Blueprint of the Common European Energy Data Space

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Germany

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AUTHORS

Alberto Dognini (Fraunhofer FIT)
Antonello Monti (Fraunhofer FIT)
Antonio Kung (Trialog)
Arturo Medela (Eviden)
Charukeshi Joglekar (Fraunhofer FIT)
Christoph Schaffer (FH Hagenberg)
Daniele Stampatori (EUI)
Diana Jimenez (Trialog)
Erik Maqueda (Tecnalia)
Fabio Coelho (INESC TEC)
Florian Mancel (EDF)
Georg Hartner (Hartner Consulting)
Gianluca Lipari (EPRI)
Javier Valiño (Eviden)
Joseba Jimeno Huarte (Tecnalia)
Laia Guitart (E.DSO)
Laurent Schmitt (Digital4Grids)
Ludwig Karg (B.A.U.M.)
Maarten Kollenstart (TNO)
Maider Santos Mugica (Tecnalia)
Marc Kurz (FH Hagenberg)
Marion Arles (Gireve)
Markus Stroot (Fraunhofer FIT)
Maro Baka (Que Technologies)
Martina Galluccio (RINA)
Massimo Bertoncini (Engineering)
Maurizio Fantino (Links Foundation)
Oliver Hödl (FH Oberösterreich)
Olivier Genest (Trialog)
Ricardo Bessa (INESC TEC)
Rita Dornmair (B.A.U.M.)
Sonia Jimenez (IDSA)
Tasos Tsitsanis (Suite5)
Thomas Strasser (AIT)
Volker Berkhout (Fraunhofer IEE)

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CONTENTS

1 Introduction

The shift in the energy sector, outlined as a key aspect of the Green Deal and detailed in the REPowerEU plan, necessitates a widespread substitution of fossil-fuel-based power generation with low-CO_2 technologies. Although substantial progress has been made towards meeting the targets, achieving a complete transformation remains a lengthy and intricate process. Central to this transformation is the electrical grid, which already plays a crucial role in facilitating our contemporary lifestyle. However, its significance has now heightened due to the increased electrification of sectors like mobility as well as temperature control of buildings. Now more than ever, Europe requires an electrical network that is resilient, cyber-secure, flexible, and reliable. Meeting this demand is contingent on the implementation of advanced automation solutions and the comprehensive digitalization of entire energy systems.

Data spaces play a pivotal role in advancing the digitalization of electrical energy systems, ushering in a new era of efficiency, reliability, and sustainability. In fact, data spaces address both the new business opportunities as well as the existing technical challenges. As the energy landscape undergoes a profound transformation, characterized by the integration of renewable sources, electrification of various sectors, and a growing emphasis on decarbonization, the need for intelligent and interconnected systems becomes increasingly evident. Moreover, data spaces facilitate predictive analytics, enabling proactive maintenance and reducing downtime in critical components of the electrical grid. Additionally, data spaces support the deployment of advanced automation solutions, enabling adaptive and responsive grids that can dynamically adjust to changing energy demands and supply conditions. Furthermore, the interconnected nature of data spaces promotes collaboration among various stakeholders, including utilities, regulators, technology providers, and consumers. This collaborative environment fosters innovation, accelerates the development of smart technologies, and ensures a more inclusive and participatory approach to the energy transition. Hence, data spaces emerge as catalysts for the digital transformation of electrical energy systems, offering a comprehensive and interconnected approach to managing the complexities of modern energy landscapes. Through the integration of data spaces, the energy sector can harness the power of information to build resilient, efficient, and sustainable electrical systems for the future.

1.1 Scope

This document addresses the concept of a Common European Energy Data Space (CEEDS), providing detailed approaches and recommendations for its real-world realization. In particular, the main objective of this blueprint is to guide on enhancing the existing data infrastructures, the energy domain, towards the full embracement of data space solutions. Bridging this gap will empower the introduction of novel energy services, which will increase the efficiency and reliability of the energy systems while providing substantial benefits for every stakeholder.

The key scope of this document is to present (i) a framework for new economically feasible business use cases and (ii) the general data space architecture that can enable them. This architecture aims to interconnect the existing data infrastructures, of legacy systems, with federated data spaces; at this scope, technical specifications have been included.

The blueprint is organized as follows: Section 2 provides general insights into the data space concepts and, particularly, specifically related to the energy domain; Section 3 describes the reference use cases for CEEDS while Section 4 presents the proposed architecture that enables their realization. Notable insights and references for the technical, semantic and governance interoperability of energy data spaces are discussed in Section 5. Section 6 concludes the document.

2 Data Spaces Concept

The conceptualization of data spaces was initiated several years ago, providing the basis for characterization in specific domains like energy. Considering a domain-agnostic perspective, a data space is defined in the DSSC Blueprint [1] as *"a distributed system defined by a governance framework, that enables trustworthy data transactions between participants while supporting trust and data sovereignty. A data space is implemented by one or more infrastructures and supports one or more use cases"*.

In light of this definition, three transversal features must be considered in the data space deployment:

- **Security and Privacy**: Concentrating on ensuring the security and privacy of the exchanged data within the designated data space.
- **Quality and Integrity**: Relating to the quality and integrity of the data residing within the data space. This encompasses elements associated with metadata, such as data validation, data cleansing, data accuracy, and data consistency.
- **Governance and Policy**: Encompassing the structure of governance and policies dictating the data spaces, addressing decision-making, data governance frameworks (comprising rules and practices for management and operations), policies for data sharing and access, as well as energy-related policies and regulations.

Furthermore, the deployment of a data space is performed according to five main dimensions, which reflect the transversal features described above. These dimensions correspond to:

- **Business:** examining the business model related to data exchange, such as utilizing consumption data for implementing flexibility planning in the wholesale market and delineating the business roles of involved parties.
- **Legal:** Delving into the legal framework, encompassing (a) overarching legal frameworks, (b) organizational aspects, and (c) contractual instruments.
- **Operation:** Providing insights into the operational framework, including use cases, processes, and activities.
- **Functional:** Describing the technical and governance building blocks, deployed based on necessary technical services (and their dependencies), as well as adherence to data standards.
- **Technology:** Offering specifications on adopted standards, references, or required software components. A primary objective is to ensure interoperability among internal parties and with other data spaces.

The realization of a data space in the energy domain must, then, address every indicated dimension and implement the required measures; even if existing solutions are already in place and well advanced for individual dimensions (e.g., an operational framework for grid management or a standardized data model that addresses a specific interoperability point), consistent work must be deployed to synchronize and align all the different dimensions simultaneously and in a defined system.

2.1 Overall Strategies

From the overall viewpoint at the highest level, the CEEDS is foreseen as the common framework that federates different data spaces (each of which is implemented at the national, sub-national level or international level) and allows the participation of the single users. Different layers are then defined, from the local data space solutions to the federated ecosystem of data spaces, following a decentralized configuration. Considering the representations in Figure 1, from a closed ecosystem (on the left, panel I), a further expansion consists of implementing data exchanges with external participants (who, in any case, subscribe to the governance rules) achieving an open ecosystem (panel II). Additionally, as the next expansion, the structured interactions among different ecosystems (i.e., following the interoperability of the specific governance rules) allow to reach the ecosystem of data space solutions, as a federation (panel III); it is worth highlighting that the participation of single users remains a foremost feature in the federation of ecosystems.

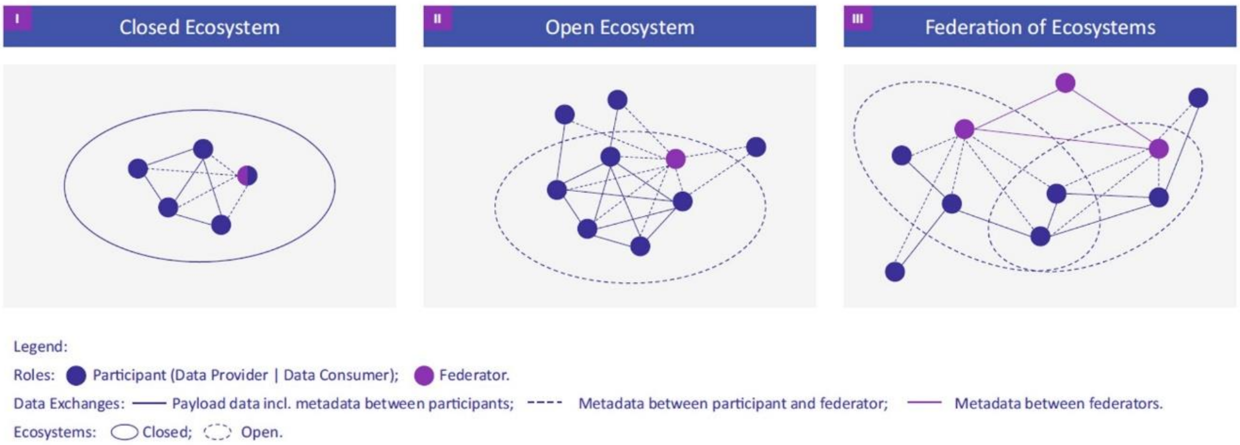

Figure 1 - Possible ecosystems strategies for data spaces (from [2]).

The federation of ecosystems is the model that will be pursued to interconnect the data space instances of the cluster projects, paving the way for the CEEDS. This federation relies on specific measures for technical, semantic and governance interoperability, which will be described in section 5 of the present document.

2.2 Defining Data Spaces Across Diverse Uses

In the evolving landscape of digital transformation, data spaces have emerged as a foundational element for fostering innovation, enhancing interoperability, and ensuring governance across various sectors. These collaborative environments[1] enable stakeholders to share, access, and manage data securely, fostering a new era of efficiency and innovation. The concept of data spaces transcends traditional data management approaches by emphasizing user control, privacy, and the seamless exchange of information across diverse ecosystems. As we delve into the specifics of data spaces, it is crucial to understand their multifaceted roles and the objectives they serve, which include:

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[1] https://datacollaboratives.org/

1. **Educational Purpose and Research:** Facilitating access to vast datasets and fostering collaborative research environments, the data spaces enhance educational outcomes and drive forward scientific inquiry and innovation.
2. **Data Exchange and Interoperability:** By enabling the secure and efficient exchange of data between entities, data spaces overcome interoperability challenges, ensuring seamless interaction across different systems and platforms.
3. **Innovation and New Business Models:** Data spaces act as incubators for new business models, supporting startups and established businesses alike in developing innovative services and products through shared data insights.
4. **Data Analysis and Visualization:** Providing powerful tools for data analysis and visualization, data spaces empower organizations to derive meaningful insights from complex datasets, enhancing decision-making processes.
5. **Governance and Regulation:** Data spaces can act as data-driven frameworks, evidence-based for supporting public authorities and national agencies at different levels to enhance decision-making processes, streamline regulatory compliance, and foster transparent governance mechanisms. This infrastructure enables the effective monitoring, analysis, and dissemination of information critical to societal welfare, economic stability, and environmental sustainability.

Table 1 summarizes the different data spaces categories across uses.

Table 1 - Categories of data spaces.

Data Space Categories	
Categories	**Scope and Description**
Educational Purpose and Research	Data spaces support the sharing of educational resources, academic research, and collaboration across institutions and countries. They enable access to a wide range of data, fostering innovation and knowledge dissemination.
Data Exchange and Interoperability	They are crucial for enabling the exchange of data between different entities, improving interoperability among diverse systems and platforms. This facilitates seamless data sharing and collaboration across sectors, enhancing service delivery and operational efficiency[2].
Innovation and New Business Models	By allowing secure and controlled access to data, data spaces drive innovation, supporting the development of new business models, products, and services. They enable companies to leverage shared data for creating value-added services and improving competitive advantage.[3]
Data Analysis and Visualization	Data spaces facilitate the transformation of data into actionable insights through advanced analysis and visualization tools. This enables more

[2] https://www.gradiant.org/en/blog/data-spaces-europe/
[3] https://www.geograma.com/en/blog/common-data-spaces-their-usefulness-and-current-situation-in-the-european-union/

	informed decision-making and reveals hidden trends, driving efficiency and strategic initiatives.
Governance and Regulation	Data spaces can empower public authorities and agencies to enhance regulatory frameworks and improve the governance of society and systems. By providing a reliable infrastructure for data governance and compliance, they support the development of more effective policies and governance models.

3 Business Use Cases for Energy

The energy system is in need of strong digital advancements that can enable more efficient, secure and carbon-free power generation, distribution and consumption. At this scope, new energy services are required, which seamlessly interconnect various stakeholders including consumers, local communities, TSOs, DSOs, multi-energy utilities, e-mobility operators, RES investors and operators, and non-energy service providers. These energy services relate to new business opportunities for the energy stakeholders; in particular, a set of high-level Business Use Cases (BUCs) has been defined by the cluster of energy data spaces projects, which exploit and fully rely on the use of data space technologies. Nevertheless, a crucial prerequisite for maximizing the advantages of the data spaces in the energy domain is the integration of data from diverse sources and with standardized data models and ontologies; the BUCs describe the specific data exchanges that occur among the involved actors. The scope of this chapter is to present what are the new business opportunities that are emerging in the energy sector, putting an emphasis on their business and technical feasibility.

The five BUCs foster and support the large-scale deployment of the CEEDS, maximizing the benefits of data exchanges via the data spaces approach towards the enablement of new energy services.

The BUCs correspond to:

- **Use case #1 – "Collective self-consumption and optimized sharing for energy communities"**
- **Use case #2 – "Residential home energy management integrating Distributed Energy Resources (DER) flexibility aggregation"**
- **Use case #3 – "TSO-DSO coordination for flexibility"**
- **Use case #4 – "Electromobility: services roaming, load forecasting and schedule planning"**
- **Use case #5 – "Renewables O&M optimization and grid integration"**

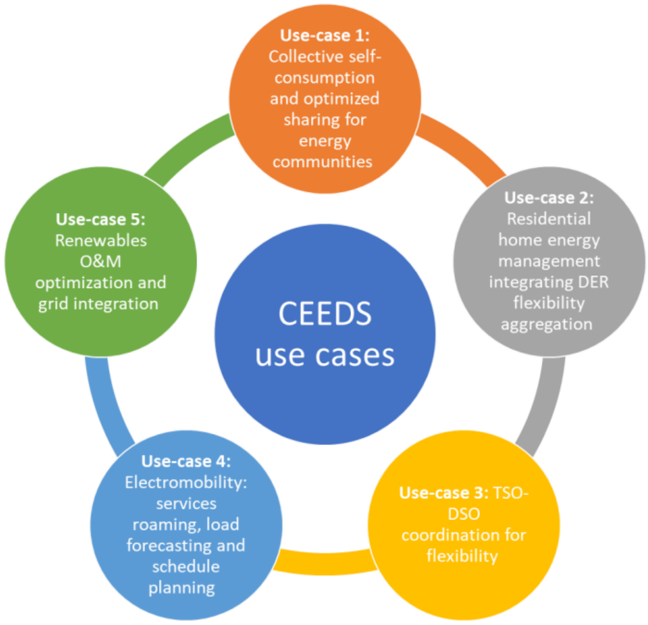

Figure 2 - Identified reference use cases for CEEDS.

The following sub-sections describe the technical details of every BUC. They are presented according to the general scope, the technical description of implemented services and the scenarios (i.e., the involved actors and the technical details of the data exchange instances, represented in sequence diagrams). It is worth highlighting that every actor of the BUCs corresponds to a data space participants, with the role of data provider or data consumer.

Table 2 compares and summarizes the five BUCs with respect to (i) Scope, (ii) Data Exchange Focus and main (iii) Key Actors, while Table 3 presents a taxonomy for different data space uses: (i) Educational Purpose and Research, (ii) Data Exchange and Interoperability, (iii) Innovation and New Business Models, (iv) Data Analysis and Visualization, (v) Governance and Regulation.

Table 2 - Summary of the BUCs.

Use Case ID	Use Case Title	Scope	Data Exchange Focus	Key Actors
#1	Collective self-consumption and optimized sharing for energy communities	Residential and Commercial Energy Communities; energy sharing optimization	Data collection/sharing for flexibility and energy savings; non-intrusive load monitoring	Energy service companies, Energy traders, Market information aggregators, Resource aggregators
#2	Residential home energy management integrating DER flexibility aggregation	Optimization of DER through data spaces for reducing grid congestions and critical peak prices	Real-time data exchange and streaming; leveraging IoT, edge computing	Prosumers, DER operators, Flexibility Service Providers (FSP), Local energy management providers
#3	TSO-DSO coordination for flexibility	Enhancing resilience and integration of large RES; non-cable solutions for congestion and voltage issues	Forecasting of loads and generation for resource scheduling; real-time control	TSOs, DSOs, DER operators, FSP
#4	Electromobility: services roaming, load forecasting, and schedule planning	Optimization of EV charging infrastructure and services; predictive charging consumptions for grid management	Booking and scheduling of EV charging services; predictive analytics for EV charging demand	Charge Point Operators (CPO), e-Mobility Service Providers (eMSP), EV users
#5	Renewables O&M optimization and grid integration	Optimizing O&M of renewable energy assets; efficient integration of distributed energy sources into the smart grid	Leveraging data for fault detection, automated diagnosis, and maintenance; smart grid integration analytics	RES plant owners/operators, DSOs, Original Equipment Manufacturer (OEM), Component manufacturers, Data analytics service providers.

Table 3 - Data spaces objectives with respect to the BUCs.

Data Spaces Objectives	BUC #1: Collective Self-Consumption and Optimized Sharing	BUC #2: Residential Home Energy Management	BUC #3: TSO-DSO Coordination for Flexibility	BUC #4: Electromobility: Services Roaming, Load Forecasting, and Schedule Planning	BUC #5: Renewables O&M Optimization and Grid Integration
Educational Purpose and Research	Developing community models and energy sharing mechanisms	DER optimization strategies and technologies	Advanced grid management and flexibility solutions	EV charging patterns and infrastructure optimization	Innovative O&M techniques for renewables integration
Data Exchange and Interoperability	Exchange of energy consumption and generation data	Real-time data streaming from IoT devices	Sharing of flexibility needs and resources	Interoperability between CPOs, eMSPs, and EMRSPs	Sharing of operational data for O&M optimization
Innovation and New Business Models	Novel community energy sharing models	Home energy management solutions	Market-based approaches for flexibility	New business models for EV charging services	Data-driven O&M and grid integration solutions
Data Analysis and Visualization	Analysis of energy patterns for optimization	DER performance and optimization analytics	Forecasting and visualization of grid status	Analysis and forecasting of charging demand and infrastructure needs	Visualization of O&M insights and grid performance
Governance and Regulation	Governance frameworks for community energy sharing	Regulations for DER integration	Coordination frameworks between TSOs and DSOs	Standards and protocols for electromobility services	Regulatory compliance for renewables integration

3.1 Use case #1 - "Collective self-consumption and optimized sharing for energy communities"

3.1.1 Scopes

The general scope of this use case is the instantiation and operation of Residential Energy Communities (RECs) and Commercial Energy Communities (CECs), aiming at the collective self-consumption, inside the communities, and the optimization of energy sharing, with the electrical system.

The specific objectives include:

- Size the technical components and conduct an economical evaluation for the deployment of energy communities, based on consumption and generation profiles as well as market data, weather data and the possibility of assets sharing business models.
- Provide the mechanisms for the collection and sharing of data, with appropriate granularity at the device level, of the energy consumption and generation, with the final goal of enabling flexibility and energy savings mechanisms.
- Extract approximated flexibility models for smart appliances (e.g., using non-intrusive load monitoring data), enabling an overall quantification of flexibility and estimation of energy savings from intelligent load control.

3.1.2 Description

The effective and large-scale deployment of energy communities, for collective self-consumption and regulated energy sharing, involves the optimization in both the network design phase (i.e., the size and location of distributed energy resources) and in the deployment of energy sharing mechanisms within the community and with the active role of electrical grid operators.

This use case includes two optimization problems, the first one aims at determining the optimal installed capacities in the REC /CEC, considering typical consumption profiles, availability of renewable energy sources, costs of technologies (both capital and operational cost) and opportunity costs of the community members (retailing tariff for the electricity consumed from the grid, and selling price for the electricity sold back to the grid). The second optimization problem considers the operation of the community constrained by the installed capacity from the first optimization problem, in particular its electrical energy sharing / trading, where the optimized dispatch of controllable energy resources (e.g., storage, thermal loads, electric vehicles) is obtained considering the opportunity costs of the community members, together with an internal electricity pricing mechanisms to settle the internal energy transactions among members, which can be computed with different approaches or algorithms, to be used to study different financial schemes for communities.

The data space environment enables the exchanges of data that are necessary for the execution of the optimization scenarios among actors, whose roles are described in [3]. In particular, the Service Provider offers, via its broker, the technical algorithms as services to which the Service Consumer has subscribed. Technical parameters (including the type of available devices, assets, and capacity constraints), pricing and financing specifications as well as consumption and generation data profiles are used as the inputs coming from the Data Provider. The consent for data sharing is obtained from the Data Owner; additionally, the data space Clearing House (which is a service for logging data exchange transactions relevant for clearing and billing as well as usage control) works as an intermediary to keep the log of the transactions. The output data are received by the Service Consumers and correspond to the optimal installed capacity, the estimated flexibility schedule and the pricing for internal and external transactions, differentiated according to the energy sharing mechanism. As an additional service, the provision of information regarding the required device maintenance is also included. Moreover, the data exchange outputs allow improving the forecasts on available flexibility (I.e., aggregated demand side flexibility potential of the energy community).

3.1.3 Scenarios

The system encompasses three sub- use cases, each designed to address specific aspects of energy management within RECs and CECs:

DER Sizing and Economic Evaluation of REC/CEC Business Model: Users subscribe to data space for DER sizing and economic evaluation. They provide parameters, request data (e.g., real consumption profiles (historical data), and solve optimization problems to determine optimal capacities and schedules, considering the maximization of collective self-consumption.

Estimation of Flexibility Potential and Energy Cost Savings from Thermal Domestic Loads: Consumers subscribe via a Broker for flexibility estimation services. Data is requested, consent is obtained, and an optimization problem enhances the Electric Water Heater (EWH) operation. Output metadata, including flexibility potential, is transferred.

Simulation of REC/CEC Operation and Computation of Internal Transaction Price: Consumers subscribe to internal pricing and REC/CEC operation services via a broker. Data is requested, consent is obtained, and the selected pricing mechanism is executed. Output metadata, including energy transacted and prices, is transferred. The objective of this service is to simulate the operation of an internal market and extracts price curves that can be used to evaluate different business models (e.g., in terms of asset sharing) and the economic potential of communities for different stakeholders, such as inclusive communities for vulnerable consumers.

In the following table, the sub use-cases are detailed with respect to the involved actors and the triggering events, which cause the data exchange and transition from the pre-condition to the post-condition of available data and accomplished actions. The use of a data space infrastructure allows trading data between organizations (i.e., the REC/CEC members and service providers, as developers of the running algorithms) while enforcing the data sovereignty stack.

Table 4 - Scenarios for the use case #1.

Scenarios				
Scenario name, description	**Actors**	**Triggering events**	**Pre-condition**	**Post-condition**
DER sizing and economic evaluation of the REC / CEC business model	Consumer, Energy service company, Energy trader, Market information aggregator, Resource aggregator, FSP, Sub-meter data hub operator	Service consumer requests service	Consumption and generation profiles / time series available in the data space & tariff data	Information available about REC / CEC optimal sizing
Estimation of flexibility potential and energy savings from thermal domestic loads	Consumer, Energy service company, Energy trader, Market information aggregator, Resource aggregator, FSP, Sub-meter data hub operator	Service consumer requests service	Technical information from the EWH available; typical profiles or historical info about shower duration and start; sensor for outlet water	Data available about estimated energy cost savings and flexibility
Simulation of energy price within the REC / CEC	Consumer, Energy service company, Energy trader, Market information aggregator, Resource aggregator, FSP, Sub-meter data hub operator	Service consumer requests service	Consumption and generation profiles / time series available in the data space & tariff data	Collective and individual operation costs or energy bills

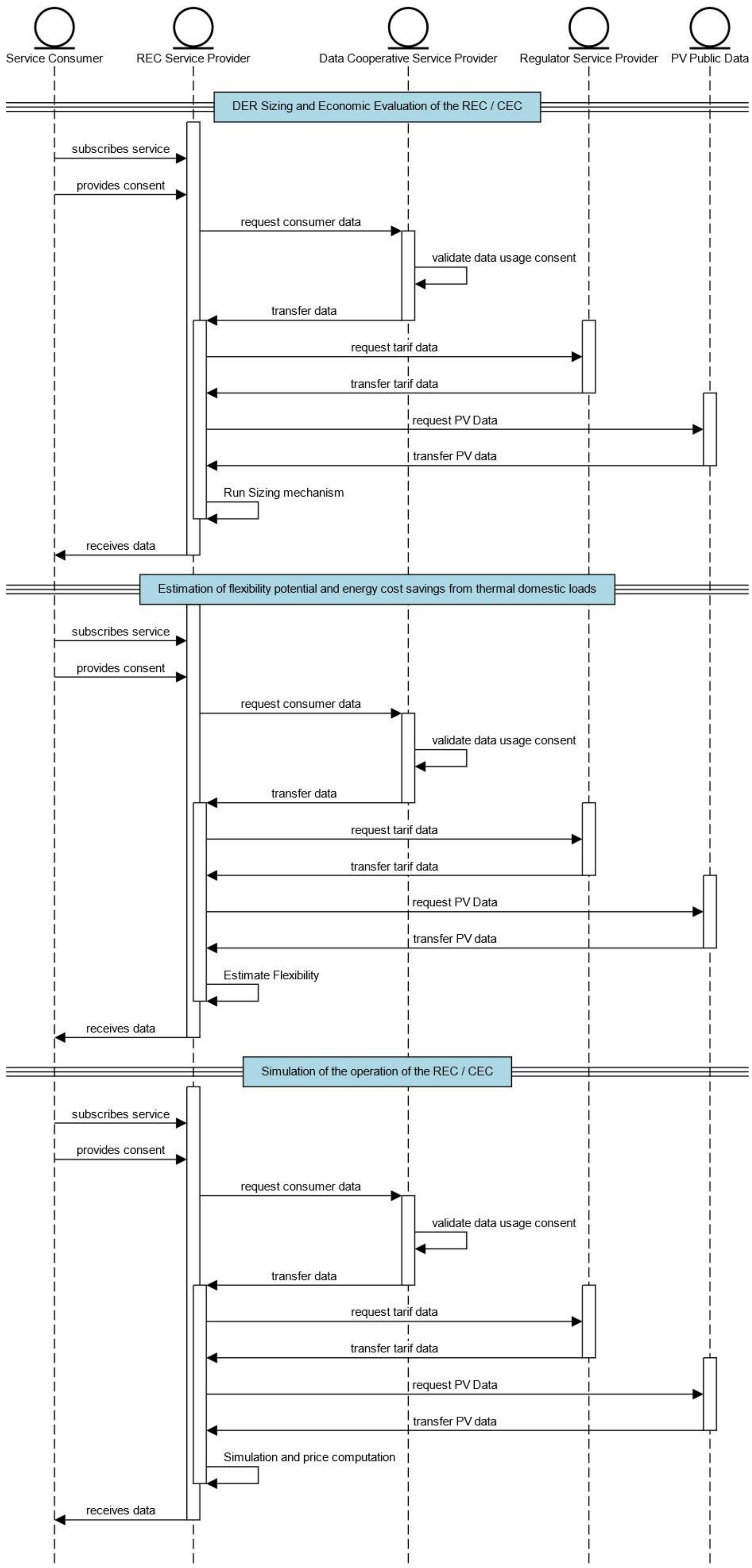

Figure 3 - Sequence diagram for the use case #1.

3.2 Use case #2 – "Residential home energy management integrating DER flexibility aggregation"

3.2.1 Scopes

Prosumers – whether residential, community, city, or industrial scale – are playing a new central focal role to enable cross-sectorial integration using their energy and flexibility data to actively contribute to a variety of flexibility markets. Moreover, the use of flexible DER located in residential environments allows to mitigate critical peak prices through wholesale markets as well as reduces TSO and DSO grid congestions. In this context new digital platforms are leveraging IoT, edge computing as well as federated cognitive cloud architectures with strategic digital features to optimally orchestrate DER through energy data spaces; this is pursued at the lowest voltage levels of the energy value chain, which includes home appliances and behind-the-meter DER and managed by resources operators and FSP that optimise the associated flexibility through their balancing portfolio. This approach requires rethinking the way data is generated from dedicated measurement devices, attached to DER, and exchanged throughout different federated actors of the electricity value chain: requirements involve real-time data exchange and streaming, taking advantage of a variety of domain-specific data exchange standards through consistent data space dictionaries.

3.2.2 Description

Future carbon-neutral houses will soon require providing new net-zero analytics as defined through the directive "Energy Performance of Buildings[4]" and, hence, provide near real-time indications to homeowners about their home energy efficiency as well as their available flexible capacity to respond to grid congestions and emergency events. The home energy use will be continuously optimized while maximizing local PV self-consumption and minimizing electricity costs (associated with new real-time energy and flexibility prices). New flexible DERs are in the meantime introduced through the home environment, such as heat pumps, EV bidirectional chargers as well as home batteries; these devices require new local home edge optimization across these resources. New integration approaches are considered to automate and facilitate the associated integration, such as all-in-one residential home energy stations that integrate bidirectional EV and home stationary battery and solar PV (directly with DC technology, resulting in the default consumer data interfaces).

Local home energy management solutions are becoming essential building blocks to share residential DER data through multi-sided data exchange platforms, which are operated through distributed cloud infrastructures of OEM and integrate advanced real-time energy optimization as a service. Multi-sided platforms are accessed, on one side, by prosumers through their DER specific app or high-level energy management apps while the other side is accessed by FSP accessing consumer data to enrol them (with their consent) in DER specific flexibility programs.

[4] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en

This BUC is typically associated with large residential assets offering flexibility to home owners, namely heat pumps, smart heating equipment, EV chargers (V1G and V2G) as well as residential hybrid inverters for solar and storage applications.

Reference DER data dictionaries are managed to enable plug-and-play registration of DER infrastructures in TSO-DSO flexibility markets; moreover, new real-time data stream across key actors of the energy flexibility value chain: from DER operator to energy community managers as well as with FSP and grid operators (TSOs and DSOs), hence automating associated residential DER transactions. The associated data space should allow managing all type of DER integrating the latest power electronics, edge computing and data streaming technologies to exchange relevant residential energy data (obtained from the main smart meter as well as from any other accessible DER submeters/dedicated measurement devices). The data space should be distributed through different federated cloud infrastructures and enable consent based on data exchanges across actors.

3.2.3 Scenarios

Table 5 - Scenarios for the use case #2.

Scenarios		
Scenario name, description	**Actors**	**Additional information**
Residential energy and carbon footprint monitoring	Prosumer, Resource aggregator	
Residential DER registration by DER operators	Prosumer, Resource aggregator, Consent administrator, Flexibility register, Flexible product qualifier	Registration consists in messages to registers customers in the DSO flexibility register.
Residential home energy optimization	DER, Local energy management, Weather forecast provider, FSP, Balancing responsible party	
Residential baseline calculation	Data provider, Resource provider, Resource aggregator, Balancing service provider, FSP	Provision of baseline data calculated by the service provider or the final customer, also based on weather/carbon/other data.
Residential flexibility intraday calculation	Data provider, Resource provider, Resource aggregator, Balancing service provider, FSP	
Residential flexibility bidding	Balancing service provider, FSP, Market operator, TSO, Flexibility buyer	Onboarding to market platform (and activation tests/product prequalification). Data exchange and communication requirements need to be tested for balancing services.
Residential flexibility activation	Market operator, TSO, Flexibility buyer, Balancing service provider, FSP, Resource provider, DER, Prosumer	When flexibility is activated (either through a bare execution of a bid, or via set points), a controllable unit can receive these signals either via the Service Provider or directly from

		the System or Market Operator. Service Providers may use the Kafka-based streaming infrastructure for both communication with the market, but also with their units under control.
Residential flexibility observability	Market operator, TSO, DSO, Resource aggregator, Resource provider, DER	After the delivery phase, measurements at different points need to be transferred to the Flexibility Registry Operator, to make them in turn available to the Settlement Responsible Party for service validation and perimeter correction.
Residential flexibility transaction management	Flexibility settlement party, Metered data responsible, Metered data collector, Balancing service provider, FSP, Resource provider, DER, Prosumer	

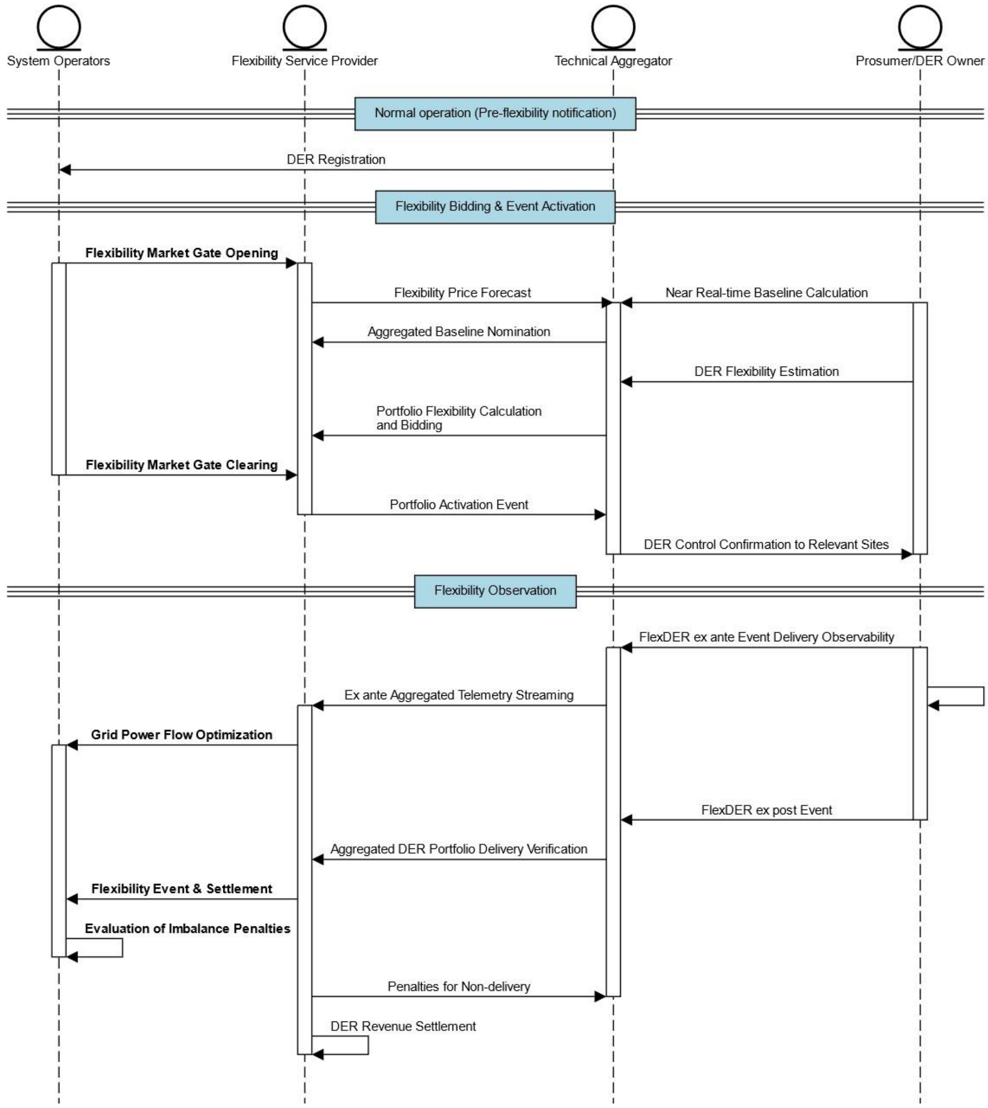

Figure 4 - Sequence diagram for the use case #2.

3.3 Use case #3 - "TSO-DSO coordination for flexibility"

3.3.1 Scope

With the increasing decentralization and decarbonization of the energy system, TSOs and DSOs are faced with the challenge of ensuring the resilience of the energy system, while enabling the integration of large RES to contribute to the achievement of ambitious RES deployment targets. The uncertainty of loads and generation flows poses increased challenges over-optimized network operations. Congestions and voltage issues that have been typically addressed with costly network upgrades need to be tackled with smarter, cheaper, non-cable alternative solutions that flexible DER offers through their power electronics interfaces and technologically existing aggregation potential. Active network management regimes for network control need to be developed, which require advanced forecasting of loads and generation for resource scheduling and real-time control. Moreover, a variety of analytics are necessary to ensure that appropriate measures exist to satisfy compliance with evolving reliability standards and security of supply. In their role as system operators, TSOs and DSOs are required to explore, evaluate, and deploy non-network alternatives that include the operation of market-based approaches such as frequency containment and reserves.

The development of new market-based approaches shall be non-discriminatory and services might be offered from all eligible participants (either aggregated or direct end-users) at different voltage levels, while the operation of the transmission and distribution networks shall be performed collaboratively between TSOs and DSOs to ensure synergetic service provision and avoidance of conflicting actions while co-optimizing the operation of both systems (distribution-transmission-national) and reducing the overall OPEX. As electricity network management evolves towards more collaborative management structures, it is of utmost importance that TSOs and DSOs are involved in bilateral data-sharing agreements (facilitated by energy data spaces) towards exchanging flexibility requirements, enabling the identification of critical operational events at both levels of electricity grid operation and allowing for their common criticality prioritization while matching available flexibility resources towards ensuring the smooth operation of power grids under evolving conditions through optimal collaborative operational scheduling and activation of offered flexibility. They also need to engage in data sharing with aggregators towards gaining increased visibility over available flexibility sources and proper clusters of them based on information shared by the relevant actors.

3.3.2 Description

The exploitation of flexibility, stemming from generation, demand, storage and EV assets, for solving network issues, such as balancing and congestion, is not a novel idea. However, on the one hand the sparsity of adequate real-time information about the available flexibility and on the other hand the fact that the majority of flexible assets and several sources of flexible generation are connected to the distribution system, poses significant barriers to the efficient exploitation of the flexibility by the transmission system operator. To this end it is of utmost importance that novel approaches (data-driven and intelligence-enabled) are defined, at first for the real-time or near-to-real-time aggregation of the available flexibility provided by distributed energy resources located in the distribution network. Since the majority of the resources located in the distribution system are small-scale, they need to be aggregated to be efficiently included in the operational planning of either DSO or TSO. Moreover, tools enhancing the fast and efficient coordination between TSO and DSO should be developed, so that flexibility from the distribution system to be transferred to the TSO for balancing the system or solving network issues.

The coordination between TSOs and DSOs is critical for effective flexibility management. Both types of operators need to work together to prioritize and address the flexibility needs in their respective networks. To achieve this, improved forecasting approaches and flexibility analytics are needed, as well as coordinated and collaborative scheduling and dispatch practices and tools, for the accurate identification and effective prioritization of critical events expected to occur across the electricity grid. Both System Operators will need to obtain access to previously non-reachable data from DERs across their networks (including local demand data from flexible loads, RES generation data, along with flexibility-relevant data from storage assets/ inverters and associated short- and mid-term forecasts) and fuse them with SCADA and metering data so that they can effectively forecast their flexibility requirements, match them to the available flexibility offered by the variety of prosumers, DERs and other flexible assets, prioritize procurement strategies (according to the criticality of events) and successfully dispatch the respective signals to ensure the end-to-end resilience of the energy system in the most favorable economic terms.

3.3.3 Scenarios

Table 6 - Scenarios for the use case #3.

Scenarios				
Scenario name, description	**Actors**	**Triggering events**	**Pre-condition**	**Post-condition**
Performant data search across federated data spaces	Data asset consumers (role obtained by TSOs, DSOs and FSPs)	A party needs to create a service without having at its disposal all the necessary data assets	Raw data, analysis results, reports, visualizations allowing for automated consumption.	The party is able to consume the data asset that has been acquired based on a valid asset contract.
Sharing, trading and bartering of raw and derivative data assets, available in federated data platforms/ hubs	Data asset providers, Data asset consumers (both roles obtained by TSOs,	Request for access to previously non-reachable data	1) Raw data, analysis results, reports, visualizations allowing for automated consumption; 2) Availability of mechanism to search for	A data asset (raw data or computations on data in the form of analysis results, reports or visualizations) is shared between two or

(incl. OEM platforms)	DSOs and FSPs involved in bilateral data sharing)		data and other data-based assets	more data value chain stakeholders
AI-enabled Grid-level energy demand and generation forecasting	DSOs, TSOs	On demand by the operator	1) Metering and acquired DER data for training and executing the respective forecasting models; 2) Access granted to AI analytics results referring to individual and aggregated DERs	Consolidated forecasts of demand and generation across the entire network
AI-enabled Grid-level flexibility profiling and forecasting	FSP	On demand by the FSP	DER data for training and executing the respective analytics models	Detailed flexibility profiles and forecasts at individual DER and aggregated levels
Operational events identification in the short and mid-term	DSOs, TSOs	On demand by the operator	1) Detailed data for the existing transmission and distribution network topology and infrastructure; 2) Availability of short/ mid-term Demand and Generation forecasts	Identification of anticipated critical operation events and their occurrence probability
Short-/ Mid-term Network Operation Planning	DSOs, TSOs	On demand by the operator	1) Detailed data for the existing transmission and distribution network topology and infrastructure; 2) Flexibility profiles and short/ mid-term forecasts	1) Definition of margins and requirements for flexibility to address the anticipated events; 2) Specification of the flexibility sources to effectively tackle the identified critical operation events

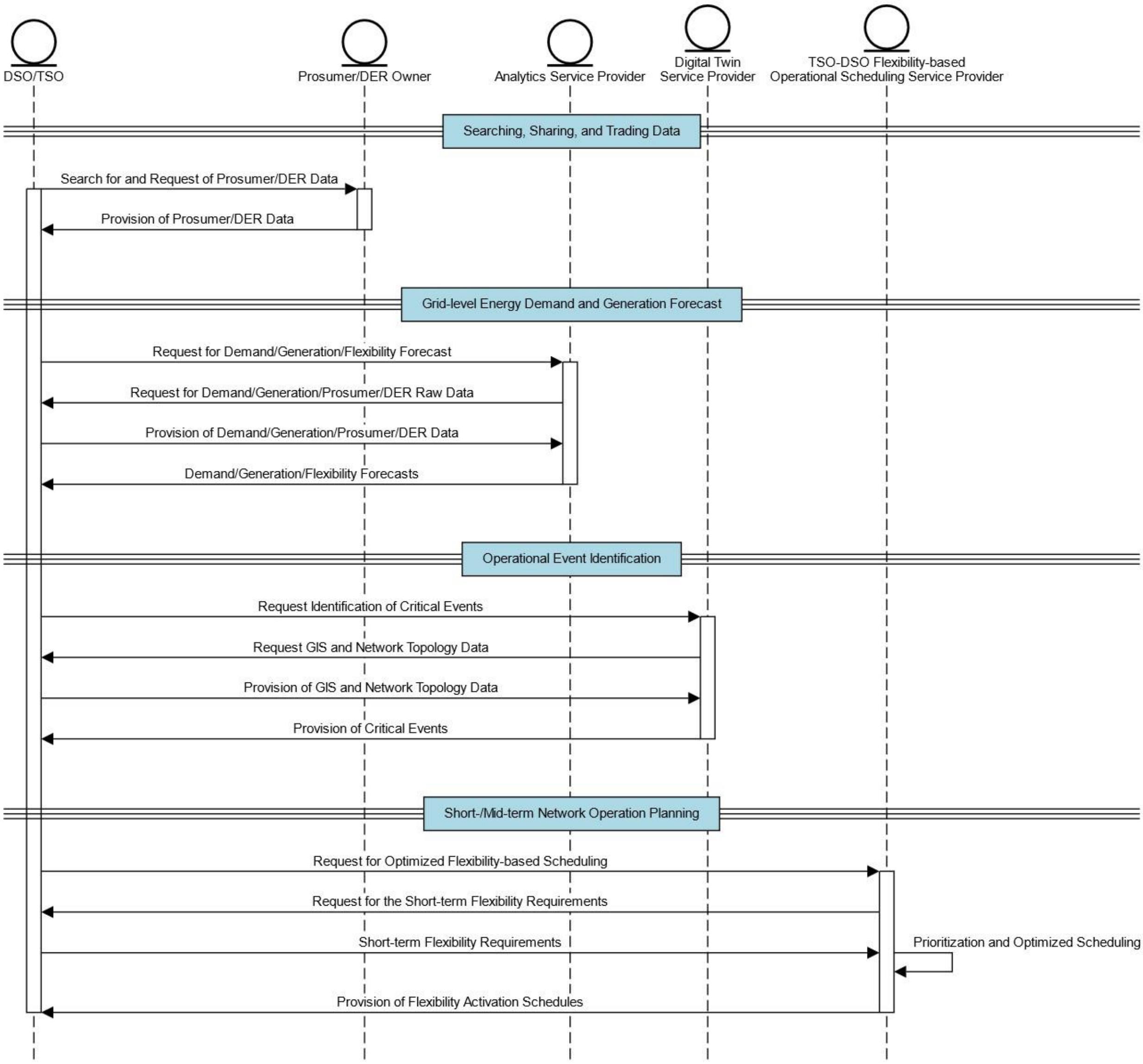

Figure 5 - Sequence diagram for the use case #3.

3.4 Use-case #4 - "Electromobility: services roaming, load forecasting and schedule planning"

3.4.1 Scopes

Given the peculiarity of this sector in the energy domain, the interfaced actors are introduced; they correspond to:

- **Charge Point Operator (CPO):** party responsible for provisioning and operating EVCI (EV Charging Infrastructure), optimizing the costs & revenues from charging sessions (on the behalf of one or several EVCI owners).
- **e-Mobility Service Provider (eMSP):** party responsible for providing high-value service related to the use of an EV. All these services require a subscription to the eMSP from the EV user. Users

can access to the services with an application (System actor: e-Mobility Service Provider Application).

- **Electro Mobility Roaming Service Provider (EMRSP):** party responsible for offering a universal intermediation service between CPOs and eMSP. It can also offer interface services with other EMRSPs, thereby broadening the range of responses available to subscribed eMSPs. Moreover, this actor is responsible for exchanging data on consumption schedules with DSOs and TSOs.
- **Electric Vehicle User (EVU):** person or legal entity using the vehicle and providing information about driving needs and consequently influencing charging patterns.

In the electromobility context, this BUC aims to address the following objectives:

- Offer a simplified recharging service for electric vehicle users;
- Provide Charing Point Operators (CPOs) with a charging schedule to optimize their stations (charging pools);
- Provide DSOs/TSOs with charging consumptions schedule based on CPOs' charging schedules and reserved powers, to enhance the accuracy of system operators' forecasts and planned operations.
- To find out more (in the near future):
    - Give CPOs access to EVU research to help them identify future station locations;
    - Give TSO/DSO predictive charging consumptions based on past charging sessions at different geographical scales;
    - Provide EVUs with an intelligent route calculation that not only saves EVU time, but also optimizes the use of charging points and electricity networks.

3.4.2 Description

In this use case, an EVU who wants to book a charging service must connect to an eMSP, as an application or platform. On this application, he is going to have visibility on the existence of infrastructures, their availability, and will be able to reserve a charging point.

Once connected to the application, users can search for available charging points according to their criteria of location, time and technical specifications for charging. Moreover, the user can compare the different rates applied according to operator and charging criteria.

Furthermore, the user can then reserve a charging slot by specifying the information required for accessing the charging pool, charging his car, and paying for the session (physical characteristics, means of authentication at the charging point, etc.) He/she can access an estimate of the final charge price (calculation based on the selected criteria and provided details). Once the charge has been completed, the user will be able to access his detailed invoice from the eMSP application and will be charged the final amount due.

The cluster of energy data spaces projects aims to make this standardization service available throughout Europe, thus aggregating all CPO services and facilitating access to them for all electric vehicle users. For this use case, the data space will only address the Electro Mobility Roaming Service Provider (EMRSP) part providing the mediation and aggregation interface between eMSPs and CPOs. The scenarios envisioned by this use case form the entire recharging activity of the electric vehicles, including the resolution of unusual conditions. In particular, they correspond to: (i) search available charging points based on geographic area, time range and technical criteria; (ii) search for available time slots on a charging station (list time slots with criteria like time of charge preference, etc.); (iii) book available time slot; (iv) cancelation; (v) no show; (vi) consumption of the reservation; (vii) report the charging session; (viii) billing. The data on the energy consumption, associated with the scheduled and performed charging session, are exchanged between the EMRSP and the DSO/TSO to improve the load forecasting and electrical grid operations.

3.4.3 Scenarios

Table 7 - Scenarios for the use case #4.

Scenarios				
Scenario name, description	**Actors**	**Triggering events**	**Pre-condition**	**Post-condition**
Search for available charging points (based on geographic area, time range and technical criteria)	EVU, eMSP, EMRSP, CPO	Action of the EVU in the eMSP app.	1) EVU is authenticated to the eMSP App; 2) eMSP is registered as a consumer of EMRSP services; 3) CPOs are registered as providers on EMRSP app; 4) (Optionally) EMRSP are registered as provider of other EMRSP	List of charging stations available with additional information: connectivity, power, tariffs, additional services (e.g., restaurants)
Search for available time slots on a charging station (list time slots with criteria, e.g., time of charge preference)	EVU, eMSP, EMRSP, CPO	Action of the EVU in the eMSP app (choose a charging station)	Choose a charging station	List of time slots available with the connectivity associated and the estimated price of the charge
Book available time slot	EVU, eMSP, EMRSP, CPO	Action of the EVU in the eMSP app (choose a time slot and make a reservation)	1) Choose a time slot in a charging station with a specific power; 2) Have completed authentication information (i.e., charging point authentication)	1) Reservation contract 2) DSO/TSO receives data on energy consumption

Cancelation	EVU, eMSP, EMRSP, CPO	Action of the EVU in eMSP app Action of the CPO in his system (must inform EVU)	Have a reservation contract	1) Notification EVU; 2) Notification CPO; 3) Calculation fees (if necessary) 4) Update DSO/TSO on the modified energy consumption
No Show	eMSP, EMRSP, CPO	CPO triggers no show when the EVU doesn't use the reservation slot (timeout)	Have a reservation contract	1) Notification EVU; 2) Calculation fees (if necessary)
Consumption of the reservation	EVU, CPO	EVU authenticate on charging point and start the charging session	Have a reservation contract	
Report the charging session	CPO, EMRSP, eMSP	CPO triggers when end of charging session is detected	1) Have a reservation contract; 2) Receive charging session start	Send report on charging session
Billing	CPO, EMRSP, eMSP, EVU	1) CPO send the report charging session 2) CPO send the notification of a no show 3) CPO send the notification of cancelation (with fees)	1) Have a reservation contract; 2) Receive charging session end or cancelation or no-show event.	Bill sent

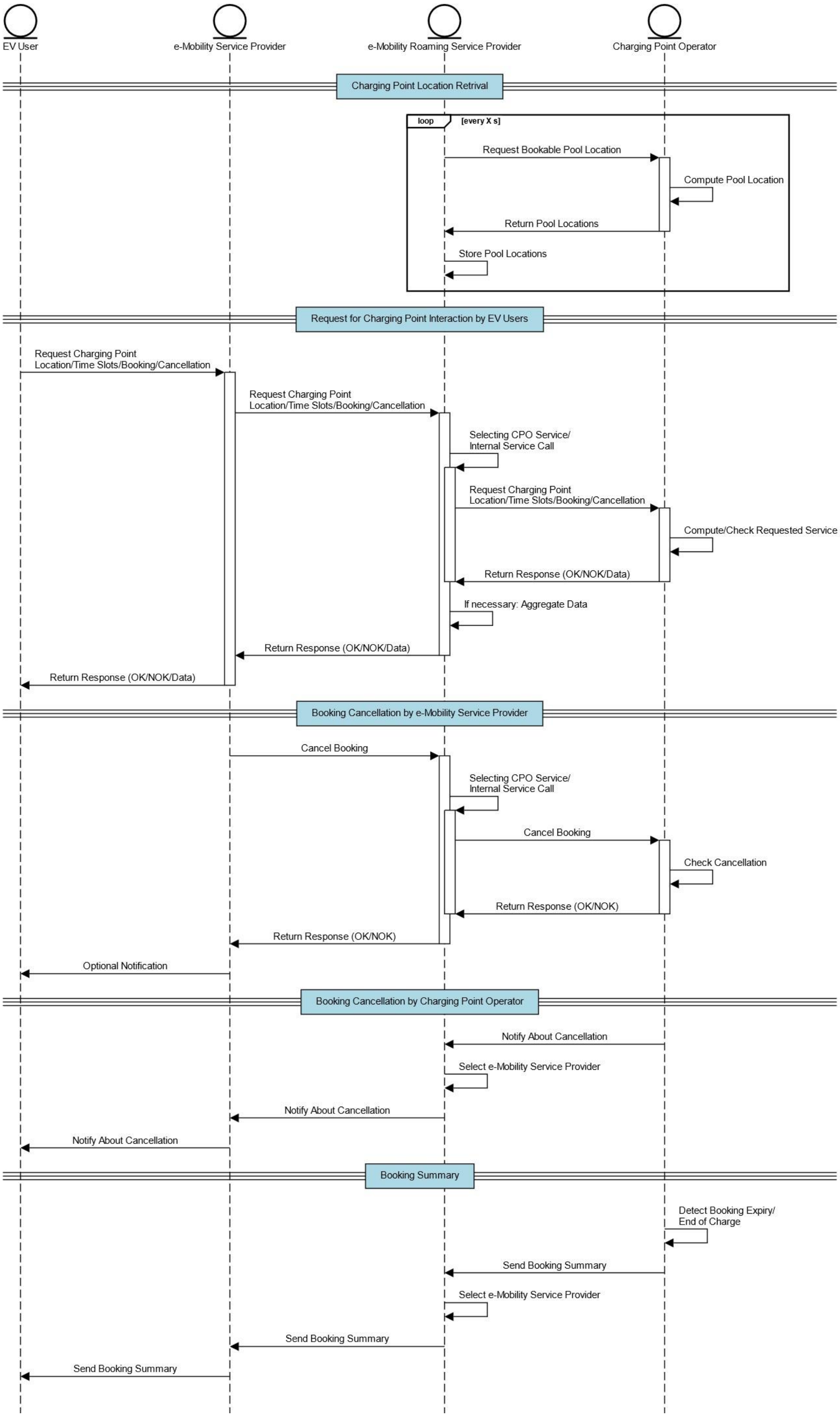

Figure 6 - Sequence diagram for the use case #4.

3.5 Use case #5 – "Renewables O&M optimization and grid integration"

3.5.1 Scopes

The main challenges of renewable energies for getting larger deployment are cost competitiveness and smart grid integration. Therefore, the scopes of this use case are:

1. Develop more robust algorithms for optimizing the operation and maintenance of renewable energy assets by leveraging data from multiple renewable energy plant owners. This will allow a more reliable and earlier fault detection, automated diagnosis and maintenance prescription resulting in reduced operation and maintenance costs (OPEX).
2. Develop data analytics to enable efficient integration of distributed energy sources into the smart grid by monitoring data from different actors such as consumers and producers and data from the grid itself anticipating potential issues, like congestion or voltage volatility, impacting on quality and security of service. This can facilitate decision making on the optimal location and size of renewable resources in the overall system.

3.5.2 Description

An optimized operation and maintenance (O&M) of renewable assets along their lifetime is key to reduce the Levelized Cost Of Energy (LCOE) by increasing the Performance Ratio (PR) and reducing O&M costs and Weighted Average Cost of Capital (WACC). Moreover, high penetration rates of Renewable Energy Sources require special measures by the DSO to ensure the quality and security of energy supply.

In this context, it is crucial to develop innovative digital services that leverage existing data to overcome the abovementioned challenges. However, nowadays data are normally kept in silos within companies. This is one of the main blockers for AI since the ability of the algorithms to learn and generalize is limited by the company´s data, which generally covers a limited range of possible operating conditions. Data Spaces enable access to a wider range of information than the one related to one single portfolio, enhancing the generalization capacity of AI algorithms for different operating conditions. Furthermore, in some domains, such as wind energy, some relevant actors such as component manufacturers (Tier 2-3 categories), ICT companies, SMEs and academia do not have access to operational data, causing the block of their capacity to improve existing products and develop innovative digital services. Finally, to come up with an optimal solution for smart grid management that can facilitate RES integration data from different stakeholders (prosumers, DSO, aggregator) are required. Consequently, it is necessary to foster data exchange amongst different actors of the energy system, to develop innovative solutions that can help to optimize the operation and maintenance of renewable assets and facilitate their integration into the existing energy system while ensuring data security, privacy and sovereignty.

In this BUC, the category of data providers includes RES plant owners, RES plant operators, OEMs, DSOs and consumers/producers; the data users are component manufacturers (Tier 2-3 categories) and data analytics service providers.

3.5.3 Scenarios

In terms of the crucial datasets for exchange, this encompasses SCADA data for RES operation, meteorological data, smart grid data, and prosumer energy consumption data. The extent of data exchange varies with the specific application. For optimization purposes, the scope is global, aiming to gather real operational data from similar assets in diverse operating conditions worldwide. On the other hand, for smart grid integration, the scope is more localized or regional. The majority of the required datasets are proprietary and, in some instances, contain business-critical information. Additionally, certain datasets, such as prosumer data, may include personal information that necessitates compliance with GDPR. Notably, meteorological data is typically open source.

Concerning the willingness of data providers to engage in a European data space and share data across borders, this largely depends on the renewable technology involved. For example, solar PV data are typically owned by PV plant owners/operators who are open to sharing data. Conversely, in the wind energy sector, this data is predominantly owned by OEMs who are less inclined to share. This difference is because the wind energy sector is shifting its business model from selling turbines to provide O&M services, and data is a key competitive advantage to provide this type of services. The data exchanged through the Common European Energy Data Space is used to provide energy services by processing raw data through data-driven algorithms. These services include for example, RES O&M optimization service, Digital Twins for RES assets and Smart Grid, Prosumer Energy Demand/Generation forecast, smart grid reinforcement planning service, etc.

Table 8 - Scenarios for the use case #5.

Scenarios				
Scenario name, description	**Actors**	**Triggering events**	**Pre-condition**	**Post-condition**
RES O&M optimization	OEM, RES plant owners/operators, TIER2-3 component manufacturer, Data analytics service providers	RES plant owners/ operators requests service	RES operational data available in the data space	Early detection of failures, optimized maintenance schedule, optimal operation prescription.
RES smart grid integration	RES plant operators, prosumers, DSO	DSO requests service	Smart meter data and RES operational data available in the data space	Anticipate potential issues (congestion or voltage volatility, etc.) and prescribe corrective actions.
Optimal RES sizing (prosumer/ community)	Consumer/Producer, Data analytics service providers, DSO	Customer/ Community request	Generation, consumption and storage data available, geographic parameters, EV and prices	Provide optimal size for RES integration

DSO resources optimal location	DSO, Consumer/ Produces, Data analytics service providers	DSO Request	Generation, consumption and storage data available, grid model (info for digital twin) grid information (existing problems), assets that can be installed	Provide optimal location for DSO resources

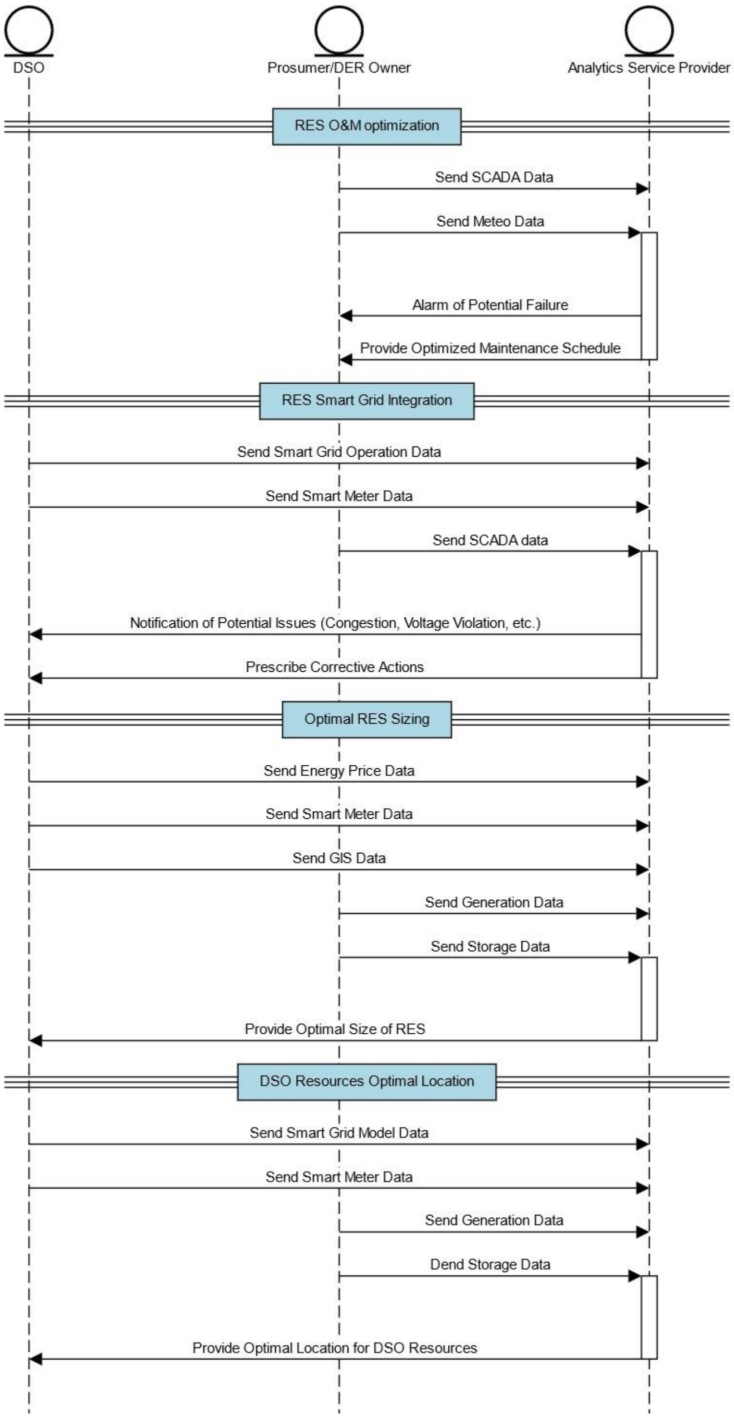

Figure 7 - Sequence diagram for the use case #5.

3.6 Grid codes requirements

A crucial area where energy data spaces can potentially act as a game changer is in the implementation of new rules mandated by the network code on demand response; particularly relevant for the presented use cases #1 "Collective self-consumption and optimized sharing for energy communities" and #2 "Residential home energy management integrating DER flexibility aggregation".

Experts from the EU DSO Entity and ENTSO-E are collaboratively drafting the legal text proposal in close cooperation with European stakeholders. Market actors are increasingly calling for efficient value-stacking options between market platforms and various participants on the demand side. To gain a better understanding of the matter, it is worthwhile to review how future legislation is likely to define specific concepts and allocate responsibilities.

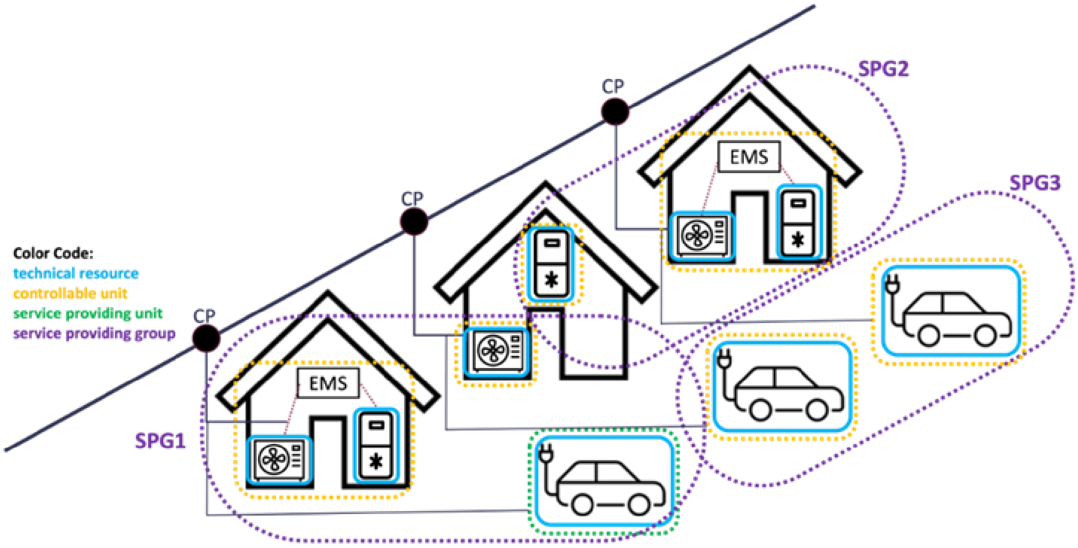

Figure 8 - Definitions as basis for rules on demand response.

To allocate responsibility in the future energy scenario, it is necessary to categorize key assets that play active roles in the market mechanisms under transformation. Referring to Figure 8, assets will be categorized as follows:

- "Technical resource": an individual power generation, energy storage, or demand module.
- "Controllable unit": a single technical resource or a group of technical resources behind the same connection point, provided that these technical resources can be collectively controlled. In this context, the controllable unit remains under the full sovereignty of the final customer, who has the authority to decide which aggregator or service provider will market the flexibility of the asset.
- "Service providing unit" (SPU): a single controllable unit or a group of controllable units, a "service providing group" (SPG), connected to the same connection point. SPUs and SPGs are defined by the service provider to deliver local or balancing services.
- "Service provider" or "aggregator" is a market participant with a legal or contractual obligation to supply local or balancing services from at least one SPU or SPG.

With this conceptual framework as a foundation, regulations govern complex services and the markets associated with them. High-level real-time monitoring requirements will need to be managed by service providers. Simultaneously, the provision of local services must be coordinated and potentially constrained by system operators to avoid violating grid limitations. Submetering will be integrated into the European regulatory framework, and multiple FSP, as well as multiple suppliers, will be permitted to operate behind a final customer's connection point. Controllable units are required to be "switchable" between aggregators, restoring grid users' sovereignty over the hardware they have purchased and effectively separating hardware from aggregation markets. These rules represent a significant leap forward, posing substantial data management challenges for all stakeholders in the field. Anyway, the markets they facilitate will not function without full digitalization and efficient data exchange environments.

4 Proposed Architecture for CEEDS

The reference BUCs for CEEDS, described in Section 3 of this document, are based on an ecosystem of data spaces (following the approaches presented in section 2.1) that is strictly necessary to deploy regulated and efficient exchange of energy-related data. In fact, the scenarios of BUCs exploit the availability of data and services, indexed, and discovered in the data spaces catalogues, to operate the energy services. The implementation of this data space approach allows, moreover, to enlarge the set of involved actors as active participants in the energy systems operations, with benefits (in terms of monetary savings as well as the quality of the services and reliability of electricity distribution) for every involved party.

As already mentioned, the data spaces ecosystem, which sustains the execution of the presented BUCs, will not be constructed entirely from scratch. Instead, it will constitute an extension and enhancement of the prevailing data exchange ecosystem, which presently operates in isolation without interconnection. The objective is to establish a data infrastructure that facilitates the seamless and equitable exchange of data, transcending local barriers and limitations. In the current section, the existing solutions for energy data exchange are taken as a starting point; the goal is to describe the necessary adaptations to realize the CEEDS through implementing the proposed energy data space infrastructure.

Focusing on the realization, the proposed model corresponds to the creation of an energy data space as the **combination of (1) multiple "distributed data ecosystems" (i.e., existing legacy data platforms) with (2) an overarching layer defined as the "federated data space" side.** This approach reflects the concept of DERA 3.0 (data exchange reference architecture 3.0[5]), which has been defined in the Bridge Data Management WG. Specifications of local and federated parts of the architecture are described hereafter.

The **(1) "distributed data ecosystems" side** (with reference to Figure 9) of the architecture refers to data platforms (including the already existing ones), either associated with (i) closed ecosystems including individual actors (e.g., the data platform from a retailer, or a prosumer) or groups of actors (e.g., the data platform of an energy community), or (ii) larger ecosystems as organization data platforms for energy market/system as whole (e.g., the Data Hub of metering data, the Flexibility Register, the SCADA/EMS, the national flexibility infrastructures that involve local TSO, DSO and utilities). Those current existing platforms are already capturing and persisting their own data, which is usually inputted into tailored applications. These legacy systems, as data platforms or data hubs, interact with existing energy stakeholders that assume the roles of actors in the presented BUCs scenarios, behaving as data providers and/or data consumers. The set includes, among many others, DSOs, TSOs, prosumers, FSPs, balance service providers and DER owners. Most of these actors are already interconnected to the platforms to manage, process and visualize the data. Therefore, since different data space

[5] https://op.europa.eu/en/publication-detail/-/publication/dc073847-4d35-11ee-9220-01aa75ed71a1/language-en/format-PDF/source-294051153

participants are associated with different legacy data platforms, the CEEDS guarantees data exchange among them. The endpoints for energy-related data correspond to entities that act as sources and/or receivers of data, for example: field devices that provide real-time measurements (sensors, voltage and current transformers, PMUs, RTUs) and receive actuating commands (IEDs, tap-changers, switching devices), SCADA and EMS infrastructures that contains real-time databases and forecasts data, inputs from prosumers regarding the loads schedule, EVs and DERs actual and forecasted power consumption and generation. These data are bidirectionally exchanged with the distributed data ecosystems via the existing communication infrastructures, which accommodate different technologies such as 5G, LTE, fiber optics, PLC, etc.

Looking inside the data platforms on the “distributed data ecosystems” side, various strategies for data collection and storage originate various implementation approaches for data management. These existing strategies for data management are described by two significant sources: the TSO-DSO Data Management Report [6]and the GEODE Data Management Fact Sheet[7]. Notably, the latter extensively explores the implications of adhering to Article 23 of Directive (EU) 2019/944, which delegates the responsibility for shaping the approach to data management for energy services to Member States. This empowers them to address European legal requirements based on their specific subsidiary needs. Consequently, the strategies result in three primary architectural approaches observed in numerous Member States, often applied in parallel for different types of data (i.e., from different sectors or applications), and described hereafter.

a) In the **decentralized model**, data remains at its point of origin (e.g., metering information at DSO, contract information at the supplier and generation for DER). Collaborative efforts among market actors are underway to establish standardized market communication and exchange data, either with explicit consent from the data subject or within clearly defined business processes. Examples of frameworks adopting this approach can be found in Austria (EDA), the German market communication, and France.
b) The **centralized model** involves a data hub that receives and stores data. All business processes operate within this hub, and outcomes are transmitted back to its clients. This model is managed and developed by a specific entity or service provider, with market participants utilizing its functionalities. This approach is implemented, for instance, in Finland and Estonia.
c) The **hybrid model** combines elements from both previous models. While all market participants can communicate in a decentralized manner, specific central structures are employed in certain use cases (e.g., compliance monitoring or facilitating access to data brokerage). In the context of smart metering, Spain serves as an example where data

[6] https://www.entsoe.eu/2016/07/27/tso-dso-data-management-report/.
[7] https://www.geode-eu.org/wp-content/uploads/2020/05/202005-Fact-sheet-GEODE-Data-Management-FINAL.pdf.

remains with the DSO as the "metered data administrator," and access for end customers and third parties is facilitated through the AELEC-operated DataDis[8].

The **(2) "Federated Data Space" side** of the architecture (with reference to Figure 9) refers to where data is indexed, making it discoverable and providing a sort of marketplace for sharing (and, possibly, trading) both data and data services. In doing so, the data space will rely on multiple actors and data platforms (the previously described ones, in the distributed data ecosystems side) federating through the data space connectors and offering their data under pre-recorded policies, verified credentials, data models and contractual agreements. At this scope, the federated data space side includes a set of components to implement foundational building blocks that perform the required functionalities of the data space; these components are described in detail in Section 4.1.

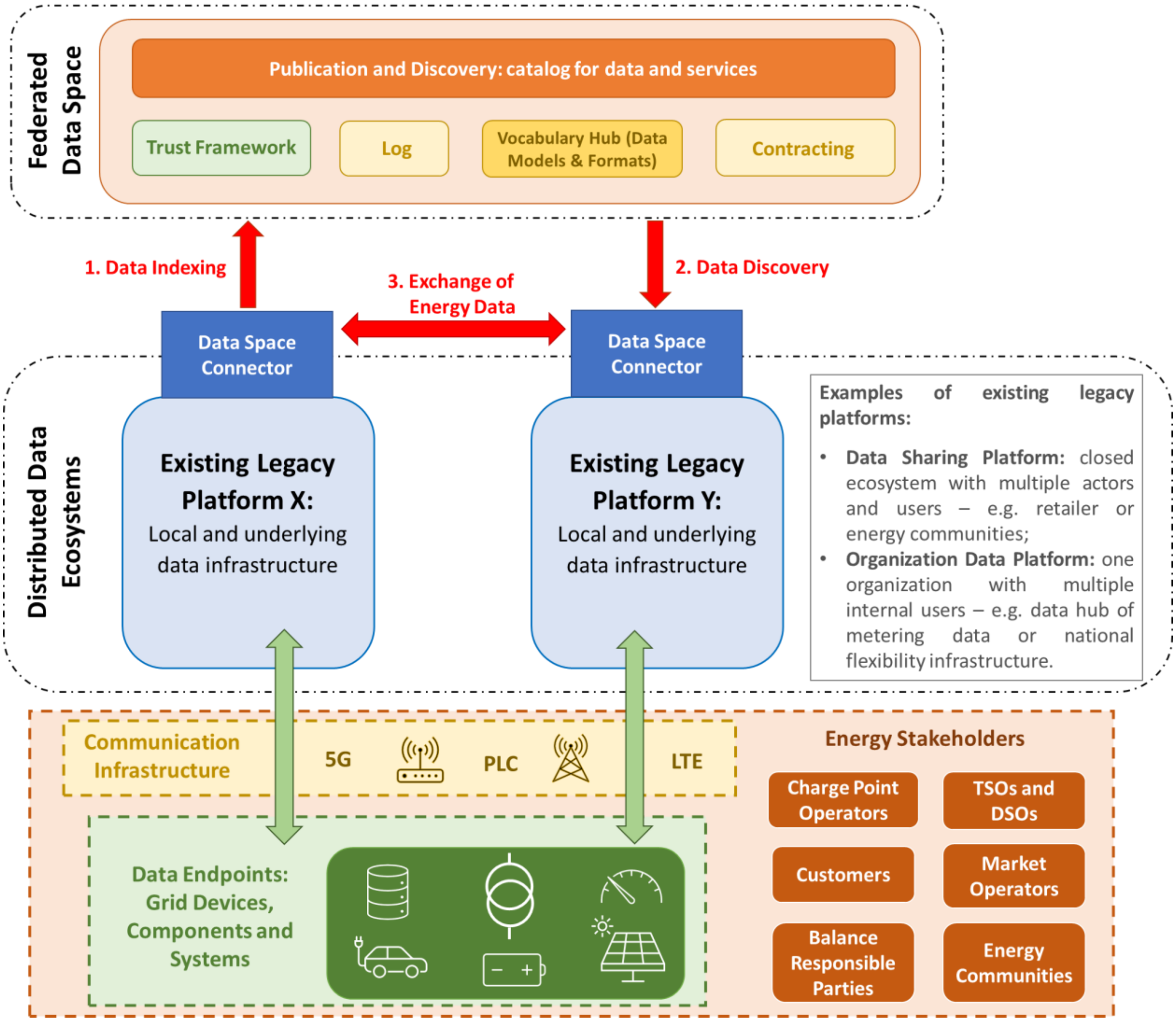

Figure 9 - Exchange of energy-related data among different data legacy platform (as data spaces participants).

The different data space participants are connected through a software component commonly referred to as "**data space connector**" (the blue box in Figure 9), which realizes the interconnection and data

[8] DATADIS - https://aelec.es/datadis/

exchange; in particular, the data space connector should be incorporated into the (pre-existing) platforms to enable identification, data harmonization and brokerage towards data spaces. This can be useful for integrating data from different sources, or for allowing multiple applications to access the same data without having to duplicate it in multiple places. Data space connectors typically use standardized protocols to facilitate the transfer of data between different systems. This can help to ensure that the data remains consistent and accurate across all the connected systems. Beyond trustworthy and interoperable data exchanges, it can provide seamless service utilization.

When implemented in the proposed model for the CEEDS, the data space connector enables also the exchange of energy data and execution of services among the existing legacy platforms (in the "distributed data ecosystem" side) and through the federated, overarching layer of the data space (with the mechanism explained hereafter). The data connector can be run by a participant (i.e., a legacy data platform) or on its behalf. That provides connectivity with similar data connectors run by (or on behalf of) other participants. Moreover, the data connector provides more functionality than is strictly related to connectivity, for example: data interoperability functions, authentication interfacing with trust services and authorization, data product self-description, contract negotiation, etc. The data space connector therefore has links to many different building blocks located in the federated data space side (e.g., trust framework and vocabulary hub); this includes, in addition to the data exchange, the components reported in the federated side of the data space.

It is noteworthy the key role of the data spaces connector to operate the exchange of metadata (e.g., via the identity manager and credential manager components) and traded data (e.g., via the publication and discovery – catalog - component). Additionally, Figure 9 indicates how different legacy platforms are deployed in the energy data space and, specifically, their exchange of energy-related data; the red arrows indicate cases of:

1. **Data indexing** of own data in a data space (between a data space participant and the federated data space);
2. **Data discovery** in data space (between the federated data space and a data space participant);
3. **Bilateral exchange of the traded data**, energy-related, among two legacy platforms.

The complete CEEDS architecture is shown in Figure 10. In this case, additional details are added for the components of the federated data space (i.e., for the trust framework as well as the log and contracting components), which are described in detail in Section 4.1; moreover, the representation of existing legacy platforms is enriched: the inner components manage the acquisition/provision of data, together with their storage and process in the dedicated analytics and energy services.

Regarding the data exchanged between the different instances of data spaces connectors and the federated data spaces, the approach of the **control plane** and **data plane**, proposed in the DSSC Blueprint v1.0, is deployed. The control plane oversees decisions related to the management, routing, and processing of data, including tasks such as user identification and the enforcement of access and usage policies (i.e., commonly referred to as metadata). In contrast, the data plane is tasked with the physical movement of data, encompassing the actual exchange of information (i.e., the energy-related data). With respect to the specific data exchange instances reported in Figure 9, on the contrary, Figure 10 maintains a generic configuration while locating the use of control and data planes.

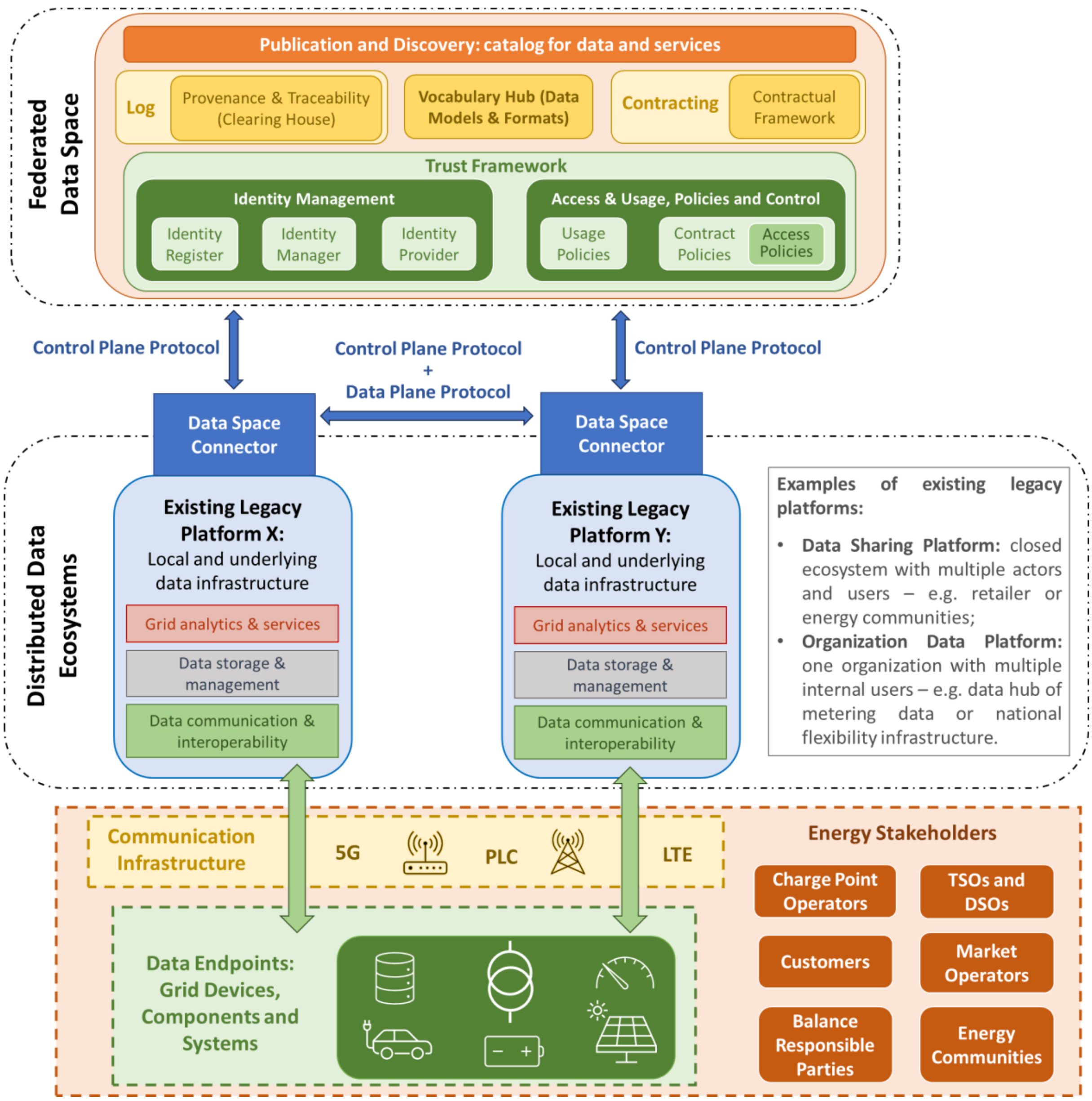

Figure 10 – Complete CEEDS architecture.

4.1 Components of the Data Space Federated Side

With respect to the proposed architecture for CEEDS, represented in Figure 10, the components that form the federated data space side are hereafter individually described [1], [3].

- **Trust Framework**, which is associated with two building blocks: "Access & usage policies and control" and "Identity Management".
  - **Access & usage policies and control.** This building block is connected to the concept of data sovereignty which, in the context of data spaces, is about the control of access

and usage of data. Different policies are normally used to express the rights and obligations to maintain the control of data usage; hence, one objective in data space management is the definition of interoperable policies, i.e. rules to give access to a specific energy service (e.g., booking a charging slot with a eMSP or executing a saving estimation in an energy community) and understanding the rules for the usage of the data (i.e., which energy services they enable, the privacy rules with respect to other energy stakeholders).

Two types of policies are defined:

- **Access policies**, which specify the conditions to access services and data.
- **Usage Policies**, which specify rights and obligations for the usage of the data, including the future usage of data.

To enable the decision-making process in evaluation policies, connection to other building blocks is required for identification, authentication and authorization. Expression of policies and rules are provided from different contexts (e.g. data space level, contractual relationship, law) and must be consolidated into a machine-readable and executable way. In addition, during a data transaction, the policies need to be evaluated and decisions on access to data and services and data usage need to be taken. Access and usage policies in a data space ensure a trusted data ecosystem within a data space; the two main policy groups that are central to the functionality of a data space are access policies (which control access to data and services), which can be included in the contract policies (which review attributes that must be provided at the contract negotiation). While the trust framework provides the existing possibilities for policies in the different categories, the implementation is performed via the data space connectors.

- **Identity Management**. This concept relates to many practical use-cases: (i) identifying data space participants, via an identity registry in which parties are registered that have committed to the data space governance framework and comply with any other requirements, (ii) identifying connectors and other technical components and (iii) identifying trusted data providers (such instances enable data space participants to learn which parties have been certified to provide particular data).

Multiple sub-components form the identity management building block:

- **Identity Governor**: the data space role that is used to refer to the party that performs the identity governance function for a specific identity registry.
- **Identity Manager**, which is used to refer to the party that performs the identity management function for a specific identity registry.
- **Identity Provider**: the data space role that is used to refer to the party that performs the identity provisioning function for a specific identity registry.

The identity management enables authorization mechanisms based on identity attributes. The deployed functionalities are:

- Security/Resilience. Identity provision and management are critical parts of a cyber-secure system.
- Open Source. The way to implement identification, at any potentially interested infrastructure, should be kept as simple and as open as possible.
- Interoperability. It is very important not just to enable easy federation, but also to make sure the identification mechanism proposed is aligned at European level, maximizing the interoperability with other data spaces, either in the energy or different sectors.

In OPEN DEI building blocks the identity management is associated with the "Trust" category, whereas GAIA-X deploys a decentralized approach based on self-sovereign identity.

- **Log.** This component is used to log information or store information about data usage (e.g., incidents) and is associated with the building block "**Provenance & Traceability".** This element is linked to the need to specify the information stored for each transaction, as well as how access and usage are regulated and controlled. Both traceability and provenance serve as vital functional requirements for every participant in a data value chain, particularly one involving multiple data transactions. In data spaces, the observability of each transaction activity, including the provision of evidence, is often essential. This need for observability may arise from legal mandates, the governance framework of the data space, contractual agreements, or other policies. The Provenance & Traceability component is closely associated with the concept of a "Clearing House," defined as an intermediary that offers clearing and settlement services for financial and data exchange transactions. It records all activities during a data exchange, which subsequently proves useful for billing and conflict resolution. Additionally, the Clearing House monitors and logs data transactions, enforces policies, and provides a platform for data accounting.
- **Vocabulary Hub.** It provides endpoints to enable seamless communication with data space connectors and infrastructure components. Vocabularies are defined as commonly known, standardized terms to describe data, services, and contracts; hence the vocabulary hubs give access to the defined terms and their descriptions present changes and outline the different versions. Moreover, it provides information about the ontology/language used for data and, on the other hand, checks that the data being indexed is compliant with the provided vocabulary. Again, being this an energy oriented approach, IEC (CIM, 61850, COSEM, etc.) and ETSI (SAREF, etc.) standards are what this vocabulary module is expected to be reliant on. The different functions of this component include:
    - Storing vocabularies: the Vocabulary Hub stores and lists valid vocabularies, making them available for the public and long-term use.

- Search on the semantic sources: the Vocabulary Hub allows data space participants to search for semantic resources based on specified criteria, providing a qualified results list with links to vocabularies and other semantic resources.
- Documenting non-standardized data: the Vocabulary Hub permits data space participants to include semantic information about non- standardized data during ingestion, making this information discoverable within the data space.
- Export semantic sources: the Vocabulary Hub enables data space participants to export semantic sources in various formats, including serialization options or human-readable formats.
- Automatic integration with the catalog: the Vocabulary Hub offers continuous integration, ensuring that the catalog of vocabularies has complete access to the semantic information of a vocabulary with appropriate user permissions.
- Validation of data: the Vocabulary Hub allows data space participants to validate their data against specific vocabularies.

- **Contracting**, which is linked with the building block **"Contractual Framework".** The foundational element of the contractual framework encompasses contract templates, model clauses, or modules that empower transaction participants to manage and execute specific data transactions. Integrating tools to automate various stages of the contracting process, such as concluding contracts, monitoring compliance, and terminating agreements, can further streamline data transactions while upholding the legal validity of the agreed-upon terms. This framework delineates the rights and responsibilities of participants within the data space, including providers of enabling energy services (e.g., the data analytics service provider) and the governing authority of the data space. Its primary objective is to translate agreements among these entities into unambiguous and legally binding contractual obligations. Additionally, this component may embed elements of contract automation, utilizing technologies like smart contracts to simplify and automate the creation and execution of contracts. Through the reduction of transaction costs and the enhancement of overall efficiency, contract automation contributes to the improved functioning of the energy data space.
- **Publication & Discovery.** The publication and discovery building block acts as a catalogue containing self-descriptions of the data products available in a data space. These descriptions are published in the catalogue by the providers of these products so that they become discoverable for potential users. In order to allow this, the publication and discovery building block provides the following key capabilities:
  - Management of self-descriptions, including publication, update and removal of self-descriptions by the providers.
  - Facilitate discovery of self-descriptions by potential users, so the catalogue follows as much as possible the FAIR (Findable, Accessible, Interoperable, Reusable) principles.
  - Enable dynamic transactions, bringing together providers and potential users and paving the way for them to establish a relationship that will end up in a provisioning and/or transaction.

- Manage the access to self-descriptions, since the catalogue may contain descriptions accessible just to a specific group of participants (access control to descriptions and policies to determine access rights).

This building block, necessary to ensure loose coupling between data providers and potential users, is critical for facilitating dynamic data transactions between these participants in the data space. It can be implemented through two different scenarios:

- Centralized or distributed catalogue, which includes all descriptions coming from the providers, and publishes them either in a centralized (a unique catalogue for the whole data space) or distributed (several catalogues that will have to implement some kind of synchronization) way. An example of such implementation could be the Metadata Broker specifications provided by IDSA, which contain an endpoint for the registration, publication, maintenance and query of Self-Descriptions.
- Decentralized or p2p catalogue, where the capabilities are included as part of the data connector used by each participant in the data space. In this case, participants directly contact each other on a p2p basis and establish the relationship by using the functionalities defined in the control plane of the connector.

5 Interoperability Aspects

To fully achieve the deployment of CEEDS, starting from the federation of projects' data space instances, detailed interoperability measures are necessary. The interoperability requirements are grouped into technical interoperability, semantic interoperability and governance interoperability.

5.1 Technical Interoperability

Technical interoperability refers to the minimum technical framework that is required for all participants of a data space in the energy domain to be able to process and understand the information (metadata) of the services/data offered in the data space and be able to perform data transfers between them (participants). Specifically, this technical interoperability framework covers the following aspects:

1. Building blocks
2. Actors
3. Data formats
4. Data transmission protocols

To implement the various capabilities in a data space, technology is needed. In most of the data spaces the component "data space connector", described above as part of the CEEDS architecture, is used to provide an endpoint, enabling actors to participate in a data space. In addition, (shared) registries and services are needed to provide common/shared functionalities in a data space. For example, to register the participants of a data space.

5.1.1 Building Blocks

From the technical viewpoint, nine building blocks are defined, which are grouped into:

- Data interoperability: capabilities needed for the exchange of data: (semantic) models, data formats and interfaces (APIs). This also includes functionalities for provenance & traceability.
- Data sovereignty and trust: capabilities needed for the identification of participants and assets in a data space, the establishment of trust and the possibility to define and enforce policies for access and usage control.
- Data value creation: capabilities used to enable value-creation in a data space, e.g. by registering and discovering data offerings or services, providing marketplace functionality and enabling monetization of data sharing.

The technical building blocks, initially defined by OPEN DEI and included in the DSSC analysis, are shown in the Figure 11.

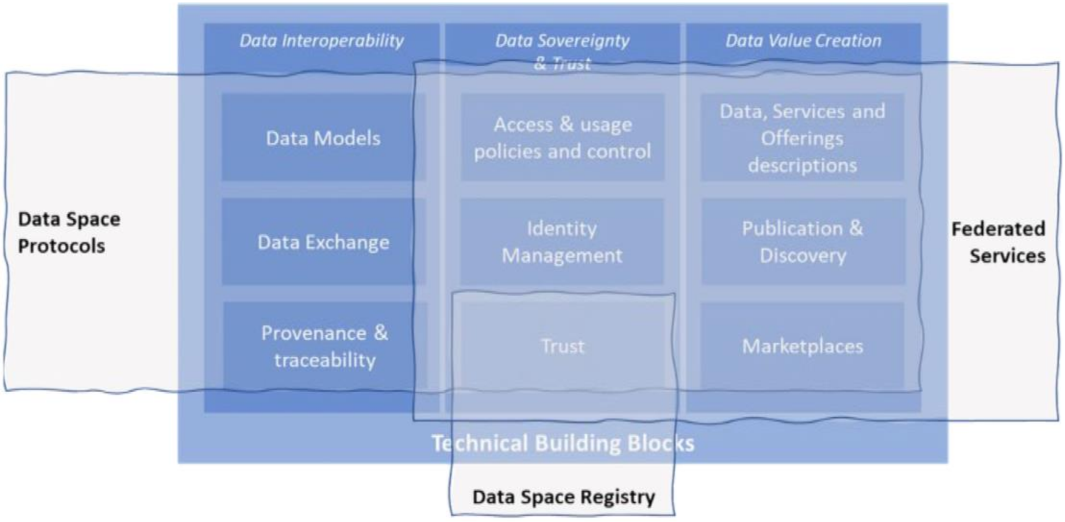

Figure 11 - Technical building blocks, proposed by OPEN DEI and DSSC [1].

From an implementation standpoint, there is not a direct one-to-one correspondence between building blocks and technical components. Often, a single technical component may be associated with multiple building blocks.

As already introduced in the previous section, it is crucial to differentiate between the control plane and the data plane. The control plane is responsible for determining how data is managed, routed, and processed, including user identification and the enforcement of access and usage policies. On the other hand, the data plane is tasked with the actual movement of data. To illustrate, the control plane addresses user identification, access management, and policy enforcement, while the data plane facilitates the physical exchange of data. Consequently, the control plane can be standardized at a high level, incorporating common standards for identification and authentication. Meanwhile, the data plane may vary across different data spaces, adapting to diverse data exchange requirements. Some data spaces prioritize large dataset sharing, others focus on message exchange, and some follow an event-based approach. There is no universal solution, although certain mechanisms can facilitate the collaboration of different data planes.

5.1.2 Actors

Apart from the building blocks, it is important to have a common definition of actors and their possible interactions. In this sense, DSBA has recently published the technical convergence paper[9] which has defined the main actors:

- Data Space Governance Authority
- Data Space
- Participant
- Participant Agent
- Data Space Registry

[9] https://data-spaces-business-alliance.eu/wp-content/uploads/dlm_uploads/Data-Spaces-Business-Alliance-Technical-Convergence-V2.pdf

- Credential Issuer
- Identity/Authentication & Authorization, Identity provider

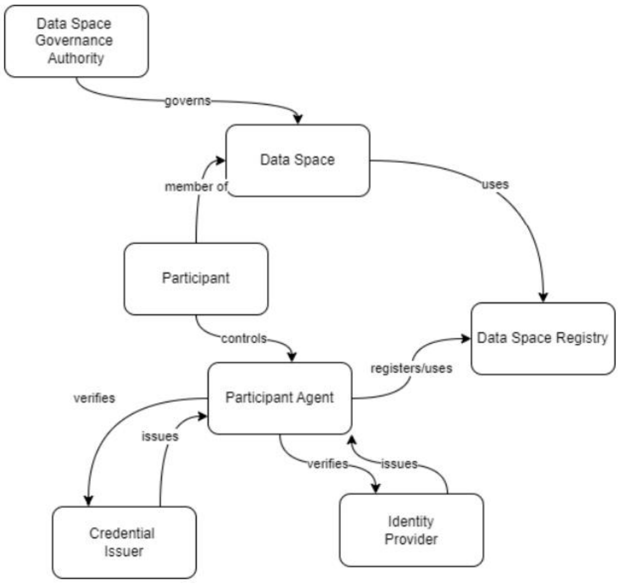

Figure 12 - Relations among data spaces actors (from [6]).

The Figure 12 shows the relationships among the actors.

5.1.3 Data Formats

As the main reference, JSON constitutes a lightweight, language-independent data interchange format, easy to parse and generate. It provides a way to create a network of standards-based machine-interpretable data across different documents. Particularly relevant, as specific proposed solution, is the use of JSON-LD, which serializes linked data in JSON.

5.1.4 Data transmission protocols

The dataspace protocol[10] comprises specifications intended to facilitate interoperable data sharing among entities governed by usage control and utilizing web technologies. These specifications detail the necessary schemas and protocols for entities to publish data, negotiate agreements, and access data within a data space. To share data between autonomous entities, metadata is required to facilitate the transfer of datasets, utilizing a data transfer (or application layer) protocol. The dataspace protocol outlines how this metadata is provisioned, including the deployment of datasets, the syntactic expression, and electronic negotiation of agreements governing data usage, as well as how datasets are accessed using "transfer process protocols". To summarize, the dataspace protocol supports interoperability within data spaces. It ensures fundamental technical interoperability for participants, a prerequisite for joining any data space. The dataspace protocol aims to define the minimum standard of

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[10] https://docs.internationaldataspaces.org/ids-knowledgebase/v/dataspace-protocol/overview/readme

communication so that each actor manages to communicate with other connectors (even if other connectors deploy different features, semantic models, or business procedures).

5.2 Semantic Interoperability

Semantic interoperability refers to the ability of different systems and devices to exchange and interpret information consistently and accurately, based on a shared understanding of the underlying meaning and context.

Harmonization frameworks for data sharing under a shared semantic context are beneficial for interoperability as they enable consistent and standardized data exchange. These frameworks establish common vocabularies, data models, and ontologies, ensuring a unified understanding across different systems. By harmonizing data-sharing practices, stakeholders can seamlessly integrate and interpret data, facilitating effective communication and collaboration. Harmonization frameworks reduce complexity, improve data compatibility, and enhance interoperability, enabling seamless interactions and promoting efficient decision-making within the smart grid ecosystem. In this regard, the CEEDS relies on the harmonization and usage of prominent standards-based data models and ontologies such as SAREF, IEC 61970, IEC 61850, OCPP, Open Data Protocol (OData) and the Common Information Model (CIM).

In data spaces where there is data exchange, approaches based on data ontology (highlighting the relations among the data instances) are a requirement in order to avoid silos. External systems cannot know about the relationships unless they are provided with a machine-readable format. RDF is a framework for expressing linked data so it can be exchanged between applications without loss of meaning. RDF allows the expression of simple facts in the form of triples (subject, predicate and object). The subject and the object represent the two resources being related. The predicate represents the nature of their relationship in a directional way (from subject to object). RDF uses URIs to name the relationship between things as well as the two ends of the link. There are various concrete syntaxes for RDF, such as Turtle [TURTLE], TriG, [TRIG], and JSON-LD [JSON-LD].

Common ontologies provide a shared vocabulary and conceptual framework, enabling a consistent understanding of data. They facilitate interoperability, integration, and fusion of data from diverse sources. Vocabulary Hubs, where different data models are published are key to link the Marketplace for data /service offering discovery. Moreover, standards provide a common framework for defining data models, formats, and protocols. By adhering to semantic and syntactic standards, open data sources can align their data structures and semantics, facilitating seamless interoperability between diverse systems and applications.

5.3 Governance interoperability

Data space governance aims to address fundamental questions about regulatory dynamics, decision-making authority, stakeholder participation, and accountability within a given data space. It involves a collective effort by relevant actors who share a common goal, focusing on determining how decisions are reached, who has the authority to make them, and how they are communicated and enforced.

The new paradigms in the management of energy flows in the energy systems (e.g., associated with the active roles of DER, e-mobility, flexibility solutions) are favoring unprecedented interactions among stakeholders and, consequently, new streams for data exchange. Foremost importance is then assigned to the identification of these necessary interactions (i.e., the stakeholders to be involved) while equipping the data spaces with solutions that respect policies and regulations as well as fostering the development and adoption of new services for reliable energy systems.

The governance framework of data spaces is divided into four distinct layers[11]:

- Common European framework for data ecosystem: private-public data governance (e.g., Data Act or Data Innovation Board);
- Domain-specific building blocks governance: inter-data spaces governance;
- Data space governance: intra-data space governance;
- Governance of a soft infrastructure: operational level of data space to provide essential services.

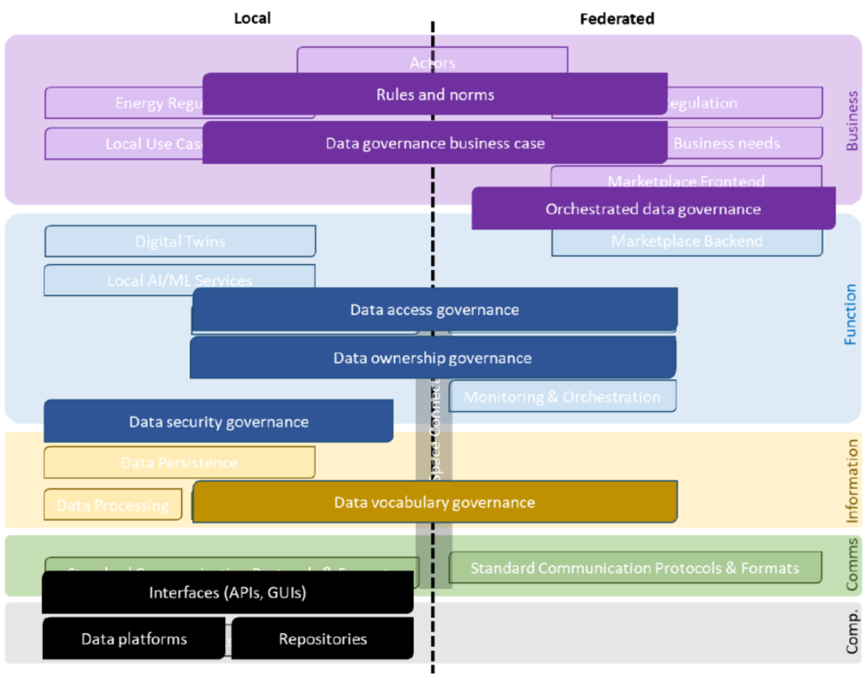

Figure 13 - Governance interoperability in the DERA 3.0 model (from [4]).

With respect to the DERA 3.0 model (developed in the Data Management working group of Bridge, at [4]) the governance components are depicted and mapped to (i) the local (left – i.e., the distributed data ecosystems with legacy data platforms) and federated (right – i.e., the federated data space) parts as well as to the five SGAM interoperability layers (vertically). They are shown in Figure 13; in total, there are ten building blocks that have been defined, across every SGAM layer, to address the governance

[11] https://internationaldataspaces.org/wp-content/uploads/dlm_uploads/Report-OPENDEI-State-of-the-Art.pdf

interoperability. The governance framework must acknowledge the diversity of platforms and systems, tailored to various market designs and business processes. It should promote cross-stakeholder, cross-border, and cross-sector data exchanges, guaranteeing convenient data access that complies with GDPR requirements. Additionally, the governance model should facilitate coordination between TSO and DSO from a customer perspective, ensuring scalability through the open-source principle and agreed-upon rules.

In this regard, it is worth to highlight the proposal highlighted in the int:net whitebook "Engagement Towards Interoperability in Governance" [7]. The analysis conducted on the governance interoperability in SGAM concluded that the 5th SGAM layer is much oriented to business cases and cannot cover political or regulatory and not at all societal interoperability in broad systems; for this reason, the inclusion of a 6th SGAM layer, named "framework" layer is proposed (Figure 14).

This layer addresses interoperability among a large set of energy stakeholders, including:

- Policymakers in politics and public authorities on multiple levels from national to municipal;
- Regulatory bodies;
- Market operators (from global to national to regional and local marketplaces);
- Standardization organizations (national and international);
- Supplier associations, for energy (e.g., ENTSO-E, DSO Entity) and technology (e.g., T&D Europe, AIOTI);
- Consumption Associations (industry and other business associations, building associations, consumer associations);
- Research, innovation and other funding programs (national, transnational, international);
- Institutions for education and human capital development;
- Infrastructure operators (e.g., for transport, health);
- Finance and investment institutions (e.g., ECB, EIB, EU facilities, EFRAG).

The framework layer allows to the identification of specific barriers and requirements for interoperability, hitherto hidden, and to undertake necessary actions that enhance governance fulfillment in data space solutions.

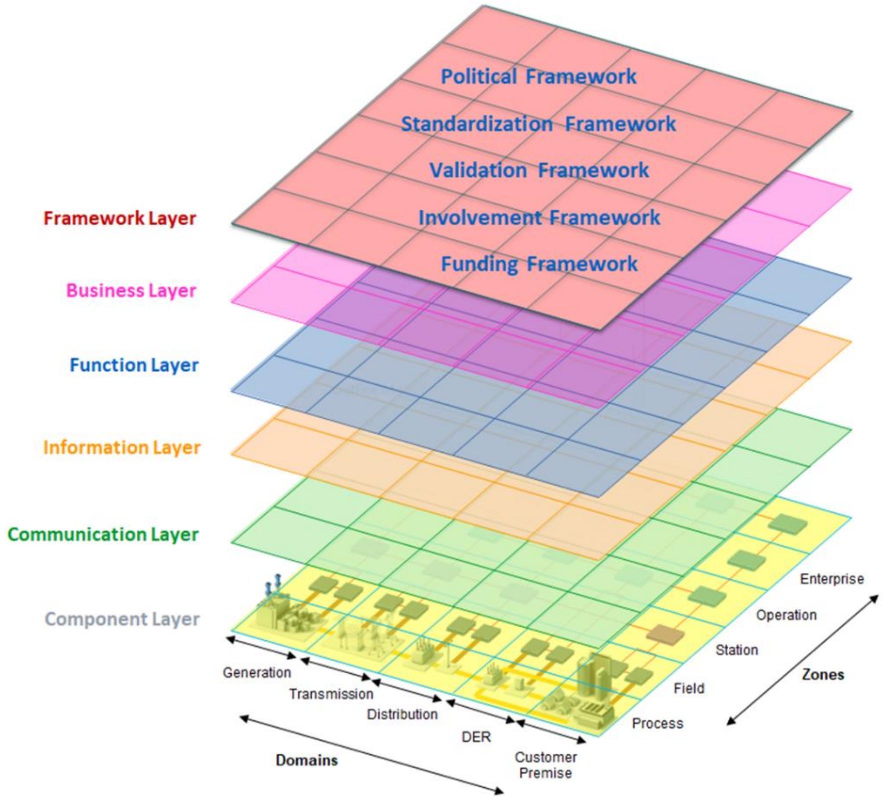

Figure 14 - SGAM plus: the 6th layer "Framework" (from [7]).

Moreover, the DSSC blueprint v1.0 deepens the organizational and business building blocks, reaching the definition of the following **governance building blocks**:

- Organisational governance. Governance in a data space is multi-faceted and encompasses various key decisions. Examples of these key decision points include the scope of the data space, the position the data space initiative wishes to take in the ecosystem, openness concerning entering participants, the support it wishes to arrange for its participants, or the principles it wishes to implement (e.g. democratic). The specific choices made will differ between data spaces, but they should aim to promote collaborative, multi-stakeholder governance for effective data space operation.
- Data sharing governance. It concerns how data transactions are facilitated within the data space. As a part of the data space governance framework, a governance authority can mandate rules and standards for the security, performance, interoperability and observability of data transactions. Clear data-sharing rules are essential for building trust between data space participants and directly reflect the functionality of the data space.

6 Conclusions

The presented blueprint underscores the critical need to adopt data space solutions within the energy domain, marking a pivotal moment for the transformation of the industry. The fundamental pillars of data spaces, as highlighted in this paper, not only foster the active engagement of key stakeholders across the energy value chain but also promise mutual benefits, ranging from monetary compensations to an elevated quality of services. At this scope, the establishment of clear rules, policies and regulatory adaptations is a linchpin in facilitating fair data exchange, paving the way for an open market that fosters the participation of new actors, including data and service providers, as well as data consumers.

The document delves into an in-depth analysis of existing challenges within the energy sector and crafts business use cases that form the backbone of the CEEDS implementation. The contribution of this blueprint is twofold.

First, reference use cases for the data spaces are energy are defined and chosen with respect to the existing challenges and opportunities in the domain. The diversity of these use cases (spanning areas such as mobility, energy communities, TSO-DSO interactions, residential energy optimization, and renewables O&M) underscores the blueprint's comprehensive approach. The success of these use cases is intricately tied to the widespread adoption of energy data spaces, necessitating a detailed examination of data exchange mechanisms, requirements, and the involved actors.

Consequently, to implement the presented use cases, an architecture for the CEEDS is proposed. This architecture envisions the integration of existing data platforms, including legacy systems, through the implementation of a federated data space. Moreover, as the blueprint unfolds, it turns its focus toward identifying and addressing existing challenges in interoperability at technical, semantic, and governance levels. Practical actions and recommendations are outlined, guiding stakeholders on the standards and communication protocols crucial for achieving seamless interoperability.

Looking ahead, the cluster of energy data spaces projects is committed to further investigations aimed at enhancing interoperability, offering invaluable insights for large-scale replications. The emphasis on the exploitability and interoperability of solutions, coupled with the demonstration of the CEEDS use cases, highlights the commitment to practical applicability and scalability. Therefore, this blueprint is an invitation to a broader audience, extending to stakeholders, decision-makers, and professionals in the energy sector. Their active engagement is crucial for translating the blueprint's vision into reality, as energy data spaces transition from conceptualization to tangible implementation in real-world scenarios. The collaborative efforts of the wider community are essential for shaping the future landscape of the energy sector, ushering in an era defined by innovation, efficiency, and sustainability.

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8 List of Figures

9 List of Tables

10 List of Abbreviations

CIM - Common Information Model

COSEM - Companion Specification for Energy Metering

CPO - Charge Point Operator

DER - Distributed Energy Resources

DERA - Data Exchange Reference Architecture

DSO - Distribution System Operator

EMRSP - Electro Mobility Roaming Service Provider

EMSP - e-Mobility Service Provider

ENTSO-E - European Network of Transmission System Operators for Electricity

EV - Electric Vehicle

EVCI - Electric Vehicle Charging Infrastructure

EVU - Electric Vehicle User

FSP - Flexibility Service Provider

GDPR - General Data Protection Regulation

IEC - International Electrotechnical Commission

OEM - Original Equipment Manufacturer

O&M - Operation and Maintenance

OCPP - Open Charge Point Protocol

PV - Photovoltaic

RES - Renewable Energy Sources

SAREF - Smart Appliances REFerence ontology

SCADA - Supervisory Control and Data Acquisition

SPG - Service Providing Group

SPU - Service Providing Unit

TSO - Transmission System Operator

11 Glossary

Access & Usage Policies and Control: Policies that define the rights and obligations for accessing services and using data within CEEDS, ensuring control over data usage.

CEEDS (Common European Energy Data Space): A collaborative initiative aimed at enhancing data sharing and interoperability within the European energy sector to foster innovation, efficiency, and sustainability.

CIM (Common Information Model): A standard developed to allow the interchange of power system information between utilities, network operators, and other stakeholders.

COSEM (Companion Specification for Energy Metering): A set of standards for energy metering data exchange, facilitating interoperable and accurate energy consumption measurements.

CPO (Charge Point Operator): Entities responsible for installing, operating, and maintaining electric vehicle charging stations.

Contracting: Focuses on managing and executing specific data transactions through contract templates, model clauses, and possibly smart contracts to streamline and automate the contracting process within CEEDS.

Control Plane and Data Plane: Differentiates between management, routing, and processing of data (control plane) and the actual movement of data (data plane), pivotal for standardizing data exchange in CEEDS.

Cybersecurity in Energy Systems: The protection of energy infrastructure and data from cyber threats and attacks, ensuring the reliability, integrity, and availability of energy systems and data.

Data Space Connector: A software component that enables interconnection and data exchange between different IT systems/platforms and data-using applications, facilitating interoperable and trustworthy data exchanges in CEEDS.

Data Spaces: Conceptual frameworks that enable secure and sovereign data exchange across different domains and industries, promoting interoperability and collaboration.

DER (Distributed Energy Resources): Small-scale units of local generation connected to the grid at distribution level, including solar panels, wind turbines, and energy storage systems.

DERA (Data Exchange Reference Architecture): A framework for facilitating efficient and secure data exchange in distributed energy resource environments.

Demand Response (DR): A change in the power consumption of an electric utility customer to better match the demand for power with the supply.

Digital Twin Technology in Energy: The creation of a digital replica of physical assets, processes, people, places, systems, and devices for various purposes in energy management and optimization.

Distributed Data Ecosystems: Collections of data platforms that capture and manage their own data, usually inputted to local services for tailored applications, fundamental to the CEEDS architecture.

DSO (Distribution System Operator): Entities responsible for operating, maintaining, and developing the distribution network for electricity, ensuring secure and reliable energy supply.

EMRSP (Electro Mobility Roaming Service Provider): Organizations that provide interoperability among different e-mobility service providers, facilitating seamless electric vehicle charging across networks.

EMSP (e-Mobility Service Provider): Companies that offer services to electric vehicle users, including charging and billing.

Energy Data Analytics: The process of analyzing large datasets to uncover patterns, correlations, market trends, customer preferences, and other useful information to make informed decisions in the energy sector.

Energy Efficiency: The goal to reduce the amount of energy required to provide products and services, enhancing energy conservation in processes, buildings, machines, and devices.

Energy Storage Systems (ESS): Technologies used for storing energy for later use, including batteries, flywheels, pumped hydro storage, and thermal storage, playing a critical role in balancing supply and demand in the energy grid.

ENTSO-E (European Network of Transmission System Operators for Electricity): An organization that represents European TSOs, promoting the development of an integrated national and cross-border transmission system to support the EU's energy goals.

EV (Electric Vehicle): Vehicles that use one or more electric motors for propulsion, relying on battery storage for energy.

EVCI (Electric Vehicle Charging Infrastructure): The set of hardware, software, and services that provide electric energy for the recharging of electric vehicles.

EVU (Electric Vehicle User): Individuals or entities that own or operate electric vehicles.

Federated Data Space: An overarching layer that indexes data from multiple distributed data ecosystems, making it discoverable and facilitating a marketplace for trading both data and data services in CEEDS.

Flexibility Service Provider (FSP): Entities that aggregate and manage flexibility services from DERs or demand response to provide valuable services to the grid, such as balancing and congestion management.

GDPR (General Data Protection Regulation): European Union regulation that sets guidelines for the collection and processing of personal information from individuals who live in the European Union.

IEC (International Electrotechnical Commission): An international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies.

Identity Management: Enables the identification of data space participants, connectors, and trusted data providers, crucial for authorization mechanisms in CEEDS.

Interoperability: The ability of different systems, devices, applications, and services to work together within and across organizational boundaries to meet the diverse needs of users.

IoT (Internet of Things) in Energy: The network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data, enhancing operational efficiency, and energy management.

Log: Used to log information or store data about data usage, incidents, and activities within the data space, associated with the "Provenance & Traceability" building block in CEEDS.

Microgrid: A localized group of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized grid (macrogrid), but can also disconnect to "island mode" and function autonomously as physical or economic conditions dictate.

Metering: The process of measuring energy consumption or production, critical for enabling high-level, real-time monitoring requirements managed by service providers within CEEDS. It supports the digitalization and efficient operation of energy markets.

OEM (Original Equipment Manufacturer): a company that produces parts and equipment that may be marketed by another manufacturer.

O&M (Operation and Maintenance): Activities associated with operating and maintaining energy systems and infrastructure to ensure they function efficiently and effectively.

OCPP (Open Charge Point Protocol): An application protocol for communication between electric vehicle charging stations and a central management system, also known as a charge point operator.

PV (Photovoltaic): Technology that converts light into electricity using semiconducting materials that exhibit the photovoltaic effect, widely used in solar panels.

Publication & Discovery: Acts as a catalogue for the data products available within CEEDS, managing self-descriptions and facilitating the discovery of data products by potential users.

RES (Renewable Energy Sources): Energy sources that are replenished at a faster rate than they are consumed, such as solar, wind, hydro, and biomass.

SAREF (Smart Appliances REFerence ontology): A shared model of consensus that facilitates the interoperability of smart appliances, promoting the integration and communication between different devices and systems.

SCADA (Supervisory Control and Data Acquisition): A control system architecture comprising computers, networked data communications, and graphical user interfaces for high-level process supervisory management, while also allowing other software applications to perform essential process control.

Smart Grids: Electricity networks that use digital technology to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users.

Smart Meters: Electronic devices that record consumption of electric energy in intervals of an hour or less and communicate that information back to the utility for monitoring and billing.

SPG (Service Providing Group): Entities or consortia that offer a range of services, potentially across different sectors, leveraging collective capabilities to meet diverse customer needs.

SPU (Service Providing Unit): The individual operational units within a service providing group, each responsible for delivering specific services or functions.

Submetering: The measurement of energy use beyond the primary utility meter, allowing for detailed tracking of energy consumption or production at a granular level within premises. Integrated into the European regulatory framework, it enables multiple Flexibility Service Providers (FSPs) and suppliers to operate behind a final customer’s connection point.

Sustainable Energy Transition: The process of shifting from fossil fuel-based systems of energy production and consumption to renewable energy sources, improving energy efficiency and reducing greenhouse gas emissions.

Trust Framework: A set of building blocks, including "Access & Usage Policies and Control" and "Identity Management," ensuring a trusted data ecosystem within CEEDS.

TSO (Transmission System Operator): Entities responsible for transporting electricity over long distances via high-voltage power lines, ensuring the stability and reliability of the electrical grid.

Virtual Power Plants (VPPs): A cloud-based distributed power plant that aggregates the capacities of heterogeneous Distributed Energy Resources (DER) for the purposes of enhancing power generation, as well as trading or selling power on the electricity market.

Vocabulary Hub: Provides endpoints for seamless communication with data space connectors and infrastructure components, storing and documenting vocabularies, ensuring compliance within CEEDS.

CONTACT

Interoperability Network for the Energy Transition (int:net)

c/o Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V.
Hansastrasse 27c, 80686 Munich
Germany

mail: info@intnet-project.eu