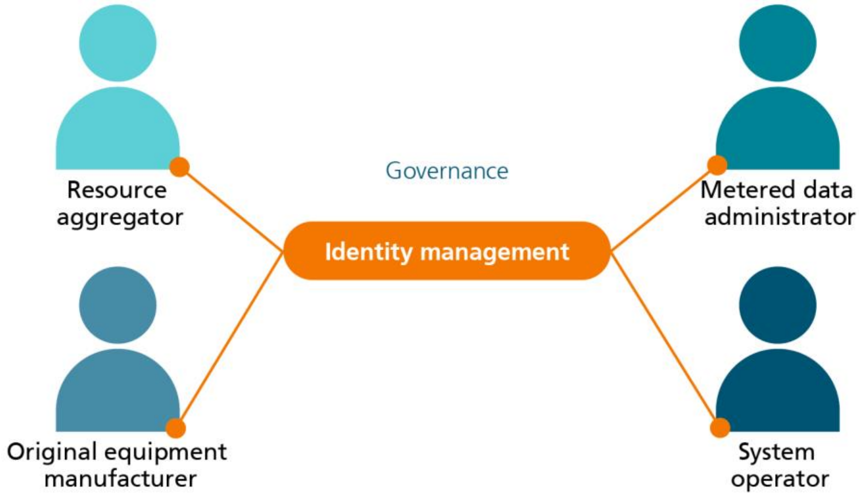
1) Aggregators
Aggregators as flexibility providers need access to metering data and the consent of consumers to control assets to provide their services. They would profit from a single data access point independent from any specific underlying AMI.
2) Metered data administrators
The electricity market role of metered data administrators is regulated—they should administer and provide data to eligible third parties if demanded by or consented to by a customer (European Commission 2023g). The organisation taking the role of the metered data administrator is often a business unit within a DSO itself or an entity closely linked to a DSO.
3) System operators
Both TSOs and DSOs share an interest in developing flexibility markets in order to have access to flexibility products for grid operations at scale. For markets with low availability of smart metering data, access to data from devices within HEMS such as charging points, heat pumps, or inverters may provide further information on the state of the grid. Due to their role in the network, system operators' technology choices tend to set the de facto standard for other stakeholders.
4) Original equipment manufacturers (OEMs)
OEMs define the communication and data management capabilities of their devices in the design phase and usually operate their own backend solutions to store and process data for monitoring and other services. Given the expected flexibility potential of the mobility and heating sectors, special focus would lie on automotive and heat pump OEMs. Additionally, stationary battery storage suppliers, OEMs for inverters and providers of HEMS would be relevant. The upcoming Data Act (Council of the European Union 2023a) may introduce further usage rights for operators of devices that OEMs have to provide. The implementation of the provisions from the Data Act will likely coincide with the deployment of the data space. OEMs as data holders may meet their obligations by using the data space.

Table 6: Step 1 -Action plan for development of core ecosystem

Actor	Action items
EU COM / Industry associations	Consult actor groups on further data space implementation plan
EU COM / MS / NRA	Define role and commitment of European and national regulation authorities in the further development of the energy data space

6.2 Define and establish the data space framework and governance

Figure 21: Step 2 - Establish data space framework and governance



Defining the scope and the regulatory environment for the data space has a major impact on the requirements for interoperability as laid out in Section 5.1. Given the complexity of use cases and stakeholders, a Common European Energy Data Space will mean multiple data spaces, which would then be federated based on core interoperability requirements that would need to be defined. Ongoing Horizon Europe projects could form the starting point for developing interoperability and could also be complemented with further interoperable data spaces coordinated by the IDSA working group on energy and the int:net project.

On a legal and organisational level, the development of a governance structure and the consensus of participants should start early in the process. Governance of a data spaces instance includes the set-up of rules for participants in the ecosystem, methods for decision-making and an approach to fund the cost of operating the data space. Further governance topics relate to the ecosystem and the domain governance of several data spaces (Steinbuss 2023).

Given the regulated nature of the energy sector and the involvement of system operators, coordination with national regulatory authorities to enable compliance through data space communications is essential. Rethinking compliance within a data space architecture may be necessary. European bodies for regulations and cooperation in the energy system such as CEER and ACER can support this by coordinating the process on the European level.

The level of technical interoperability will also determine the availability of software components. Given relatively high costs to deploy these building blocks, data spaces will likely face a lock-in effect. Advice and consultancy from the Data Space Support Centre (DSSC 2023b) will help to make informed decisions.

Identity management solutions are at the core of technical interoperability as organisations would be granted access to additional data spaces based on their trusted IDs. The convergence process within the DSBA (Data Space Business Alliance 2022) and contributions from the DSSC have yet to provide guidance in this regard.

As the energy sector is highly regulated, integrating the electricity market roles of organisations into the identity management approach could be beneficial. Options to achieve this should be explored.

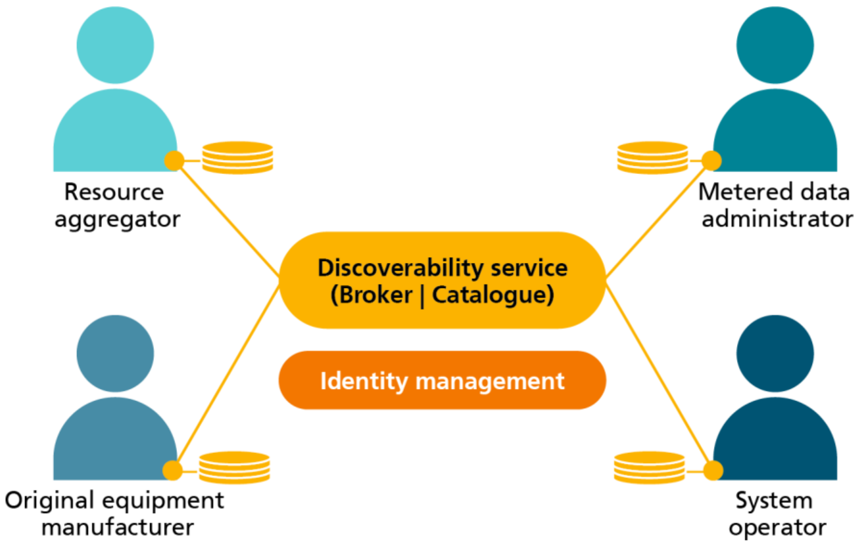
An optional part would be the selection of a connector software component that fulfils the interoperability requirements. This would be the piece of software that participants would integrate into their system environment. The onboarding of participants would then continue with acquiring an ID, providing a self-description, and testing the ID provision.

Table 7: Step 2 -Implementation plan to establish a data space framework

Actor	Action items
EU COM	Start data space as a federation of data spaces
EU COM	Fund deployment project(s) for data space
EU COM	Fund reference implementations for software components and key processes
European Data Innovation Board	Specify core interoperability criteria
Data Space Governance Board	Assess intended scalability requirements and initiate scaling and performance tests with components
CEER / ACER	Work with national regulatory authorities towards a common approach on data spaces as part of national energy regulations
ACER, National regulation authorities	Explore and develop mechanisms to integrate market roles with identity management
National regulation authorities	Rethink requirements for regulatory compliance regarding a data space architecture
Participants	Agree on governance structure
Data Space Governance Board	Decide on identity management approach
Data Space Governance Board	Decide on connector software, if necessary
Participants	Implement connector software on premises
Participants	Acquire ID, provide self-description and test ID provision
ACER or NRA	Provide guidance (FAQ) on legal aspects on contracts to participate in data spaces for assessments in companies' legal departments.

6.3 Make data assets discoverable

Figure 22: Step 3- Make data assets discoverable



In this step, participants start to provide information on their available data assets through a discoverability service, such as a metadata broker or a catalogue. This requires integrating the connector with the internal systems of participants. As workshop feedback and surveys indicate (Forum für Zukunftsenergien, Celron Consulting, Fraunhofer IEE, Themen magazin 2023), data quality is critical and needs to be addressed by companies internally, including implementing data structures according to relevant standards and semantics.

Registering data assets and their self-descriptions, including metadata, will make information more discoverable. A common approach on metadata would be helpful. The metadata will then affect generic information on data assets and additionally contain domain specific metadata.

During this stage, defining usage policies for data assets would also be possible. However, the first transactions within the data space will likely be permission-based, with more specific policies developed when participants' needs become clearer over time. Discussions within industry associations and regulators can be initiated to agree on best practices for usage policies and access rules for widely used data sets. A standard set of widely agreed upon usage rights and policies will increase transparency for the data provider and enhance trust.

Table 8: Step 3 -Implementation plan on data discoverability

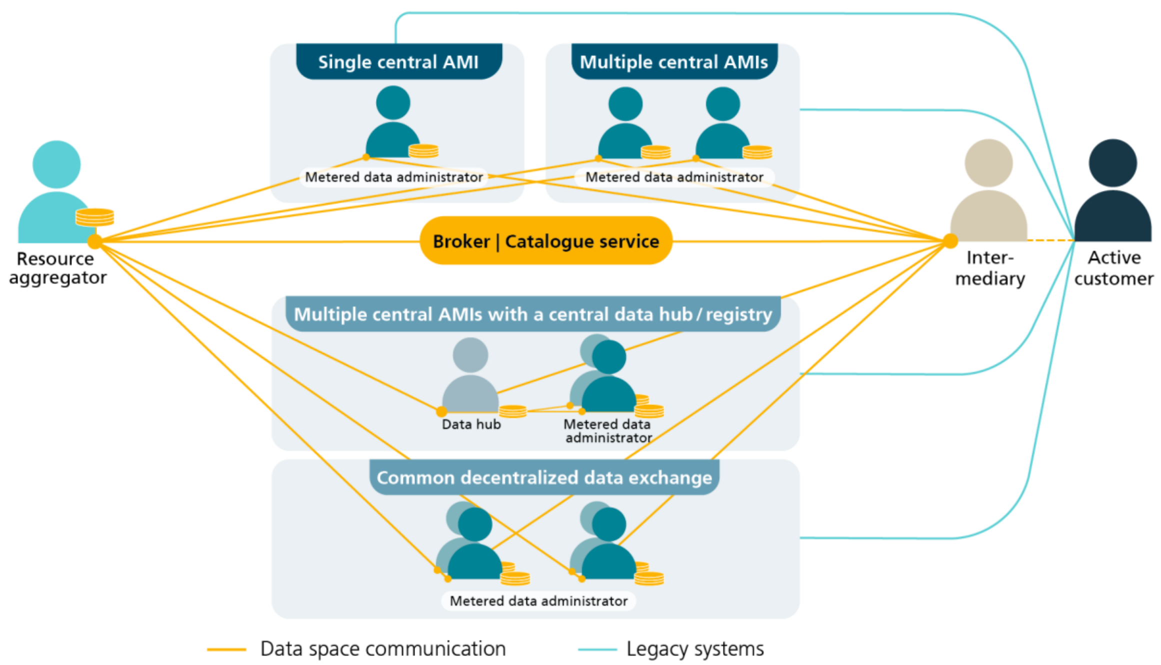
Actor	Action items
Governance boards	Decision on technology choice
Data space operators	Deploy discoverability service
Data space operator	Provide "readiness self-check" for participants to identify open issues in data preparations
European Data Innovation Board / Governance boards	Provide guidance on set of metadata based on available standards
Participants	Address internal data quality issues

Actor	Action items
Participants	Ensure availability of data according to relevant standards
Participants	Integrate connector with internal systems
Participants	Create self-description for data assets and register them to the broker and catalogue
Industry associations	Develop a standard set of usage rights and policies for the main applications

6.4 Develop and provide processes to solve pain points

The actions in this step are intended to address the pain points within the HLUCs. They might be addressed in parallel or consecutively, depending on the level of coordination and resources that are available.

Figure 23: Use case - Access to smart metering data - Make data assets available for European AMI concepts



One main pain point identified within this study was the access to metering data in the diverse landscape of AMIs in the EU. Scalable access to metering data is obligatory for a large number of flexibility services and is currently a barrier for cross-country service offerings and uptake in several Member States. As a unique feature of the Common European Energy Data Space it could enable access to this data, regardless of the underlying systems in any specific Member State.

Thus, developing and providing a data space-based process according to the implementing regulation for access to metering and consumption data (European Commission 2023g), could be a key feature to attract industry actors and enable further innovation and the adoption of a common energy data space.

Countries with a single or multiple central AMIs would require the MDAs to connect their platforms to the data space. In more decentralised ecosystems, the approach would be the same, but the number of actors involved multiplies. Therefore, very specific guidance and support would be required, such as providing open-source reference implementations and involving the main IT suppliers from the decentralised MDA. For countries with multiple, central AMIs and a central data hub or registry, different options on whether MDAs could directly participate in the data space, or only through the hub or registry, need to be explored.

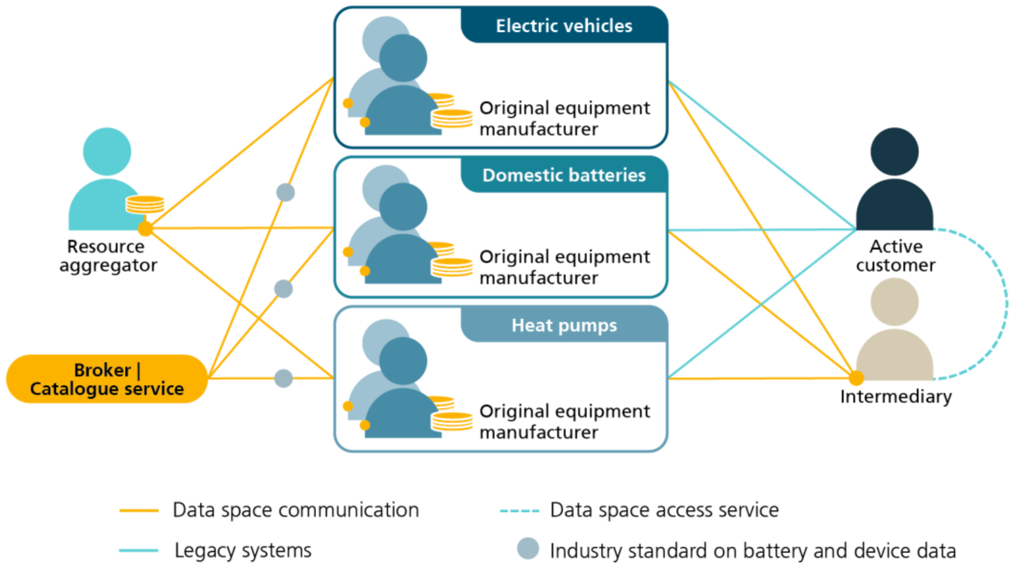
If MDAs are the single source of smart metering data at Member State level, it is crucial that they lead the first implementation of EDS-components, such as the connector and the discoverability service. In a Member State with a common decentralised data exchange, the standards defining party might lead the process to an EDS compliant data exchange solution, as in Austria, the Netherlands, or Sweden. Nevertheless, this might not be applicable for DSOs which are the ones singly responsible, as is the case in Ireland and France. In these instances, selective European cooperation from the beginning might be useful. The DSOs can share resources and knowledge as well as support interoperability at an early stage. This involvement should be selective, however, as too many stakeholders in this early development phase can lead to a lack of focus and paralysis.

It should be noted that there may be inconsistencies with existing regulations (e.g. the German PKI for smart metering), which need to be discussed individually.

Table 9: Iteration 4-1 — Action Plan on access to smart metering data

Actor	Action items
National regulators	Evaluate regulatory barriers and related national policies to establish an EDS-based data exchange of validated smart meter data (e.g., in Germany the SM-PKI of the German MaKo might be opened for an EDS-approach)
MDA	Embrace leading role in data provision through the data space and develop a collaborative adoption environment
Central data hub / registry operator	Specify solutions for data provision and lead implementation with connected MDAs
Central data hub / registry operator and MDAs	Adapt or reuse current consent management and access control mechanisms for data space implementation
Intermediary	Explore the practical implementation, e.g. create customer services to establish the new identity service provider role of the new EU COM Implementation Regulation in the context of smart metering (European Commission 2023g)

Figure 24: Use case EV charging - Focus on OEM clouds and standardisation



Issues identified in Section 4.2 were: the need to advance the flexibility provision from EV charging as well as to standardise both the data, and the access to data, especially to battery data.

Standardisation refers to several aspects: there is the need for a common data standard for V2G applications. As the market for this technology grows, wide adoption of the ISO 15118-20 data standard will support interoperability in the sector. Data from EV batteries is another major concern in this use case. At present, there are no agreed upon standard data model and format among OEMs in the automotive industry. The development and adoption of such a standard need to accelerate.

The proposal for the upcoming Renewable Energy Directive (RED III, article 20a (European Commission 2021b)) would grant the customers and their service partners of choice the right to access battery data for flexibility-providing applications. This right would also apply to owners of stationary domestic batteries. These data flows need access provisions, which could be facilitated by the data space.

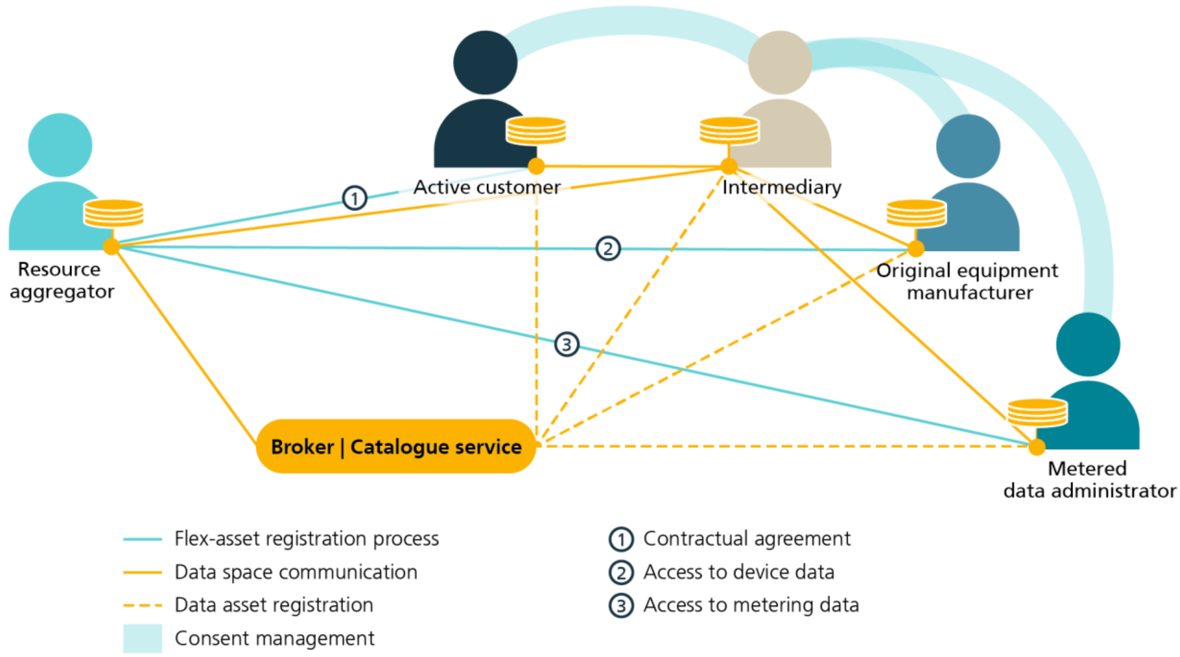
In more general terms, the access to data not only from EVs, but also from heat pumps, domestic batteries, and other relevant devices through an OEM's cloud systems will be highly relevant and would integrate well into the data space.

Table 10: Iteration 4-2 — Action plan on standardised data from OEMs' cloud services

Actor	Action items
EU COM, automotive industry association	Build consensus on standard for EV battery data provision
EU COM, battery industry association	Build consensus on a standard for domestic-battery data provision
EU COM, automotive industry association	Build consensus on a standard protocol for V2G flexibility applications

Actor	Action items
Automotive OEMs	Provide data asset for EV battery data through a data space
Domestic battery OEMs	Provide data asset for battery data through a data space
Heat pump OEMs	Provide data asset for heat pump data through a data space

Figure 25: Use case – VPP and aggregation – Implement asset registration process



A straightforward way to register customer assets with resource aggregators will facilitate access to the flexibility market for smaller asset classes, which in turn aligns with the goals in the Renewable Energy Directive III. Interoperability is key to empowering customers to switch between aggregators, creating a competitive market and avoiding vendor lock-in.

For the registration process, the minimum and maximum data required from any given asset could be defined by industry associations. This data set would then be made available and registered to the broker. This standardised approach would ensure a consistent and streamlined registration. Consumers can seek support from intermediaries to navigate the data space and maximise their access and engagement.

As a result, registering an asset would only need a consumer's consent to access the data and to control the device. In some cases, original equipment manufacturers (OEMs) could also directly provide this data through the data space, further simplifying the registration process.

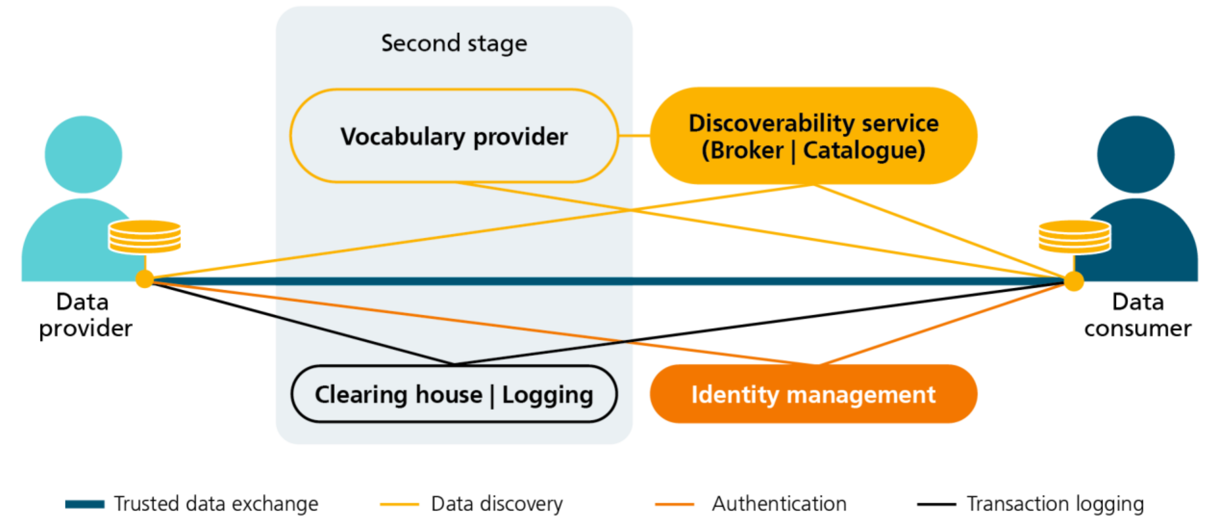
Table 11: Iteration 4-3 — Action plan on asset registration process standardisation

Actor	Action items
FRP	Agree on required minimum and maximum data set
EU COM	Harmonise the assessment criteria and registration process of a flexibility product

Actor	Action items
EU COM	Fund data space-based asset registration process reference implementation as an open-source software
Resource provider	Register asset self-description and provide consent to resource aggregator access
HE projects	Create and adopt semantic standards to enable a common understanding and interpretation of asset registration
HE projects	Establish semantic mapping and transformation processes to enable the conversion of asset registration data from different formats and structures into a common semantic model
Data space governance	Establish a metadata management framework to enable standardised and consistent metadata for registered assets, enhancing discoverability, search ability, and interoperability of asset information

6.5 Extend data space features in iterative process

Figure 26: Extend data space features in iterative processes



Once discoverability and access control policies have been put in place, services that can take advantage of the data space can be added in a second stage of deployment. To support the development of these applications, a semantic services provider would ensure machine-readable semantic interpretation of data assets. A software implementation would provide the vocabulary, as in the IDSA reference architecture.

Another feature would be the provision of a clearing house or logging service. This building block would support compliance needs, where transaction logging is needed, as activity in the data space can be tracked. As the informational content may allow for insights on market activities with relevance for compliance, such as with anti-trust rules, further study on the benefits and risks of this kind of data collection should be conducted.

Table 12: Iteration 5 -Action plan on continuous, iterative development and extension

Actor	Action items
EU COM	Require and fund semantic models as part of data space operations
EU COM	Explore benefits and risks of tracking and reporting data in clearing house or logging service
EU COM	Run and monitor minimum viable products MVP(s) to adopt and test semantic and technical interoperability
EU COM	Where possible, require or incentivise the development of physical infrastructure (smart meter, connectivity, etc.)
Data space operator	Select and deploy a semantic services provider
Data Space Governance Board	Prepare the application of a semantic model in terms of scope of models, technological approach, performance, and community and governance
Data Space Governance Board	Organise an iterative development process

Take away – implementation plan for data space development

→ Five steps for implementation are suggested as a start into an agile development process, starting with a sound understanding of business cases of key participants.
→ Governance, identity management and a discoverability service are key elements in the early stages of data space development.
→ Access to metering data across different AMI concepts is proposed as a key feature of the Common European Energy Data Space.

7 Summary and outlook

A Common European Energy Data Space combines components which address the challenges of providing digitally enabled, flexibility services at scale for the energy transition. It does this within the broader agenda of fostering a data sharing infrastructure that will serve as the backbone for the European data economy.

Operationalising a data space and understanding what concrete advantages it can bring to both the participants and to the European Commission means understanding the existing landscape, identifying the obstacles to data sharing, and presenting specific recommendations that demonstrate what is (and what is not) possible with a data space. With regard to this objective, an inventory of initiatives across 16 countries has revealed the organisations and initiatives currently driving the energy flexibility sector. The inventory provides insights into their roles and offers information regarding the flexibility products available. This included examining the business models and data management of virtual power plants and aggregation; price-responsive charging and discharging and balancing services from EVs and smart residential flexibilities. Identified pain points include access to field data (especially smart metering data) and access to data from OEMs in a standardised, interoperable way.

General communication of metering data currently relies on *meter data management systems* (MDMS) for data storage, data management and data analytics solutions. These systems vary based on the number of central AMIs and the total number of market participants, and result in a complex combination of centralised and decentralised implementations of metering data exchange processes. Data spaces would be an effective way to unify and simplify access to metering data across current meter data management systems. Aggregating assets that provide flexibility for the different sectors of demand-side management, e-mobility and smart buildings shows that most applications use underlying generic processes such as asset registration, prequalification, baseline registration, and registration of planned activation. Asset registration is highly relevant to the development of the market as it determines how easy it is to start offering assets as resources to flexibility providers and determines the efforts to switch between different resource aggregators.

Regarding the *access to device data from OEMs* aspect, ongoing legislation proposals in RED III and the Data Act will likely establish new usage rights that will allow active consumers to access device data and grant third parties access. However, standardisation between OEMs needs improvement. Standardised access to EV battery data in the e-mobility sector would be particularly relevant. Unlike the situation with metered data, the upcoming legislation provides an equal incentive and opportunity across OEMs to provide a "clean" solution to share device data through data spaces.

An important aspect or objective of data spaces is to ensure that data can be found and shared in an appropriate way. As such, not only can data spaces help develop a unified and interoperable way to share this necessary data, but they can also help with discoverability and access to data that include access control mechanisms. These essential components are already a part of the "building blocks" for data spaces, which would include organisations that help govern data sharing, such as functions like an identity provider and a metadata broker.

A data space could be implemented via actions of several actors in five iterations and in a continuous, iterative development:

1) define initial use cases and understand business motivation of key participants;
2) define and establish the data space framework and governance;
3) make data assets discoverable;
4) develop and provide solutions to resolve pain points in selected use cases;
5) extend data space features in an iterative process.

Concrete suggestions for actions as part of an implementation plan have been developed in Chapter 6. System operators, also in their role as metered data administrators, resource aggregators and OEMs, form the core actor groups in the seed ecosystem that is envisaged around the business case of accessing smart metering data across Europe as an enabler for flexibility services.

Outlook

A detailed understanding of the motivation and benefits for the different actors within the seed ecosystem and their commitment to collaboratively invest in the build-up of the Common European Energy Data Space is a crucial basis for its successful development and deployment. Therefore, additional industry consultations should take place to complement the findings from this study.

In addition, trust between actors and participants of the data space needs to be cultivated from the beginning. Building transparent governance structures and having clear communications on objectives and development actions will contribute to that. Given the overall complexity of the journey to interoperable data spaces spanning several industry sectors, it will also be key to build the data space gradually and keep the system as accessible as possible for participants.

On the technical level, challenges remain, especially regarding the definition of interoperability mechanisms for data spaces. Also, the level of digital sovereignty on the underlying infrastructure aspects that may be achieved as part of the GAIA-X initiative needs further clarification. As this affects basic design decisions, guidance from the European Commission on expected technical features and design choices that are left to industry need to be available from the start of an implementation project. Regarding the timeline, there will be trade-offs between the full specification of requirements on interoperability mechanisms and the intended timeline for the data space going live.

Participating organisations will benefit from scalable data collaboration in combination with specific data usage policies in a secure environment. Performant reference implementations for metering data access and further automated processes will convince and attract companies. Investment decisions to join the Common European Energy Data Space will be facilitated by commitments and technology choices of large actors, especially system operators.

Another wider issue is the involvement of the consumer in the data space. While the European single market for data focusses on non-personal data, highly relevant metering data in the energy sector is personal data. Thus, the involvement of consumers and the implementation of GDPR compliance is currently an open issue and will need further consideration.

The drafted implementation plan can guide the development of the initial stages. Mature software solutions exist for the most relevant building blocks on identity management and discoverability of data. The development of the Common European Energy Data Space is therefore the chance to jointly enable flexibility provision, a step-up in digitalisation, while addressing environmental challenges with a living network of key actors such as system operators, metered data administrators, original equipment manufacturers as well as resource aggregators.

8 List of figures

9 List of tables

A.1 Annexes

A.1.1 Approach and methods

This study on a common Energy Data Space builds on desk research and interaction with stakeholders to analyse flexibility needs and potentials for the European energy sector.

A key outcome is an inventory of private and public European initiatives on flexibility provision. This inventory is being built within a defined geographical scope that covers a wide range of tech-nical and regulatory conditions across Europe.

For the collection of initiatives, a two-step process has been applied. Firstly, the initiatives were identified and master data on categories, country and contact information were collected; In the second step, the initiatives owner were directly contacted, and further details were gathered through a web-based questionnaire. 42 responses were returned between 19 April and 17 May 2023. 17 replies provided additional information that has been used in the analysis in section 3.1. A high level of detail and the sensitivity of some information that were asked may have led to the limited response rate.

Based on the inventory and the desk research, main use cases for digitally enabled flexibility provision have been analysed with special focus on data management and business cases, allowing to define the implications for building blocks of a data space.

Additionally, an online workshop was held on 16 May 2023 with stakeholders with a total of 106 attendees from industry, research and policy and administration. The purpose of the workshop was to gather input from the sector on the main pain points and expectations on political priorities to address these pain points. Participants of dedicated use case sessions were asked to select the top three pain points among issues that were collected in a brain writing session. In a second vot-ing round all participants were asked to place between none to three votes on issues where they expected impact from policy making. The issues were clustered. Chapter 4 includes the outcome of the workshop results per high level use case.

In parallel the role of the energy data space has been described based on the European Interoperability Framework (European Commission 2017), the data space roles and building blocks. These have then been matched with the pain points to map out where data space technology can provide solutions to existing pain points.

With these inputs recommendations on further steps toward the Common European Energy Data Space have been drafted within the team of authors and colleagues working on the data space support centre project (DSSC 2023b) have been consulted on specific questions. Again, draft recommendations were presented to industry representatives in a hybrid workshop format on 20 June in Brussels and to online participants, with 26 participants on site and another 32 partici-pants online.

All findings have then been merged into the creation of an implementation plan that can guide the next steps towards the Common European Energy Data Space. For the development of the different stages experience from further data space initiatives such as the Mobility Data Space in Germany (2023) and CATENA-X (2023) were taken into account. The development stages were then complimented with action items that were derived from the initial set of recommendations, feedback and insights from workshop discussions and internal expertise..

A.1.2 Inventory

The inventory table has been designed based on characteristics that are described in this section. The characteristics have been operationalised into more specific data objects that were collected from initiatives from the market. For the collection of initiatives, a two-step process was applied. Firstly, the initiatives are being identified and master data on categories, country and contact information are defined; in the second step, the initiatives owner were directly contacted, and further details were collected through a web-based questionnaire.

While information for the first step was available it turned out that more detailed information was in a lot of cases difficult to obtain. The required data was so specific that it was usually was not available from public resources and in some cases assessed as sensitive and confidential data. Therefore, responses on the survey came from six private initiatives and 11 European research projects in the period between 19 April to 17 May 2023.

Technical Scope

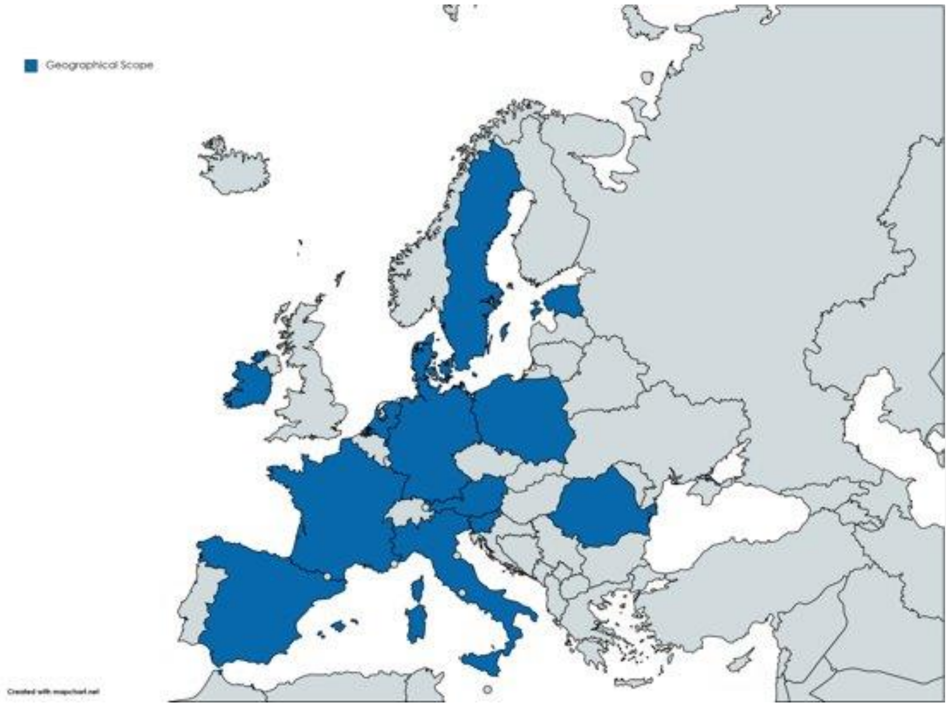
The technical scope includes a short description of the initiative, the type of flexibility, the area of interest, the grid voltage level and the control technology applied as categorised for the project.

As types of flexibility wholesale market (i), congestion management (ii) and ancillary services (iii) can be alternatively selected.

Geographical scope

The geographical scope is shown in Figure 27. It consists of a total of 13 countries: Austria, Denmark, Estonia, France, Germany, Ireland, Italy, Poland, Romania, Slovenia, Spain, Sweden, The Netherlands. In addition, Horizon Europe and Horizon 2020 projects have been analysed for flexibility services. Initiatives from these programmes have also been included in the inventory regardless of the country of origin.

Figure 27: Geographical Scope of Inventory



Technical readiness level

For the assessment of technical maturity, we use the technical readiness level (TRL) (European Commission), which is widely adopted in the European research landscape. As the intend of the inventory is to list initiatives that are available on the market or very close to commercialisation, the minimum TRL for initiatives in the inventory is set to TRL 7.

Actors involved

While the specific partners within each initiative differ, we seek to capture the characteristics of the digital ecosystem by identifying the market roles of participants in the initiatives. We categorise actors based on a short list of the main market roles based on the *Harmonised Electricity Market Role Model* (HEMRM) (ebIX®, EFET and ENTSO-E 2022) for the provision of flexibility.

In order to highlight the Data Space perspective, another dimension is set by the roles defined by the Data Space Role Model provided by the International Data Spaces Association (Steinbuss 2022). This information addresses what roles are taken by the organisations and actors in the cross-company usage of data. It identifies data owners and providers on the one end and data consumer and users on the other end. Besides it allows for a description of additional intermediaries such as digital service providers which are relevant for an operational data space.

Funding structure

Within this section the main founding source for the initiatives is listed as public or private. This information can help understand what the origin of the initiative is. In an additional step we aim to identify whether this financing comes from the state, from a third-party investor or from within the company as balance-sheet-based investment.

Digital Value Chain

Building on existing models of supply and value chain models from other industrial sectors, the digital value chain describes value creation from data resources through digital processes. For this project we use the model by the Big Data Value Association (BDVA) as depicted in Figure 28.

Figure 28: Big data value chain as proposed by BDVA. Source: (BDVA 2017)

As sources for the acquisition of data the advanced metering infrastructure is of high relevance. In addition, data from the flexible assets need to be gathered. There are various options to access this data, either directly from the device as an IoT edge device or through an IoT Cloud service, e.g., from the OEM of the asset. Besides, data can be acquired through a nominated electricity market operator or another third party. For processing and storage, the basic options of cloud, edge or fog options are considered.

Business Model

To understand and describe the underlying business model of an initiative we focus on main dimensions from the classical business model canvas. We also build on the description of generic business models in the St. Gallen Business Model Navigator (Gassmann et al. 2013). For generic business models and the source of the revenue stream a set of options were presented in the survey.

A.1.2.1 Resource aggregator

Country	Name of Initiative	Initiative owner	Metering and Con-sumption	VPP and Ag-gregation	Smart charging and V2G	Smart resi-dential flexi-bilities
Austria	charVIS	Smatrics	1		1	
Denmark	FlexShape	FlexShape				1
Estonia	grid.io app	Gridio 2.0 OÜ, Tallin, Estonia			1	
	Themo	Themo				1
France	tiko	Engie				1
	Total Energies Mobility	Total			1	
	Voltalis	Voltalis		1		
Germany	EnBW mobility+	EnBW			1	
	EnergieDock	EnergieDock				1
	Hubject intercharge	Hubject			1	
	ionity - charging app	ionity			1	
	Octopus energy - Kraken platform	Octopus energy group	1		1	1
	ViShare Energy Community	Viessmann		1		1
	elli - Charging site management	Volkswagen Group			1	
Other	Chargepoint	(Leer)			1	
	virta - charging as a service	virta			1	
Portugal	edp	(Leer)			1	
The Netherlands	Sympower	Sympower				1
EU	ChargePilot	Mobility House			1	
	Nibe smart price adaption	Nibe				1

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
	Sonnen	Sonnen	1	1		1
	Themo Smart Thermostat	(Leer)				1
	Enel X Way	Enel X Way S.r.l			1	
	Total of initiatives		**3**	**3**	**13**	**10**

A.1.2.2 Transmission system operator (TSO)

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Austria	Austrian Power Grid AG TSO	Austrian Power Grid AG	1			
Belgium	Consumer Centric Vision	Elia	1			
	Elia Portal Interface for Customers (EPIC)	Elia				
Denmark	Green Energy Hub (the Danish Data-Hub)	Energinet	1			
Estonia	Estonian Data Hub	Elering AS	1			
France	écowatt	RTE		1		
	eco2mix	RTE	1	1		
Germany	DA/RE	Transnet BW, Netze BW		1		
	EV Fleet	TransnetBW			1	
	Amprion Data Lake	Amprion	1			
	MCCS NextGen	50Hertz Transmission	1			

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
The Netherlands	flexcess / Equigy	TenneT		1	1	1
	GOPACS	TenneT TSO B.V.		1		
	Passive balancing	TenneT TSO B.V.		1		
	Reserve Power Other Purposes (ROD) (Redispatch mechanism)	TenneT TSO B.V.		1		
Ireland	National Smart Metering Programme (NSMP)	ESB Networks	1			
	EirGrid TSO	EirGrid	1			
Italy	MyTerna Portal	Terna	1			
Norway	Elhub (Electricity Hub)	Elhub AS c/o Statnett SF	1			
Sweden	Control room	Svenska Kraftnät	1			
Poland	Central Energy Market Information System (CSIRE)	Polskie Sieci Elektroenergetyczne (PSE)	1			
Romania	Transelectrica TSO	Transelectrica	1			
Slovenia	GreenSwitch	ELES		1	1	1
Spain	eSIOS-CECRE-CoordiNet	REE		1		
EU	Equigy	Equigy B.V.		1	1	1
	eSett	eSett Oy	1			
	Total of initatives		**15**	**10**	**4**	**3**

A.1.2.3 Distribution system operator (DSO)

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Austria	EDA ("energiewirtschaftlicher Datenaustausch" / Energy Data Exchange)	Energiewirtschaftlicher Datenaustausch GmbH	1			
	cyberGRID	EVN	1	1		
Belgium	Central Market System (CMS)	Atrias cv	1			
	Fluvius	Fluvius System Operator CV	1			
	Sibelga	Sibelga S.C.	1			
	RESA	RESA S.A.	1			
	ORES	ORES sc	1			
Denmark	Vores Elnet	Vores Elnet A/S	1			
	Aura Energi	AURA Energi a.m.b.a.	1			
	andel energi	Andel Holding A/S	1			
France	Central Information System (CMS) (with Linky smart meters)	Enedis	1			
Germany	E.ON Verteilnetze	E.ON SE	1			
	FlexStore	Trianel GmbH	1	1		
	Providata	Thüga AG	1			
The Netherlands	Liander	Liander N.V.	1			
	Enexis	Enexis Netbeheer B.V.	1			
	Stedin	Stedin Holding N.V.	1			
Ireland	Meter Registration System Operator (MRSO)	ESB Networks	1			

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Italy	OpenMeter	e-distribuzione S.p.A. (Enel Group)	1			
	Areti	Areti	1			
Norway	NorFlex	Agder Energi		1		
Portugal	E-REDES	E-REDES				1
Romania	SMART Transformation program	Distributie Oltenia	1			
Slovenia	Napredni merilni sistem, National data hub	DSO cooperation	1			
	Total of initiatives		**21**	**1**		**1**

A.1.2.4 Metered data administrator (MDA)

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
The Netherlands	Energie Data Services Nederland (EDSN)	EDSN B.V.	1			
Spain	Datadis Platform	Platform Datadis CB	1			
	Total of initiatives		**2**			

A.1.2.5 Original equipment manufacturer (OEM)

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Austria	Fronius Inverter	Fronius International GmbH				1
Belgium	Toyota	Toyota			1	
France	Schneider Electric devices	Schneider Electric Industries SAS		1	1	1
	Mobilize	Renault			1	
Germany	(Leer)	Volkswagen Group			1	
	Stiebel Eltron HP	Stiebel Eltron				1
	Bosch HP	Bosch			1	
	Clarios Battery	Clarios			1	
	Tesla Battery	Tesla				1
	Varta Battery	Varta				1
	Supercharger Network	Tesla			1	
	Connected Home Charging	BMW Group			1	
	Energy Data	Mercedes-Benz			1	
	Ford Pro Charging	Ford of Europe			1	
	MAN eManager	MAN Truck & Bus SE			1	
Ireland	Trane HP	Trane			1	
	Eaton Corporation HEMS	Eaton Corporation				1
Italy	Energica EV	Energica Motor Company S.p.A.			1	
	IVECO ON connected services	Iveco S.p.A.			1	
Other	LG Battery	LG				1

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
	BYC Battery	BYC				1
	CATL Battery	CATL				1
	Samsung Battery	Samsung				1
	NIO swap stations	NIO GmbH			1	
Sweden	PowerShare	Volvo		1	1	
The Netherlands	Free2move	Stellantis			1	
EU	SMA Energy Data Services	SMA Solar Technology AG	1			1
	dcbel	dcbel			1	
	Total of initiatives		**1**	**2**	**18**	**11**

A.1.2.6 Further relevant industry inititatives

Market Role	Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Market Operator	Germany	EEX	EEX		1		
	Ireland	open Networks	ENA UK		1		
	Norway	Nordpool	Nordpool		1		
	Slovenia	GEN-I	GEN-I	1			
	Spain	IREMEL	OMIE		1		
	EU	Europex	Europex		1		

Market Role	Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Balance Responsible Party	The Netherlands	Eneco example: SlimLaden® (White label app by Jedlix)	Eneco, Oxxio, om Energie & Greenchoice			1	
		FlexMeasures	Seita Energy / LF Energy			1	1
	EU	Hyphae - Autonomous Power Interchange System (APIS)	Linux Foundation for Energy (LFE)		1		
Balancing Service Provider / FSP	France	Energy Pool	Energy Pool		1	1	
		Flexcity	Veolia		1		
		Enphase Home Energy Management	Enphase Energy		1		1
	Italy	EnergyTeam	Energy Team S.p.A.		1		
	Slovenia	Ngen	NGEN Smart Grid Systems GmbH	1	1		1
	EU	Enel X Connect	Enel X S.r.l. / Enel X Germany GmbH		1	1	1
		energine	Flexcity SAS		1		
		Next Pool	Next Kraftwerke		1	1	1
Energy Supplier	Austria	VERBUND Power-Flex	Verbund AG		1		
	France	Alpiq Energie France	Alpiq		1		
	Germany	Smartes Laden	RABOT CHARGE GmbH	1		1	

Market Role	Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
	Ireland	Fixed-rate electricity plans	Pinergy	1			1
	EU	Smart2B	EDP				1
Charge Point Operator	Spain	Ibil Charging Technology and Services	Ibil Charging Technology and Services			1	
	The Netherlands	Fastned B.V.	Fastned B.V.			1	
	EU	Shell Recharge	Shell Energy			1	
		Milence	Milence (Consortium from Traton, Volvo, Daimler Truck)			1	
Customer / SGU	EU	SPINE	EEBUS				1
Meter Operator	Belgium	Thermovault BV	Thermovault BV				1
	Denmark	Neogrid Technologies ApS	Neogrid Technologies ApS				1
	Germany	todo	todo				1
	Ireland	EVHACS	EVHACS				1
	Italy	Enerbrain	Enerbrain				1
	Norway	Enode	Enode				1
	Other	FUERGY	FUERGY				1
	Portugal	Flexunity	cleanwatts				1
	EU	AirPatrol	AirPatrol - part of Ngenic AB (publ)				1

Market Role	Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
		Open Metering System (OMS)	OMS-Group e. V.	1			
Meter Data Aggregator	Italy	Sistema Informativo Integrato (SII) with Portale Consumi	Acquirente Unico S.p.A.	1			1
		Total of Initatives		**6**	**15**	**10**	**18**

A.1.2.7 Industry associations

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Austria	EDA / AIT	EDA / AIT	1			
Germany	BDEW / EDNA	BDEW / EDNA	1			
The Netherlands	GOPACS	GOPACS		1		
EU	Avere (EV)	Avere (EV)			1	
	CharIn (EV)	CharIn (EV)			1	
	European Heat Pump Association	European Heat Pump Association				1
	EPRI EUROPE DAC	EPRI EUROPE DAC				
	smartEn	smartEn	1			1
	Digital Europe	Digital Europe				
	GAIA-X	GAIA-X				
	IDSA	IDSA				
	FIWARE	FIWARE				
	ENTSO.E	ENTSO.E	1	1		
	E.DSO	E.DSO	1	1	1	1
	EU DSO Entity	EU DSO Entity	1	1	1	1
	ChargeUpEurope	ChargeUpEurope			1	
	EURELECTRIC	EURELECTRIC		1	1	
	GEODE	GEODE	1			
	ESMIG	ESMIG	1			1
	T&D	T&D	1			

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
	SolarPower Europe	SolarPower Europe	1	1		1
	Orgalim	Orgalim	1	1		
	BEUC	BEUC	1		1	1
	Platform for E Mobility	Platform for E Mobility			1	
	Plug&Charge Europe	CharIn			1	
	Flexiblepower Alliance Network	Flexiblepower Alliance Network FAN	1	1	1	1
Global	LF Energy	LF Energy	1	1	1	1
	Total of associations		**14**	**9**	**11**	**9**

A.1.2.8 Research projects

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
Estonia	INTERRFACE	European Dynamics		1		
Germany	c/sells	EAM	1	1	1	1
	Designetz	E.ON	1	1	1	1
	enera	EWE	1	1		1
	NEW 4.0	HAW Hamburg	1	1		1
	Pebbles	Pebbles German project	1		1	1
EU	ALPGRIDS	Interreg Alpine Space	1	1		
	BD4OPEM	BD4OPEM project H2020		1	1	
	Bright	Bright H2020 Project		1		1
	Building Information aGGregation, harmonization and analytics platform (BIGG)	INETUM REALDOLMEN BELGIUM (Coordinator H2020 Project)				1
	Coordinet	endesa/enel		1		
	eCharge4Drivers	eCharge4Drivers - H2020 project			1	
	eCREW	eCREW H2020 project				1
	FEVER	FEVER H2020 project	1	1		
	GIFT	GIFT H2020 project		1		
	GOFLEX & FlexOffer	GOFLEX H2020 project	1			
	iBECOME	iBECOME H2020 project				1
	INCIT-EV ICT platform	INCIT-EV project H2020			1	
	InterConnect	InterConnect project H2020				1

Country	Name of Initiative	Initiative owner	Metering and Consumption	VPP and Aggregation	Smart charging and V2G	Smart residential flexibilities
	Platone	Platone H2020 project	1			
	PLATOON	PLATOON - H2020 project				1
	REstable	Restable project ERA-Net	1	1		
	SmartNet	RSE		1		
	SONDER	SONDER ERA-Net project		1		
	Universal Market Enabling Interface (UMEI)	eUniversal H2020 project	1	1	1	1
	X-Flex Platform	X-FLEX H2020 project	1			
	int:net	int:net				
	OneNet	Fraunhofer FIT	1	1	1	1
	Total of projects		**13**	**16**	**8**	**13**

A.1.3 Advanced metering infrastructures – case studies of implementations in EU Member States

In Section 3.2 different approaches for the architecture of AMI and their extensions to share smart meter data have been identified. In addition, four key features of their use in flexibility provision have been introduced: Flexibility analytics, local optimisation, remote-control access, and settlement process (details s. Section 3.2). How these possible features can be realised at Member State level, will be presented in the cases of Italy, Estonia, Germany, and Austria.

A.1.3.1 Italy

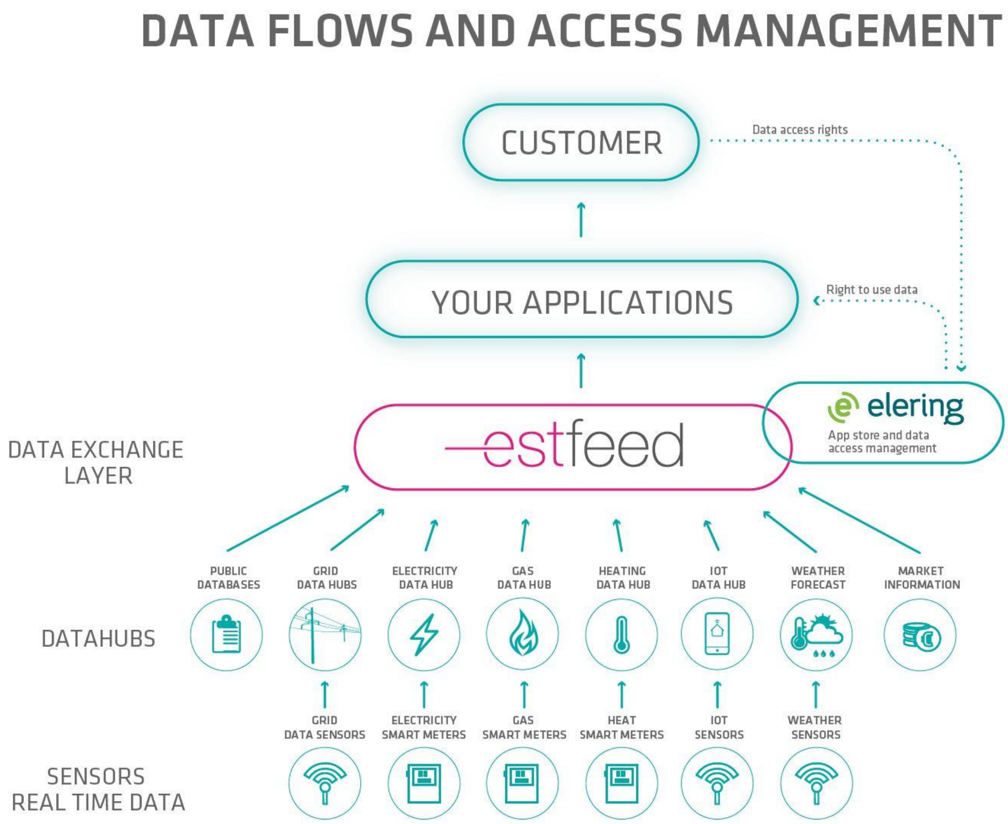
Italy started the European shift to smart metering systems in 2001 and has completed the national rollout of its *first generation* (1G) in 2011, around two years after the other forerunner of SM development in Europe, Sweden. In Italy the DSOs are responsible for their AMI development. At national level the dominating DSO *e-distribuzione* (ENEL group) has been leading the market. As part of their AMI introduction additional local DSOs have applied the same SM-technology in their grid areas. With the deployed 1G SMs it is possible, e.g. to receive monthly readings for smaller customers or hourly values for larger ones, to activate remote power (dis)connections, as well as detecting power peaks or outages. The upcoming requirement to verify older measurement devices as well as EU legislation requirements have led to a new Italian law (D.Lgs. 102/14), which is the legal basis for the latest *second generation* (2G) SMs. From a flexibility perspective especially three aspects are relevant: The possibility for a second channel from the SM for higher resolution raw data available to the customer and third parties. Secondly, the option to allow 15 minutes validated profiles possibly in combination with variable ToU price bands. Finally, the option to receive grid quality values as a DSO at a higher degree of detail. The rollout of 2G devices is already underway and is expected to be largely completed by 2025 (ARERA 2022) (ANRE 2023; ARERA 2017; Gridspertise S.r.l. 2022; Vitiello et al. 2022).

As a complementation to the central AMIs in Italy, a data hub has been created by the state-owned company Acquirente Unico S.p.A. The Sistema Informativo Integrato (SII) has been operational since 2016. Its introduction was motivated by European legislation (in particular IEM-D) to streamline energy supplier billing and changes, and to provide customers with easy access to their validated metering data, including the right to share their meter data with selected third parties (Acquirente Unico S.p.A.; Acquirente Unico S.p.A.; THEMA Consulting Group 2017).

A.1.3.2 Estonia

The Estonian power market has been reshaped by the *Third Energy Package* of the EU (includes the IEM-D). As a result, Estonia has established the company *Elering AS* as an unbundled TSO. In parallel the AMI introduction has been enforced at national level by the DSOs and finalised in 2017 with nearly full coverage. Confronted with many national DSOs *Estfeed* has been established. It's a solution to interact with market participants (B2B) as well as customers (B2C) with one central data exchange layer. This layer receives data from different data hubs like the *grid data hub* or the *electricity data hub*. The last one consists of all smart metering data provided by the DSOs' AMIs. To allow (active) customers and producers access to their own data Estfeed has been extended by the *e-Elering* portal in 2017. Furthermore, the portal enables them to share their data e.g., with authorised third parties, who might then use the implemented application (app)-store for their service offers (compare Figure 29). At the moment, Q1/2022 until Q2/2023, Elering puts into place a redesigned data hub that expands the current functionalities to consider e.g. the additional market role of *aggregators* / resource aggregator as well as the extension of current data-sets for existing market roles (check (Elering AS 2022; Navitasoft Zrt. 2022)) (Elering AS 2022, 2023; Estfeed, smart meter data share 2020; Navitasoft Zrt. 2022; Plantera; Vitiello et al. 2022).

Figure 29: Overview of the Estonian data exchange platform Estfeed (before current re-design)



Source: Elering AS (figure sourced from (Elering AS))

A.1.3.3 Germany

While the previous MSs have been strong European leaders in AMIs and related add-ons, Germany is still at an early stage of development in the overall introduction of SMs. Nevertheless, the German approach has been planned to deliver multiple aspects in the upcoming years. One special characteristic is the regulated AMI feature to provide different market participants, like grid operators or resource aggregators, access to near real-time access to smart metering data. Based on this information they will be permitted remote control access in a coordinated approach. As a result, conflicting control signals e.g. at a PCC of a (active) customer might be solved at a central service provided by each responsible metering point operator with their managed SMs (process known as *Universalbestellprozess /* Universal ordering process) (BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. 2023; Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen 2022; Sylla et al. 2023; Vitiello et al. 2022).

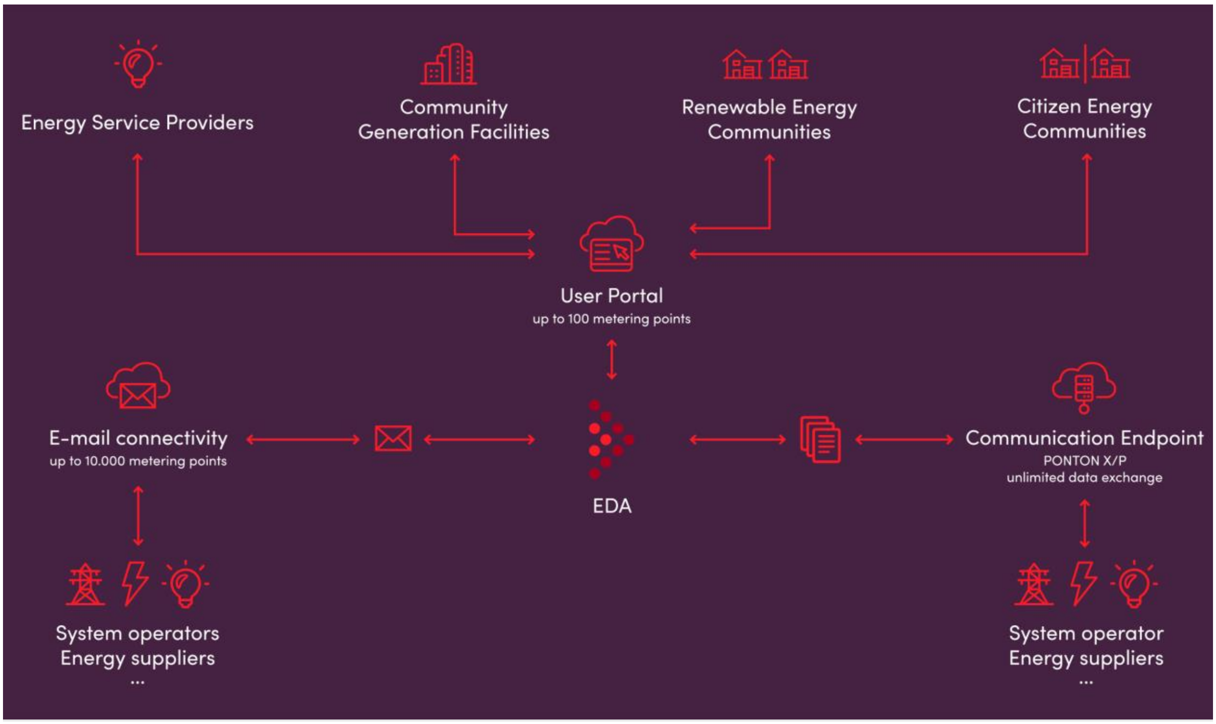
Besides the control aspect, Germany applies in the context of smart metering data a decentralised approach via the already shortly introduced MaKo. Each market participant in Germany interacts with another party (B2B) based on the common *Electronic Data Interchange for Administration, Commerce and Transport* (EDIFACT) data format developed at national level by the German working group *EDI@Energy*. Currently the data exchange is handled mostly by email services, however, this will be different with the ongoing AS4 webservice rollout until end of March 2024 (BDEW Bundesverband der Energie- und Wasserwirtschaft e.V.; Beschlusskammer 6 2022; THEMA Consulting Group 2017).

A.1.3.4 Austria

Austria is characterised by a diverse landscape of DSOs who are in this case responsible for the AMI development in their grid areas. The rollout is expected to be finalised until 2024 with at least 95% SM-equipped private consumers. If those consumers choose not to opt-out of 15-minute resolution meter data, they are able to access these at the consumer portal of their DSO a day after delivery. But if consumers decide to opt-in for non-standard pricing schemes such as a ToU tariff, this resolution is required. If this data must be shared with other parties, like an energy supplier or an energy community, a common decentralised data exchange method is applied. The EDA-solution is delivered by the Austrian TSO-DSO owned company EDA GmbH and allows a P2P-connection secured by a PKI and standardised components as well as nationally defined data formats (based also on EDIFACT messages) – see Figure 30 (EDA GmbH 2023a, 2023b; Merz 2021; Verein "Österreichs E-Wirtschaft").

As a feature for local optimization the Austrian household SMs can be connected to a standardised smart-meter-adapter. It allows private consumers to access non-validated SM data via their own HAN for self-defined purposes like a HEMS use case (Verein "Österreichs E-Wirtschaft").

Figure 30: Overview of the Austrian EDA P2P infrastructure



Source: EDA GmbH (figure sourced from (EDA GmbH 2023b))

10 References

ACER / CEER (Ed.) (2022): Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2021. Energy Retail and Consumer Protection Volume. Brussels, Belgium. Available at https://www.acer.europa.eu/sites/default/files/documents/Publications/MMR_2021_Energy_Retail_Consumer_Protection_Volume.pdf.

Acquirente Unico S.p.A.: Portale Consumi. Domande frequenti. Available at https://www.consumienergia.it/portaleConsumi/it/domande_frequenti.page.

Acquirente Unico S.p.A.: Sistema Informativo Integrato (SII). Available at https://www.acquirenteunico.it/attivita/sistema-informativo.

Autoritatea Naţională de Reglementare în domeniul Energiei (2023): Smart metering. Available at https://www.anre.ro/ro/energie-electrica/legislatie/smart-metering.

BDEW Bundesverband der Energie- und Wasserwirtschaft e.V.: Willkommen im Forum Datenformate. Available at https://www.edi-energy.de/.

BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. (Ed.) (2023): Einführungsszenario Universalbestellprozess. Anwendungshilfe. BK6-22-128 - Version: 1.0. Berlin, Germany. Available at https://www.bdew.de/service/anwendungshilfen/einfuehrungsszenario-universalbestellprozess/.

Beermann, V.; Rieder, A.; Uebernickel, F. (2022): Green Nudges: How to Induce Pro-Environmental Behavior Using Technology. Available at https://www.alexandria.unisg.ch/bitstreams/8b2fba99-9697-47f1-95ad-f85f20accab8/download.

Beschlusskammer 6 (2022): Beschluss in dem Festlegungsverfahren zur Absicherung der elektronischen Marktkommunikation Strom. Az.: BK6-21-282. Bonn, Germany. Available at https://www.bundesnetzagentur.de/DE/Beschlusskammern/1_GZ/BK6-GZ/2021/BK6-21-282/Beschluss%20BK6-21-282.pdf?__blob=publicationFile&v=2.

Big Data Value Association (Ed.) (2017): European Big Data Value Strategic Research and Innovation Agenda. Available at https://www.bdva.eu/sites/default/files/BDVA_SRIA_v4_Ed1.1.pdf.

Bundesnetzagentur für Elektrizität, Gas, Telekommunikation, Post und Eisenbahnen (Ed.) (2022): Monitoringbericht 2022. Monitoringbericht gemäß § 63 Abs. 3 i. V. m. § 35 EnWG und § 48 Abs. 3 i. V. m. § 53 Abs. 3 GWB. Bonn, Germany. Available at https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Monitoringberichte/MonitoringberichtEnergie2022.pdf?__blob=publicationFile&v=4.

Catena-X Automotive Network e.V. (2023): Catena-X. Association website. Available at https://catena-x.net.

Cleanwatts S.A. (2023): Cleanwatts™ OS. Available at https://cleanwatts.energy/cleanwatts-os/.

Commission, E. (2022): Digitalising the energy system - EU action plan. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52022DC0552&from=EN, accessed 19 01 2023.

Commission for Regulation of Utilities (2023): Smart Meters. Available at https://www.cru.ie/consumer-information/billing/smart-meters-and-services/.

Coote, D. (2022): Guide to energy management protocols. Final Report. Analytical Engines Pty Ltd. Available at https://www.iea-4e.org/wp-content/uploads/2022/11/Energy-Protocol-Report-Release.pdf.

Council of the European Union (Ed.) (2022): DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the resilience of critical entities and repealing Council Directive 2008/114/EC. 2020/0365 (COD). Available at https://data.consilium.europa.eu/doc/document/PE-51-2022-INIT/en/pdf.

Council of the European Union (Ed.) (2023a): Proposal for a Regulation of the European Parliament and of the Council on harmonised rules on fair access to and use of data (Data Act). Data Act. Available at https://data.consilium.europa.eu/doc/document/ST-7413-2023-INIT/en/pdf.

Council of the European Union (Ed.) (2023b). Council and Parliament reach provisional deal on renewable energy directive. Brussels. Available at https://www.consilium.europa.eu/en/press/press-releases/2023/03/30/council-and-parliament-reach-provisional-deal-on-renewable-energy-directive/.

Data Space Business Alliance (Ed.) (2022): Technical Convergence. Discussion Document.

Data Spaces Support Centre (2023a): Starter Kit for Data Space Designers. Available at https://dssc.eu/wp-content/uploads/2023/03/DSSC-Starterkit-Version-1.0.pdf.

Diputación de Granada (2021): Jornada de difusión sobre cambios en el sector eléctrico. Available at https://granadaenergia.es/wp-content/uploads/2021/04/5presentacionaelecplataformadatadis.pdf.

DRM Datenraum Mobilität GmbH (2023): The Mobility Data Space. Company website. Available at https://mobility-dataspace.eu/.

DSSC (2023b): Data Spaces Support Centre. DSSC. Available at https://dssc.eu.

Dublin Core™ Metadata Initiative (2012): Dublin Core™ Metadata Element Set. Version 1.1: Reference Description. Available at https://www.dublincore.org/specifications/dublin-core/dces/.

ebIX®, EFET and ENTSO-E (Ed.) (2022): THE HARMONISED ELECTRICITY MARKET ROLE MODEL. Available at https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/HRM/Harmonised_Role_Model_2022-01.pdf.

EDA GmbH (2023a): Energy Service Providers. Available at https://www.eda.at/energiedienstleister?lang=en.

EDA GmbH (2023b): How does EDA work? Available at https://www.eda.at/wie-funktioniert-eda?lang=en.

EEBus Initiative e.V. (2023): EEBUS main website. Available at https://www.eebus.org/.

Elering AS: Smart Grid. Smart grid development. Available at https://elering.ee/en/smart-grid-development.

Elering AS (2022): Estfeed developments. Developments related to energy companies. Available at https://elering.ee/en/developments-related-energy-companies.

Elering AS (Ed.) (2023): DATA HUB. Guide for Using and Joining Data Hub. Version 2.8. Singapore. Available at https://www.elering.ee/sites/default/files/2023-01/EL%20-%20Guide%20for%20Using%20and%20Joining%20Data%20Hub%202023-01.pdf.

Enedis (Ed.) (2022). Avec Linky, la sobriété énergétique à portée de main. Paris, France. Available at https://www.enedis.fr/sites/default/files/documents/pdf/cp-enedis-avec-linky-la-sobriete-energetique-a-portee-de-main.pdf.

Energie Codes & Services GmbH (2023): Über uns. Available at https://www.energiecodes-services.de/ueber-uns.html.

Energiföretagen Sverige; Independent Elhandlare; Svenska kraftnät (Eds.) (2022): Svensk Elmarknadshandbok / Swedish Electricity Market Handbook. Edition no. 22B. Available at https://www.elmarknadshandboken.se/Dokumentation/Texter/NEMHB.pdf.

Energinet (Ed.) (2018): The Danish Electricity Retail Market. Introduction to DataHub and the Danish supplier-centric model. Fredericia, Denmark. Available at https://en.energinet.dk/media/qouleeb5/danish-electricity-retail-market.pdf.

ENTSO-E (2021): Review of Flexibility Platforms. Available at https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/SOC%20Reports/210957_entso-e_report_neutral_design_flexibility_platforms_04.pdf.

ENTSO-E (2023a): MARI. Available at https://www.entsoe.eu/network_codes/eb/mari.

ENTSO-E (2023b): PICASSO. Available at https://www.entsoe.eu/network_codes/eb/picasso/.

Equigy B.V. (Ed.) (2022): Equigy. Project Development Assistance. Rambøll Danmark A/S. Available at https://equigy.com/wp-content/uploads/2022/11/Ramboll-for-publication.pdf.

Equigy B.V. (Ed.) (2023): Nord Pool and Equigy Partner for Power Flexibility. Available at https://equigy.com/2023/02/13/nord-pool-and-equigy-partner-for-power-flexibility/.

ESB Networks DAC: Meter Registration System Operator (MRSO). Available at http://www.mrso.ie/about_mrso/index.htm.

ESB Networks DAC (Ed.) (2022): Data Protection for the National Smart Metering Project. Overview. Version 3.0. Available at https://www.esbnetworks.ie/docs/default-source/publications/smart-metering-dp-overview-september-2022---final.pdf?sfvrsn=2879d026_13.

eSett Oy (Ed.) (2022): Nordic Imbalance Settlement (NBS) Handbook. Instructions and Rules for Market Participants. version 4.2. Helsinki, Finnland. Available at https://www.esett.com/app/uploads/2022/12/NBS-Handbook-v4.2.pdf.

Estfeed, smart meter data share (2020): Estfeed. Available at https://www.estfeed.eu/en/about, accessed 23.01.2023.

ETSI (Ed.) (2023): SAREF4AUTO. SAREF extension for automotive. Available at https://saref.etsi.org/saref4auto/v1.1.1/.

European Commission (Ed.): Technology readiness levels (TRL). HORIZON 2020 – WORK PROGRAMME 2014-2015. Brussels, Belgium. Available at https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf.

European Commission (2012): 2012/148/EU: Commission Recommendation of 9 March 2012 on preparations for the roll-out of smart metering systems. Available at http://data.europa.eu/eli/reco/2012/148/oj.

European Commission (Ed.) (2017): New European Interoperability Framework. Promoting seamless services and data flows for European public administrations. Luxembourg. Available at https://ec.europa.eu/isa2/sites/default/files/eif_brochure_final.pdf.

European Commission (Ed.) (2019): COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. The European Green Deal. Available at https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF.

European Commission (Ed.) (2020): A European strategy for data. Available at https://commission.europa.eu/document/download/b456e96e-5810-4bb3-94ca-16c4d8d911b2_en.

European Commission (Ed.) (2021a): 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN.

European Commission (Ed.) (2021b): Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652. RED III. Available at https://eur-lex.europa.eu/resource.html?uri=cellar:dbb7eb9c-e575-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF.

European Commission (Ed.) (2022): REPowerEU Plan. COM(2022) 230. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A230%3AFIN&qid=1653033742483.

European Commission (2023a): Access to data for demand response in electricity – requirements. Available at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13936-Access-to-data-for-demand-response-in-electricity-requirements_en.

European Commission (2023b): Access to data for switching electricity supplier – requirements. Available at https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13937-Access-to-data-for-switching-electricity-supplier-requirements_en.

European Commission (Ed.) (2023c): Code of Conduct on energy management related interoperability of Energy Smart Appliances. First Draft. Brussels, Belgium: Joint Research Centre. Available at https://ses.jrc.ec.europa.eu/sites/default/files/files/documents/draft_of_code_of_conduct_for_interoperability_of_energy_smart_appliances.pdf.

European Commission (Ed.) (2023d): Electricity Market Design. Brussels. Available at https://energy.ec.europa.eu/topics/markets-and-consumers/market-legislation/electricity-market-design_en.

European Commission (2023e): Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulations (EU) 2019/943 and (EU) 2019/942 as well as Directives (EU) 2018/2001 and (EU) 2019/944 to improve the Union’s electricity market design. COM(2023) 148 final. Available at https://energy.ec.europa.eu/document/download/63d0556f-2cbb-41ec-a803-d6bd395a1a0d_en?filename=COM_2023_148_1_EN_ACT_part1_v6.pdf.

European Commission (Ed.) (2023f): Annex to the Commission Implementing Regulation (EU) on interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data. C(2023) 3477 final ANNEX. Brussels, Belgium. Available at https://energy.ec.europa.eu/document/download/3719df92-8ef5-4576-a78f-01b34d76bd8e_en?filename=C_2023_3477_1_EN_annexe_acte_autonome_part1_v4.pdf.

European Commission (Ed.) (2023g): Commission Implementing Regulation (EU) on interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data. C(2023) 3477 final. Brussels, Belgium. Available at https://energy.ec.europa.eu/document/download/9b9cdf0f-c1a0-4e8f-9f13-d587fe29345d_en?filename=C_2023_3477_1_EN_ACT_part1_v5.pdf.

European Commission; Joint Research Centre; Koolen, D.; Felice, M. de; Busch, S. (2023): Flexibility requirements and the role of storage in future European power systems. Publications Office of the European Union. https://doi.org/10.2760/384443.

European Commission; Joint Research Centre; Saviuc, I.; Zabala López, C.; Puskás-Tompos, A.; Rollert, K.; Bertoldi, P. (2022): Explicit demand response for small end-users and independent aggregators : status, context, enablers and barriers. Publications Office of the European Union. https://doi.org/10.2760/625919.

European Union (Ed.) (1996): Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31996L0092.

European Union (Ed.) (2019): Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast) (Text with EEA relevance.). IEM-D. Available at http://data.europa.eu/eli/dir/2019/944/oj.

European Union Agency for the Cooperation of Energy Regulators (Ed.) (2022): Framework guideline on demand response to the European Commission. Ljubljana, Slovenia. Available at https://acer.europa.eu/sites/default/files/documents/Official_documents/Acts_of_the_Agency/Framework_Guidelines/Framework%20Guidelines/FG_DemandResponse.pdf.

EVTEC (2023): sospeso&charge. Product overview. Available at https://www.evtec.ch/en/produkte/sospeso.

Federal Office for Information Security (Ed.) (2023): Certificate Policy der Smart Metering PKI. Version 1.1.2. Bonn, Germany. Available at https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Publikationen/TechnischeRichtlinien/TR03109/PKI_Certificate_Policy.pdf?__blob=publicationFile&v=7.

Flexiblepower Alliance Network and LCP Delta (Ed.) (2023): Connected heat pumps in the Netherlands - update 2023. Edinburgh, United Kingdom. Available at https://flexible-energy.eu/wpcms/wp-content/uploads/2023/04/Final-report_Connected-HPs-in-NL-FAN.pdf.

Forum für Zukunftsenergien, Celron Consulting, Fraunhofer IEE, Themen magazin (Ed.) (2023): Unternehmensübergreifender Datenaustausch im Energiesektor (Energy Data Spaces). Ergebnisse einer Expertenbefragung. Berlin.

Fraunhofer ISI (2021): Enertile Langfristszenarien - Website. Available at https://www.langfristszenarien.de/enertile-explorer-en/scenario-explorer/offer.php.

Gassmann, O.; Frankenberger, K.; Csik, M. (2013): The St. Gallen business model navigator. Available at https://www.alexandria.unisg.ch/224941/7/business%20model%20navigator%20working%20paper.pdf.

Ghosal, A.; Conti, M. (2019): Key Management Systems for Smart Grid Advanced Metering Infrastructure: A Survey. In: IEEE Communications Surveys & Tutorials, 21 (3), pp. 2831–2848. https://doi.org/10.1109/COMST.2019.2907650.

Gridio (2023): The smart way to use energy. Company website. Available at https://www.gridio.io/.

Gridspertise S.r.l. (Ed.) (2022). New agreements for the sale of 650,000 smart meters and 150,000 accessories and eld operation devices to 12 DSOs. Rome, Italy. Available at https://www.gridspertise.com/search-news/news/2022/01/new-agreements-closed-smart-meters-supply.

Heer, H. de; van der Laan, M.; Armenteros, A. S. (2021): USEF - The Framework explained. Arnhem: USEF foundation. Available at https://www.usef.energy/app/uploads/2021/05/USEF-The-Framework-Explained-update-2021.pdf.

Hilpert, J.; Agnesens, A.; Weigand, A.; Abromeit, A.; Münderlein, J.; Dossow, P.; Ostermann, A.; Fait, L.; Thiele, J.; Springmann, E. (2023): Netzdienliches Laden von Elektrofahrzeugen. Konzepte aus dem Projekt unIT-e². Munch, Germany: Stiftung Umweltenergierecht; Schneider Electric; Stadtwerke München; EEBUS; Bayernwerk Netz GmbH; FfE München; Universität Kassel; EAM Netz GmbH. Available at https://unit-e2.de/123808.

Hive Power SA (2023): Smart Charging. Product overview. Available at https://www.hivepower.tech/flexo/flexo-smart-charge.

IDSA: Data Space Radar. Available at https://internationaldataspaces.org/adopt/data-space-radar/.

Italian Regulatory Authority for Energy, Networks and Environment (2022): Installazione di misuratori 2G prevista dalle principali imprese distributrici. Available at https://www.arera.it/allegati/elettricita/smartmeter_2G.xlsx.

Klobasa, M.; Kühnbach, M.; Singh, M.; Knorr, K.; Schütt, J.; Boer, J.; Rolser, O.; Hernandez Diaz, D.; Fitzschen, F.; Garcerán, A.; Reina, R.; Stemmer, S.; Steinbach, J.; Popovski, E.; Antretter, M. (2022): Digitalisation of energy flexibility. https://doi.org/10.2833/113770.

Konsman, M.; Meima, N.; Timmerman, M.; Campa, A.; Bellesini, F. (2022): Deliverable D4 3 Flexible assets DT models – first version. Boosting DR through increased communIty-level consumer engaGement by combining Data-driven and blockcHain technology Tools with social science approaches and multi-value service design (BRIGHT). TNO, Comsensus, Emotion. Available at https://www.brightproject.eu/wp-content/uploads/2022/06/BRIGHT_D4.3_V1.0_TNO.pdf.

Kroener, N.; Förderer, K.; Lösch, M.; Schmeck, H. (2020): State-of-the-Art Integration of Decentralized Energy Management Systems into the German Smart Meter Gateway Infrastructure. In: Applied Sciences, 10 (11), p. 3665. https://doi.org/10.3390/app10113665.

L'Académie des technologies (Ed.) (2019): Les compteurs communicants Linky. Une nouvelle technologie dans tous les foyers :. enjeux et inquiétudes Avis de l'Académie des technologies. Paris, France. Available at https://www.academie-technologies.fr/wp-content/uploads/2021/10/Avis_Linky.pdf.

Living Lab Smart Charging (2017): Smart Charging & Electromobility. Driving on solar and wind power! Available at https://elaad.nl/wp-content/uploads/downloads/book-smart-charging-english.pdf.

Meier, U.; Peter, F.; Jahn, A.; Hildemeier, J. (2019): Distribution grid planning for a successful energy transition – focus on electromobility. Conclusions of a study commissioned by Agora Verkehrswende, Agora Energiewende and Regulatory Assistance Project (RAP). Berlin: Agora Energiewende. Available at https://www.agora-verkehrswende.de/fileadmin/Projekte/2019/EV-Grid/AgoraRAP2019_VerteilnetzausbauElektromobilitaet_EN.pdf.pdf.

Merz, H. (2021): PONTON has been awarded as the principal provider of the Austrian energy data communication infrastructure. Available at https://www.ponton.de/ponton-has-been-awarded-as-the-principal-provider-of-the-austrian-energy-data-communication-infrastructure/.

Nagel, L.; Lycklama, D. (2021): Design Principles for Data Spaces - Position Paper. https://doi.org/10.5281/ZENODO.5105744.

Navitasoft Zrt. (2022): Elering's Estfeed data hub to receive major overhaul. Available at https://navitasoft.com/de/node/164.

NL AI Coalition (Ed.) (2023): Reference Guide for intra AI data space interoperability. Developing individual AI data space instances. Available at https://nlaic.com/wp-content/uploads/2023/04/NL-AIC-intra-AI-Data-Space-Interoperability-v3.2.pdf.

OMS-Group e. V. (2023): Open Metering System (OMS). M-Bus inside. Available at https://oms-group.org/en/.

Papaioannou, I.; Andreadou, N.; Tarramera Gisbert, A. (2022): Energy Smart Appliances' Interoperability: Analysis on Data Exchange from State-of-the-art Use Cases. Supporting the development of policy proposals for energy smart appliances. JRC Technical Report. Luxembourg: Joint Research Centre. https://doi.org/10.2760/199155.

Papouis, C.; Kylili, A.; Fokaides, P. A. (2023): Adapting to energy storage needs: gaps and challenges arising from the European directive for the electricity internal market. In: Clean Technologies and Environmental Policy. https://doi.org/10.1007/s10098-023-02510-6.

Pelletier, P.; Chapert, M.; Bazot, T.; Lauzevis, P.; Brun, S.; Luca, L. de (2017): Linky contributions in management and fault detection. In: CIRED - Open Access Proceedings Journal, 2017 (1), pp. 1875–1877. https://doi.org/10.1049/oap-cired.2017.1326.

Plantera, F.: Case study. Access to electricity and gas smart meter data in Estonia powered by X-Road technology. Available at https://x-road.global/access-to-electricity-and-gas-smart-meter-data-in-estonia.

Platform Datadis CB: datadis. Access the electricity consumption of all your contracts. Available at https://datadis.es/.

Pollitt, M.; Giuletti, M.; Anaya, K. (2021): Optimal regulation for European DSOs to 2025 and beyond. Brussels, Belgium. Available at https://cerre.eu/wp-content/uploads/2021/04/CERRE_Optimal-regulation-for-European-DSOs-to-2025-and-beyond_April-2021_FINAL.pdf.

PONTON GmbH (2020): EDA – Energy Data exchange Austria. Available at https://www.ponton.de/b2b-integration/eda/.

Project Haystack Corporation (2023): Project Haystack. An Open Source initiative to streamline working with IoT Data. Available at https://project-haystack.org/.

Ramboell (2022): Equigy Project Development Assistance. Available at https://equigy.com/wp-content/uploads/2022/11/Ramboll-for-publication.pdf.

Smart metering di seconda generazione. Le novità della regolazione (2017) (Incontro con le associazioni dei consumatori 11 gennaio 2017). Italian Regulatory Authority for Energy, Networks and Environment. Available at https://www.arera.it/allegati/elettricita/170111smartmet.pdf.

sonnen GmbH: Virtuelle Kraftwerke – ein unerlässlicher Baustein der Energiewende. Virtuelle Kraftwerke sind eine Technologie, ohne die die Energiewende schwer gelingen kann. Wir erklären, was virtuelle Kraftwerke sind und was sie leisten. Wissen | sonnenVPP. Available at https://sonnen.de/wissen/virtuelle-kraftwerke-und-energiewende/.

Steinbuss, S. (2022): IDS Reference Architecture Model Version 4. Available at https://docs.internationaldataspaces.org/ids-ram-4/.

Steinbuss, S. (Ed.) (2023): IDSA Rulebook. Dortmund: International Data Spaces Association. Available at https://docs.internationaldataspaces.org/ids-knowledgebase/v/idsa-rulebook.

SunSpec Alliance (2023): Sunspec Modbus - Website. Available at https://sunspec.org/sunspec-modbus-specifications/.

Sylla, S.; Springmann, E. (2023): The Smart Meter Rollout in Germany and Europe. Available at https://www.ffe.de/en/publications/the-smart-meter-rollout-in-germany-and-europe/.

The European Parliament and the Council of the European Union (Ed.) (2009): DIRECTIVE 2009/72/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC (Text with EEA relevance). Available at http://data.europa.eu/eli/dir/2009/72/oj.

THEMA Consulting Group (Ed.) (2017): Data exchange in electric power systems. European State of Play and Perspectives. Commissioned by ENTSO-E. Oslo, Norway. Available at https://www.entsoe.eu/news/2017/06/26/study-data-exchange-in-electric-power-systems-european-state-of-play-and-perspectives/.

Thread Group, Inc. (2023): Thread. Available at https://www.threadgroup.org/support#specifications.

Uribe-Pérez, N.; Hernández, L.; La Vega, D. de; Angulo, I. (2016): State of the Art and Trends Review of Smart Metering in Electricity Grids. In: Applied Sciences, 6 (3), p. 68. https://doi.org/10.3390/app6030068.

van Aubel, P.; Poll, E. (2019): Smart metering in the Netherlands: What, how, and why. In: International Journal of Electrical Power & Energy Systems, 109, pp. 719–725. https://doi.org/10.1016/j.ijepes.2019.01.001.

Verein "Österreichs E-Wirtschaft": DATENBLATT SMART-METER-ADAPTER. Available at https://oesterreichsenergie.at/fileadmin/user_upload/Oesterreichs_Energie/Publikationsdatenbank/Leitfaden/2022/Datenblatt_Smart_Meter_Adapter_V7_20220808.pdf.

Verein "Österreichs E-Wirtschaft": Smart Meter. Frequently Asked Questions. Available at https://oesterreichsenergie.at/smart-meter/faq.

Vitiello, S.; Andreadou, N.; Ardelean, M.; Fulli, G. (2022): Smart Metering Roll-Out in Europe: Where Do We Stand? Cost Benefit Analyses in the Clean Energy Package and Research Trends in the Green Deal. In: Energies, 15 (7), p. 2340. https://doi.org/10.3390/en15072340.

VOLTALIS SA (Ed.) (2023): Notre Solution. Paris, France. Available at https://www.voltalis.com/particuliers/notre-solution.

WAGO Corporation (Ed.) (2023): Easy Automation with LonWorks®. Germantown, USA. Available at https://www.wago.com/us/lonworks.

Wallbox UK (2023): Quasar 2. Product overview. Available at https://wallbox.com/en_uk/quasar-2-bidirectional-ev-charger.

Wargers, A.; Eck, A. van (2022a): Energy Management Opportunities For The Home. Version 1.2. Available at https://flexible-energy.eu/wpcms/wp-content/uploads/2022/12/Energy-Management-Opportunities-for-The-Home.pdf.

Wargers, A.; Klapwijk, P.; Praster, B.; Dickhof, R. (2020): In-Home Energy Flexibility Protocols. Utrecht, Netherlands. Available at https://elaad.nl/wp-content/uploads/downloads/In-Home-Energy-Flexibility-Protocols-TKI-Urban-Energy-v1-20200630.pdf.

Wargers, A.; van Eck, A. (2022b): Energy Management Opportunities For The Home. Version 1.2. Arnhem/Rotterdam, Netherlands. Available at https://flexible-energy.eu/wpcms/wp-content/uploads/2022/12/Energy-Management-Opportunities-for-The-Home.pdf.

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