European Common Energy Data Space Framework Enabling Data Sharing - Driven Across – and Beyond – Energy Services

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D2.5 Final Version of the ENERSHARE Requirements, SSH-driven Approach and Reference Architecture

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List of Acronyms

Acronym	Expanded Version
AD	Architecture Description
ADE	Architecture Description Element
ADF	Architecture Description Framework
API	Application Programming Interface
BD4NRG	Big Data for Energy
CA	Certificate Authority
CCC	Control, Comfort and Convenience
CIM	Common Information Model
CSV	Comma-Separated Values
DAPS	Dynamic Attribute Provisioning Service
DER	Distributed Energy Resources
DERA	Data Exchange Reference Architecture
DPbDD	Data Protection by Design and by Default
DSC	Dataspace Connector
DSSC	Data Space Support Center
DSO	Distribution System Operator
DTDL	Digital Twin Definition Language
EC	European Commission
EMS	Energy Management System
EU	European Union
FSP	Flexibility Service Provider
GE	Generic Enabler
GeoJSON	Geospatial JSON
GPU	Graphics Processing Unit
H2020	Horizon 2020
IDP	Identity Provider
IDS RAM	International Data Space Reference Architecture Model
IDSA	International Data Spaces Association
ISC	Integration Service Component
JSON	JavaScript Object Notation
JSON-LD	JSON for Linked Data
LoRaWAN	Long Range Wide Area Network
LWM2M	Lightweight M2M
MDB	Metadata Broker
MO	Market Operator
MVP	Minimum Viable Product
NGSI	Next Generation Service Interface
NGSI-LD	NGSI Linked Data
O&M	Operation & Maintenance
Auth2	Open Authorization 2.0
P2P	Peer-to-Peer
PPF	Privacy Protection Framework
RA	Reference Architecture

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RBAC	Role-Based Access Control
RES	Renewable Energy Sources
REST	Representational State Transfer
SAREF	Smart Appliances Reference Ontology
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SHERBA	Secure Interoperable IoT Smart Home/ Building and Smart Energy Reference Architecture
SO	System Operator
SQL	Structured Query Language
TSG	TNO Security Gateway
TSO	Transmission System Operator
UC	Use Case
WP	Work Package
XACML	Extensible Access Control Markup Language
XML	Extensible Markup Language

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Executive Summary

The Enershare project encompasses a large number of stakeholders in the electricity sector as well as cross-sectorial areas such as power-to-gas and smart buildings. The goal of the project is to implement a reference architecture that demonstrates the participation of a variety of emerging roles in a common European Data Space. It will do so while addressing concerns of trust, security, sovereignty, and interoperability in data exchange. In addition, standardization, security, legal, and privacy topics are highlighted. Furthermore, marketplace and cross-value chain AI and Digital Twin based services will showcase business opportunities. In furtherance of the effectuation of this vision, this deliverable provides the final version of the Enershare requirements, SSH-driven approach, and reference architecture.

The process involves meticulous refinement of requirements, encompassing key facets such as interoperability, privacy protocols, incentivizing data sharing, fostering trust through effective communication, addressing legal and regulatory considerations, and culminating in standardization. Subsequently, a comprehensive examination is undertaken to ascertain the alignment of Enershare with other prominent data space initiatives, including IDS, GAIA-X, and FIWARE.

To describe a complex digital ecosystem such as the Enershare Platform, the 4+1 Architectural View Model is used. Employing the 4+1 view architectural model, the conclusive version of the Enershare reference architecture is outlined within the logical view. This is followed by the fundamental components that constitute the core of Enershare. In parallel, the interactions among these core components are elucidated within the development view, providing a comprehensive understanding of the system's evolution.

Furthermore, a communication procedure exemplar is provided, serving as a detailed depiction of the process view. This exemplar illuminates the flow and exchange of information within the Enershare framework.

Finally, within the development view, an overarching snapshot is presented, encapsulating the currently deployed components. This section is rooted in the first phase of the implementation of the architecture (MVP), offering insights into the tangible progress and implementation milestones achieved thus far.

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1 Introduction

1.1 Scope of the Document

Deliverable 2.5 "Final version of the ENERSHARE requirements, SSH-driven approach and reference architecture" is the final results of T2.2 “Data-driven value-added service and data sharing incentive design for consumers and local communities”, T2.3 “Overall business concept design and functional specification”, T2.4 “Integration of privacy, ethical, cybersecurity, legal and regulatory compliance in the Reference Architecture”, and T2.5 “ Reference Architecture for a European federated Energy Data Space" within WP2 “Requirements, user stories capitalisation and Energy Data Space design".

This deliverable is divided into two parts including an “Expectation” section and an “Architecture” section.

As the “Expectation” section, the expectations, including key facets such as interoperability, privacy protocols, incentivizing data sharing, fostering trust through effective communication, addressing legal and regulatory considerations, and standardization are refined. Subsequently, a comprehensive examination is undertaken to ascertain the alignment of Enershare with other prominent data space initiatives, including IDS, GAIA-X, and FIWARE.

As the “Architecture” section, the “4+1 Architectural View Model” is used to describe a complex digital ecosystem such as the Enershare Platform. In this model, the foreseen stakeholders are end-users, developers, system engineers and project managers. The foreseen viewpoints include the logical view, the development view, the process view, and the deployment view:

- Logical view: the essence of the reference architecture is captured by the logical view. To express the reference architecture, we suggest splitting it into the orthogonal concerns of energy and data space domain architectures. As basis for the Data Space Reference Architecture, we chose BRIDGE DERA 3.0 and OpenDEI-based building blocks described in Deliverable 2.1. In order to connect it to the energy use cases, we suggest a mapping of Harmonised Electricity Market Role Model entities to IDSA RAM Energy Domain Data roles based on Deliverable 2.1 as a starting point for the Energy Domain Reference Architecture.
- Development view: the fundamental elements that constitute the core of Enershare are provided within development view. This is followed by the interactions among these core components, providing a comprehensive understanding of the system's evolution.

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- Process view: a sample of communication process within IDS RAM along with process view that deals with the dynamic aspects of the ENERSHARE Marketplace and explanation of the system processes, and how they communicate is discussed in process view section.
- Deployment view: finally, the current state of Enershare system with a list of deployed functionalities based on the MVP of architecture implementation is provided. Generally, ENERSHARE considers continuous integration during the project lifetime, and the adoption of an incremental Minimum Viable Product approach.

Note that the 4+1 view includes the use case view which is described in D2.1, and also summarised in Table 1.

The proposed validation methodology will go through different yet incremental stages, starting from an initial smaller-scale validation taking place in a controlled environment where a subset of functionalities and tools will be deployed and validated over a reduced amount of data from all pilot sites aimed to provide early feedback and allow refinements and adaptations based on an early technical integration of the ENERSHARE solutions.

The MVP includes the initial subset of the functionalities that will be deployed in the first stage of ENERSHARE. The release planning to finish with deployment of all expected functionalities is also provided in this final section.

1.2 Structure of the Document

This document is structured based on the "foundational" and "4+1" View Model. Therefore, the remainder of this document is structured as follows:

- Section 2 describes the applied methodology to create the Enershare Reference Architecture (RA) as a working basis for software architecture that guarantees compliance and provides high-level software architecture.
- Section 3 describes expectations including user scenarios and refines requirements for the Enershare system, encompassing key facets such as interoperability, privacy protocols, incentivizing data sharing, fostering trust through effective communication, addressing legal and regulatory considerations, and culminating in standardization.
- Section 4 provides the 4+1 view model including Logical View, development view, process view, and deployment view.
- And the final section concludes the deliverable with a short summary.

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2 Methodology

To create the Enershare Reference Architecture (RA) as a working basis for software architecture that guarantees compliance and provides high-level software architecture following steps are applied:

- Ensure a comprehensive understanding of stakeholder expectations and user scenarios
- Execute the utilization of the predefined set of building blocks as articulated in D2.1, grounded in OpenDEI principles. This initial step is indispensable for the development of the Enershare RA, with a primary focus on establishing the functionality of the Enershare data space. The identified building blocks span technical, organizational, business, and governance domains.
- Conduct a mapping exercise wherein each building block is systematically associated with a specific task. This task-centric approach ensures a clear delineation of responsibilities for the implementation of requisite functionalities as software components.
- Instantiate a collaborative effort using Miro board (Figure 1) and proactively involve key technical partners. This collaborative effort aims to deconstruct the system into pivotal components and the interactions between them, fostering a shared understanding among stakeholders.

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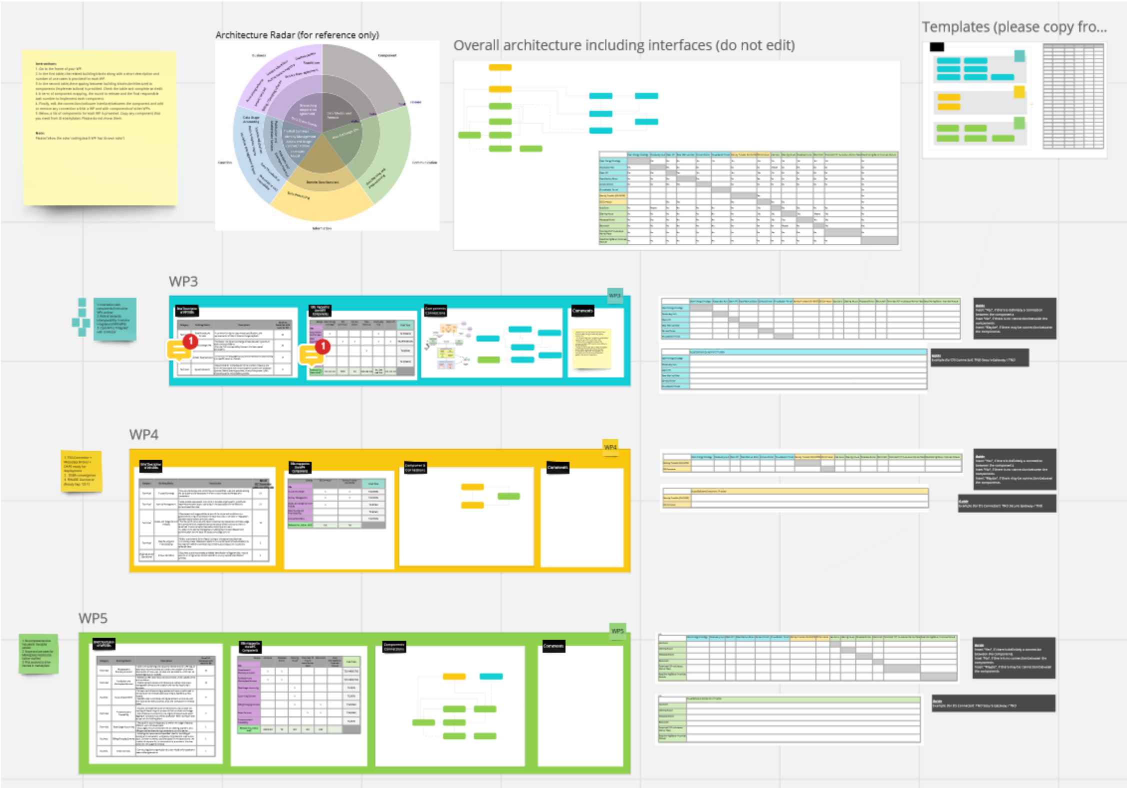

Figure 1: Miro Board

- As displayed in Figure 2, formulate an Architecture Radar to delineate the scope of functionalities to be implemented across distinct release cycles. The innermost ring encapsulates the essential core functionalities earmarked for the inaugural release, targeted for pilot deployment. Subsequent outer layers strategically outline building blocks earmarked for subsequent release cycles.

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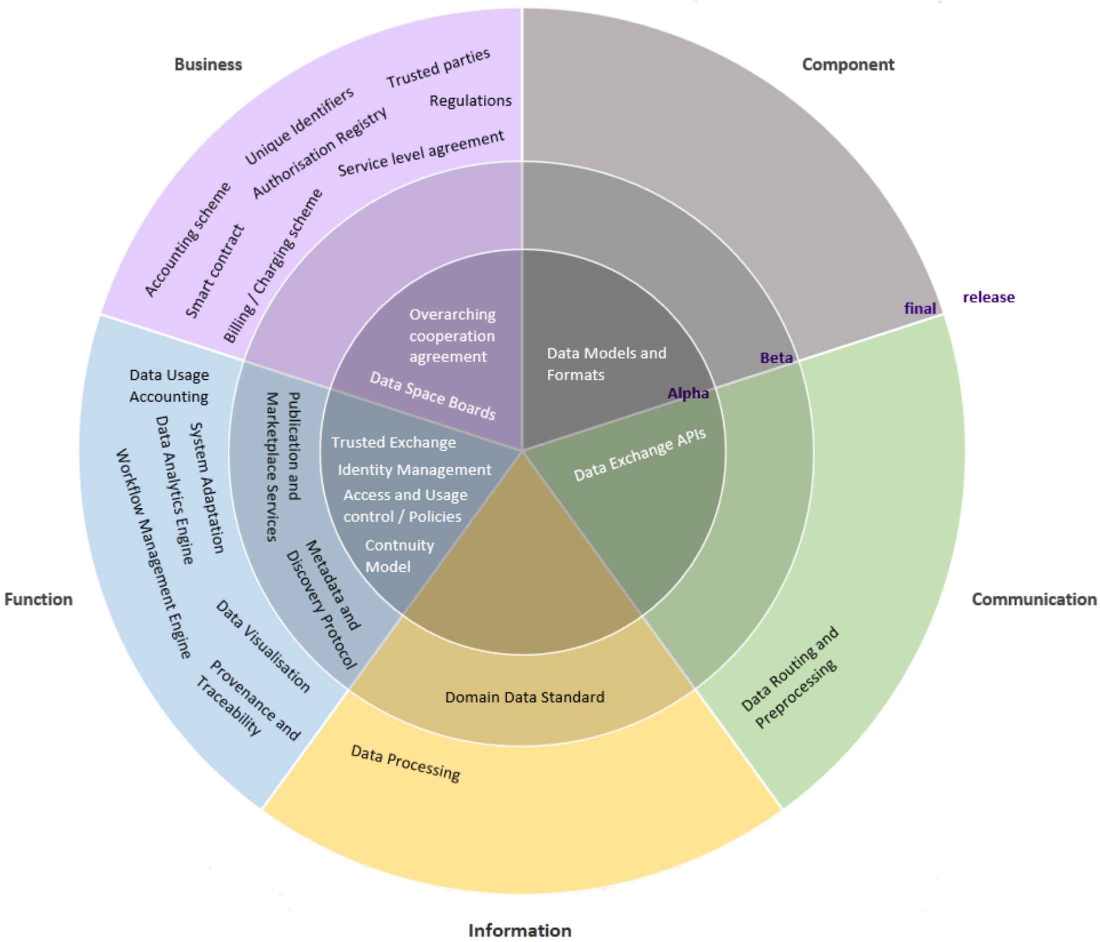

Figure 2: Architecture Radar

- Contribute to the detailed development of comprehensive documentation. This documentation is based on the foundational view and the 4+1 architectural view to cover the requirement refinements and system architecture. This comprehensive approach ensures a thorough understanding of the Enershare RA from multiple perspectives.

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Key Normative References

While there are many normative references of interest for this deliverable, we have singled out two key references:

- ISO/IEC/IEEE 42010, Systems and software engineering — Architecture description. Software architecture descriptions are commonly organized into views, which are analogous to the different types of blueprints made in building architecture. Each view addresses a set of system concerns, following the conventions of its viewpoint, where a viewpoint is a specification that describes the notations, modelling and analysis techniques to use in a view that express the architecture in question from the perspective of a given set of stakeholders and their concerns (1) and (2). ISO/IEC/IEEE 42010 is the first of a long list of standards, those that complement it (e.g., 42020 - Architecture process, 42030 - Architecture evaluation, 42024 - Architecture fundamentals, 42042 - Reference architecture) or are using it as reference (e.g., 30141 - IoT reference architecture, 30188 - Digital twin reference architecture).
- ISO/IEC 20151, Cloud computing and distributed platforms (3) — Data spaces concepts and characteristics. While the development of this standard just started at the end of 2023, it will be foundational and therefore material from this deliverable can be contributed the development of 20151.

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3 Expectations

3.1 User Scenarios

In the "4+1" Architectural View Model (4), the scenarios' view provides a representation of the system's functionality as seen from an external perspective. All other views in the model rely on the scenarios view as a guiding reference. Within the deliverable titled "D2.1: Use cases' descriptions and list of minimum Data Space building blocks required for pilots" the description of all use cases planned within the Enershare project has been summarised and the required data space building blocks from it has been derived.

In Table 1, a list of use cases of ENERSHARE with a short description is listed. It gives an overview of the use cases in scope.

Table 1: Scenarios Overview

Pilot	Use Case	Title	Scenario Overview
P1-ES	-	Wind farm integrated predictive maintenance and supply chain optimization	- Anomaly detection using hybrid model (physics-based model + data-driven)
P2-PT	A	Leveraging on consumer-level load data to improve TSO's operational and planning procedures	- Net-load forecast at substation-level - Analysis of the consumption evolution to improve grid planning - Flexibility estimation - Cross-sector opportunities
P2-PT	B	Instantiation of energy communities and digital simulation of business models	- DER sizing and economic evaluation of the REC / CEC business model - Estimation of flexibility potential and energy savings from thermal domestic loads - Simulation of energy price within the REC / CEC
P2-PT	C	Detect irregularities in energy consumption in households with seniors living alone	- Detection of irregularities in seniors' energy consumption
P2-PT	D	Suggest maintenance of appliances based on NILM data	- NILM analysis for opportunities of maintenance or renewal of appliances

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P3-SI	-	Optimal multi-energy vector planning - electricity vs heat	- Flexibility assessment - Planning of measures
P4-GR	-	Digital Twin for optimal data-driven Power-to-Gas planning	- Develop and evaluate an electricity only Digital Twin considering fuel cell technologies (short-term horizon / long-term horizon) - Develop and evaluate a sector coupled Digital Twin (natural gas + electricity) (short-term horizon / long-term horizon)
P5-IT	A	Cross-sector Flexibility Services for aggregators and DSO	- Variable demand response
P5-IT	B	Services for e-mobility CPOs, EVs drivers and DSO	- Grid monitoring - Charging schedule notification - EV users involvement - Grid congestion problem avoided
P5-IT	C	Flexibility provision for electricity grid with water pumps and predictive maintenance of the pumps	- Flexibility - Predictive Maintenance
P6-SE	-	Flexibility aggregation from behind-the-meter consumers	- Disaggregation of TSO control signal to available EV chargers - Estimation of available flexibility from EV chargers
P7-LV	-	Cross-value chain services for energy-data driven green financing	- Anonymization - PV forecast - Cost and energy efficiency calculation

Based on the use cases analysis, a list of stakeholder's expectations are derived which is discussed in the next section.

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3.2 Expectation Refinement

As provided in Table 2, the expectations are refined in this section.

Table 2: List of Expectations

Expectations	
1	Interoperability
2	Privacy
3	Data Sharing Incentives and Trust Communication
4	Legal and Regulatory
5	Standardization

3.2.1 Interoperability

One of the keys focuses in achieving interoperability is semantic interoperability. This refers to the ability of different systems and stakeholders to understand and interpret data and information in a consistent and meaningful way.

Expectation 1: Agile standardisation process to handled standardized vs. fit-for-use models

The Enershare project has semantic interoperability requirements that involve reconciling conflicting needs between data models that are fit-for-use and standardized. On one hand, the project aims to have data models that are customized and fit-for-purpose, ensuring they accurately represent the specific requirements of the Enershare ecosystem (as represented by the project's pilot use cases). On the other hand, there is a need for standardization to enable interoperability with existing systems and stakeholders.

To address these conflicting requirements, the Enershare project recognizes the need to facilitate both formal and agile standardization approaches. The formal approach involves the reuse and adoption of existing standard vocabularies and data models from formal standardization bodies. However, these need to be customized and made fit-for-purpose to prevent unnecessary complexity that may hinder adoption.

The agile standardization approach complements the formal approach by allowing for an iterative and adaptable process. It enables the refinement and customization of the vocabularies and data models to ensure they provide the necessary coverage and accuracy without overwhelming complexity. The tools and products from Enershare work package 3

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implement such agile standardization processes, allowing users and stakeholders to collaboratively derive and refine the fit-for-purpose vocabularies.

Expectation 2: Flexibility in terms of data exchange format (Linked data vs. traditional data exchange formats)

Another expectation for the Enershare project is the need for flexibility in terms of data exchange formats. The project recognizes that different stakeholders may have varying preferences and capabilities when it comes to data exchange. The project considers linked data technology (RDF combined with ontologies or syntaxes such as JSON-LD and NGSI-LD) as the preferred route to interoperability. It allows for rich semantic representation, enabling advanced data integration and reasoning capabilities. However, it is also acknowledged that RDF and ontologies can be complex and may require a steep learning curve for some stakeholders, limiting their adoption. As an alternative route, traditional syntaxes as CSV, XML and JSON are suggested as a more straightforward and easy-to-adopt format. These are all popular and widely used data interchange formats, known for their simplicity and/or compatibility with various programming languages. The requirement for flexibility in data exchange formats reflects the project's objective of accommodating different stakeholders and promoting interoperability. With such flexibility, Enershare ensures interoperability while catering to different levels of technical knowledge and implementation complexities within the energy data space.

Expectation 3: requirements on ontology specifications

An ontology, in information science and computer science, is a formal representation of knowledge or data that defines concepts, their attributes, and the relationships between them. It plays a crucial role in semantic interoperability as it provides a common understanding and a powerful shared vocabulary for different stakeholders and systems within a data space. Stakeholders use ontologies by linking (i.e., 'mapping') their data to the relevant parts of the ontology.

Since linked data is the primary method of interoperability in the project, we define an Ontology Requirements Specification, which outlines the essential criteria and expectations for the development of an ontology.

Requirements for ontologies in the energy domain include:

1. Semantic Clarity:
    - Conceptual Clarity: Clear and unambiguous definitions of energy-related concepts, such as "renewable energy," "energy efficiency," "power generation," and "carbon emissions."
2. Comprehensive Coverage:

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- Domain Coverage: The ontology should cover a broad spectrum of energy-related topics, including various energy sources (e.g., fossil fuels, renewables), energy infrastructure (e.g., power plants, grids), and energy-related policies and regulations.
- Cross Domain Coverage: The ontology should cover topics such as weather, environment, sustainability, etc.

3. Interoperability:
    - Standardization: Adherence to standard data formats and ontological languages (e.g., RDF, OWL, JSON schema) to ensure compatibility and interoperability with other systems and datasets.
    - Linked Data: Support for linking to external ontologies, datasets, and sources to enhance data integration and knowledge sharing.
4. Relationships and Hierarchies:
    - Hierarchical Organization: Define relationships and hierarchies between concepts, such as "is-a," "part-of," "uses," and "generates."
    - Temporal Relationships: Represent temporal relationships, such as "before," "during," and "after" for energy-related events and processes.
5. Data Integration:
    - Data Integration Support: The ability to integrate and relate energy data from various sources, including sensors, meters, databases, and external datasets.
    - Data Transformation: Support for transforming and standardizing diverse energy data formats into a common ontology.
6. Regulatory Compliance:
    - Regulatory Frameworks: Capture and represent relevant energy regulations, standards, and compliance requirements.
7. Energy Use Cases:
    - Use-Case Specific Extensions: Flexibility to extend the ontology for specific energy use cases, such as smart grid management, renewable energy forecasting, or energy consumption analysis.
8. Documentation and Metadata:
    - Comprehensive Documentation: Detailed documentation of ontology concepts, relationships, data types, and usage guidelines.
    - Metadata: Include metadata standards to describe ontology resources.

The Ontology Requirements Specification is based on the list of use cases defined in WP2. Four Steps are defined in T3.1: analyse each use case of pilots, delimit the scope of the ontology, define the competency questions, and extract the relevant terms.

One of the examples of the pilot 1 is presented in Table 3.

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Table 3: Example of Use Case Specification in T3.1

STEP1: Ontology Requirements Specification	
Tasks	**Description**
Use Case Analysis	Services that allow to foster data driven innovation in the onshore and offshore wind energy industry, along its value chain, to maintain its competitive advantage and contribute to the decarbonization of the economy.
Ontology Scope	1) Reduce maintenance costs and increase the availability if wind turbines: a) Ontology of maintenances: it could be taken as a basis the following: Maintenance WG – IOF Website (industrialontologies.org). It relates failures with maintenance. b) At least the 4 components to be analyzed (generator, power converter, gearbox, hydraulic pitch system) should include: maintenance last data, maintenance work, maintenance cost, next scheduled maintenance data, expected data, expected cost 2) Enhanced diagnostics of failure in the following wind turbine systems: generator, gearbox, pitch system and power converter: a) Wind turbine ontology with all components b) Ontology to represent damages, failures and failures modes related to wind turbines (it is related to 1a)
Competency Questions	Some semantic model competency questions: 1. What is the kind of the wind turbine (onshore/offshore)? 2. What is the location of the wind turbine? 3. What is the typology of the turbine, in terms of speed? Direct drive/geared. 4. What is the typology of the turbine, in terms of kind of generator? Double feed induction generator (FIG)/permanent magnet generator (PM) 5. What are the subsystems of the wind turbines?

3.2.2 Privacy

Expectation 4: Correct identification of different categories of data processed

Enershare will process various categories of data, both personal and non-personal. For each category of data specific rules apply. For a good functioning of the energy data space, it is essential to identify correctly: the categories of data processed; the types of data processing involved; the purposes for which the data are processed; the individual actors involved in the processing of data; the specific roles attributed to each individual actor involved in the processing of data; the specific requirements associated with each actors' role in the processing of data. The nature of the issues that will need to be addressed include legal and regulatory

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compliance; (cyber)security; internal (data) governance; broader social acceptance of the energy data space and (innovation) activities that fall within its scope; technical consistency.

Expectation 5: Consider emerging properties and effects of the data space

The (energy) data space is a new and largely experimental concept. Elements of data spaces are currently under (technical) development and will become more concrete as development progresses and as data spaces begin to be implemented, adopted, and used. While there is an understanding of the desired properties of data spaces, little is known about their final configurations, functioning and actual effects. New properties (desired and undesired) can emerge and should be closely monitored. A precautionary approach, especially to undesired properties and harmful effects, is highly recommended. Examples of emerging properties could be social, legal, technical, economic (e.g., unpredictable algorithmic behaviours, consumer discrimination, privacy, and copyright infringements, etc.)

Expectation 6: Data responsibility

It is important that any data collected and processed (e.g., shared among participants to the energy data space) is treated in an ethically correct, secure, and safe manner. Good etiquette for handling data dictates that data providers should make their intentions understood by data owners and other parties by:

- Being transparent towards data owners about “who, what and what for” personal data is used.
- Explaining the difference between anonymous, pseudonymous, and personal data, and which applies to the data being collected.

It should be ensured that all data collected is the ‘right’ data and no excess data is accumulated or shared:

- Make sure personal data collected are (i) adequate, (ii) proportionate and (iii) relevant to the objectives of the service.
- Guarantee that the personal data collected is accurate.

To process and manage the collected data in an appropriate manner, data providers must:

- Ensure data rights; the right to access (i), the right to approach a common-pool resource (ii), the right to withdraw (iii), to manage (iv), to exclude (v) and to alienate (vi) physically or virtually.
- Install security measures / cybersecurity, ensure anonymity of data owners, secure and sufficient storage, accessibility rights for data owners and data consumers, and trackability of data, remove stored and shared data if a person opts out (technical implementation)

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- Appoint an organization to ensure responsible data collection and data exchange, anonymity, storage, accessibility and trackability (supervision)

Expectation 7: Create a privacy community

To ensure that privacy is addressed through common practices, Trialog has set up an ECLIPSE interest group, models for privacy (5). The group has an international audience, is supported by stakeholders such as the GPS by design centre (with the participation of Ann Cavoukian), or KU Leuven (LINDDUN). The objective will be to share models for privacy impact assessment, data usage enforcement for data spaces.

Expectation 8: Leverage standardisation

Table 4 shows the standards that will be monitored and considered.

Table 4: Leverage Standardisation

ISO/IEC 27564 Privacy models	This project was started in 2022. It defines the concept of privacy models and provide guidance on their use in the engineering lifecycle process. Trialog is co-editor. Enershare will reuse input from or contribute to this project concerning privacy models in energy data spaces in WP6.
ISO/IEC 27568 Security and privacy of digital twins	This project was started in 2023. Trialog is co-editor. Enershare will reuse input from or contribute to this project concerning the security and privacy of digital twins in energy data spaces in WP6.
ISO/IEC 27091 AI – Privacy protection	This project has started in 2023 as the result of a preliminary work item. It will cover all types of AI systems (data driven, and knowledge driven). Trialog is co-editor. Enershare will reuse input from or contribute to this project concerning the AI usage in energy data spaces in WP6.

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3.2.3 Data Sharing Incentives & Trust Communication

Requirements for data sharing incentive design and data-driven service design are described in detail in chapter 4 of ENERSHARE Deliverable 2.2 Two important aspects regarding data sharing are to establish trust and engagement with the data owners, and to develop appropriate incentives and services that fit their values, needs and desires.

Expectation 9: Establish trust and engagement

- *Learn from the data owners:* explore and understand their values, needs and desires
- *Establish and maintain a relationship with data owners* be honest and realistic about benefits and constraints, manage expectations by being transparent, connect and maintain interaction, build a community by stimulating interaction between data owners, think of the level of participation that is desired, create awareness for and knowledge about data sharing and why it is relevant, create trust.
- *Communicate with data owners:* raise awareness, communicate clearly and honestly, communicate regularly without overburdening data owners, use different forms of communication, provide information on new developments and participatory activities, provide visual materials.
- *Ensure inclusion / limit exclusion and ensure diversity:* Provide information that everyone can understand and satisfy curiosity, think of who is excluded and why and if this can be done differently, ensure that all stakeholders are able to keep up with the pace of technological development.

Expectation 10: Develop data sharing services and incentives

When developing incentives and services for data sharing, the first step is to identify opportunities by engaging with stakeholders, to explore the context for which the incentives and services are being developed to create a viable, feasible and desirable business case. This includes a comprehensive exploration of financial, institutional, organizational, technological, and social characteristics from the perspective of the stakeholders, of which the data owner and the data provider play a central role.

To establish motivation and trust with data owners to share their data, it is important to:

- Connect to the data owners:
  - Communicate regularly on what is happening regarding the data and the data space and what benefits it offers to the data owners.
- The emerging propositions should connect to values upheld by either data owners or data providers in a way that both parties are motivated to make use of the concept. When values are identified the proposition still needs to be crystallized further into a more concrete way of leveraging the values of the stakeholders involved. In this process of leveraging values, it

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is important to ensure that all benefits and costs are distributed equally, also considering the people that are left out of the proposition. Develop incentives and services that are:

- Useful: Fulfilling a need or desire of the targeted users.
- Create usable incentives and services which are easy, simple and consistent to use and navigate, and are predictable
- Desirable: Simple and clear to obtain and use and attractive and enjoyable to engage with, embedding and communicating the values that have been identified.
- Accessible for everyone involved.
- Viable: Economically viable
- Feasible: Technologically and politically / regulatory

3.2.4 Legal & Regulatory

The energy data space will have to operate within a highly complex and largely (yet) unknown legal, regulatory and policy environment. To allow the proper functioning of the energy data space, a minimum of requirements have been defined and applied, and other measures are adopted (the development of the Minimum Viable Product). The minimum requirements include at least the following.

Expectation 11: Take into account both horizontal and vertical laws, regulations and policy applicable to data spaces

The energy data space will be subject to a variety of **existing laws and regulations**, both **horizontal and vertical**. Vertical laws and regulations are energy sector-specific and could also apply to the energy data space. Examples in this category could include, for example, the Directive on Energy Efficiency. Horizontal laws, regulations and policy are not sector specific and could include, for example, those regarding data protection such as the General Data Protection Regulation; or those regarding the (cyber)security of networks, such as the Directive on measures for a high common level of cybersecurity across the Union (the NIS 2 Directive).

Expectation 12: Take into account relevant laws, regulations and policy applicable at different levels: EU, national, regional and local

The energy data space will have to identify and observe all relevant horizontal and vertical laws and regulations that have been defined and apply at **multiple levels: EU, national, regional, and local.** Furthermore, it will have to consider that while some of these provisions will be relevant for the data space **as a whole**, others will be relevant only for **specific elements** of the data space.

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Expectation 13: Take into account a high level of legal and regulatory uncertainty

The energy data space will have to take into consideration the highly uncertain legal, regulatory and policy environment in which it is built now and in which it will operate in the future. The high level of uncertainty is likely to persist for the foreseeable future and should be considered already at this stage of the design and in the technical, operational and governance choices made by the project. Relevant developments should be identified, investigated, and monitored on a continuous basis and mitigation measures should be adopted if appropriate. Grounds for the high level of legal and regulatory uncertainty stems include but are not limited to:

- Lack of, or insufficient **compatibility** between the various categories of applicable laws and regulations.
- Legal and policy uncertainty owing to laws, regulations and policy measures that might become applicable in the future, but are currently still **in development**, while the energy data space is already in development.
- Legal and policy uncertainty owing to existing laws, regulations, and policy measures, but which are currently undergoing a **review** (e.g., the ePrivacy Regulation proposed to review, update, and replace the current ePrivacy Directive), while the data space is already in development.

Expectation 14: Take into account future legal and regulatory implications linked to broader interoperability requirements

The EU foresees the development of a single EU data space covering several domains: energy, health, transport, etc. It imposes broader **interoperability requirements across all sectoral data spaces**, including the energy data space. The legal and regulatory implications of this policy measure are difficult to estimate, and as such a contingency plan should be defined.

Expectation 15: Take into account critical sector or critical entity implications

Participants in the energy data space could be assigned roles as part of a critical sector or be designated critical entities themselves. Additional requirements might apply (e.g., security requirements).

Expectation 16: Take into account liability issues

The energy data space should anticipate, identify, assess, mitigate, and manage liability risks related to the data sharing, copyright, and other relevant issues to do with the legal responsibilities of participants. It should also consider upcoming relevant legislation, such as the AI liability Act. Rights and responsibilities of participants should be outlined and detailed in the governance plan.

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Expectation 17: Monitor continuously relevant legal, regulatory and policy evolution

As mentioned in the previous sections, the legal, regulatory and policy environment in which the energy data space operates is complex, fragmented, undergoing significant transformation and generally uncertain. A significant number of EU and national laws, regulations and policy measures pertaining to the energy sector in general, and to the energy data space are currently still in the process of being proposed, adopted, or reviewed. Such initiatives might be horizontal or non-energy sector specific (e.g., the EU GDPR, NIS2, the proposed AI Act, the proposed Data Act, acts currently under review such as the Machinery Directive or the ePrivacy Directive, or new acts that have been adopted but have not yet entered effect such as the Implementing Acts on interoperability requirements and procedures for access to data required for demand response and customer switching). Other initiatives might be specific to the energy domain: such as the recast of the 2019 Electricity Directive, the Electricity Regulation, national sectoral regulation, etc. Other initiatives might focus on other sectors, but still bear relevance to the energy data space. Such initiatives might come into force during or after the project has been concluded and influence the energy data space in all its aspects: technical, organisational, economic, social, etc. A future-proof data space will need to be aware of these developments, for example through a process of continuous monitoring.

Expectation 18: Draft a governance framework

The roles, rights, and obligations of all categories of participants in the energy data space, the types, and conditions of interactions between participants in the energy data space, decision-making provisions, means to address (potential) risks and other relevant issues should be addressed in a comprehensive governance framework. ENERSHARE is currently developing such a framework in WP7 (D7.2).

1) Considering the above, it is important to consider the legal standing point proposed by organizations such as IDSA. Two main resources are considered, IDSA's Rulebook and the position paper on Data Intermediaries. Regulatory Frameworks, Contractual Agreements, and Governance in Data Sharing

   Taking as reference the IDSA's Rulebook (6), where the regulatory landscape is discussed, challenges for sharing and reuse of data are discussed. Some of them are the absence of a general legal status for data, partial application of intellectual property (IP) rights, and fragmented personal data protection. To tackle these issues, the EU Commission introduced the "European Strategy for Data", outlining the vision for a unified European data space. As part of the EU's digital strategy, the Commission has suggested various regulations, including the Digital Market Act (DMA), Digital Services Act (IDSA), and AI Act, aiming to establish consistent rules for data governance, access, and utilization. The Rulebook discusses:

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- Legislative Acts:

  The "EU Data Act" has been enacted or proposed to facilitate data sharing, access, and use across economic sectors in the EU. The EU Data Act focuses on making public sector data accessible, addressing legally protected data, and ensuring technical measures for privacy and confidentiality.

  The Data Act aims to ensure fairness in the digital environment, stimulate a competitive data market, and provide a contractual framework for B2B data sharing.

- Legal Considerations:

  Beyond specific acts, other legal aspects such as antitrust/competition, data protection, security, copyright, and intellectual property should be considered when sharing data. Ongoing regulatory developments may impact the operationalization of data spaces, requiring monitoring for compliance. Within this scope, IDSA has established a legal framework task force to discuss regulatory developments and legal topics, ensuring collaboration and contribution from its members regarding the legal dimension.

- Legal Agreements & SITRA Rulebook:

  IDSA adopts SITRA's rulebook for a fair data economy, providing contractual templates and tools for building data-sharing networks, aligned with IDS principles of sovereignty and trust. So, to have a contractual framework for data sharing in a decentralized organization and address gaps and overlaps in the current legal landscape. To do so, IDSA plans to draft additional components for contract templates for IDS based on SITRA templates, focusing on specific use cases and domain-specific terms.

2) Legal and Regulatory Reflections on the Data Governance Act (DGA) and Data Intermediaries (7):

   IDSA through the Data Governance Act (DGA) outlines regulations concerning "data intermediation services," and several key articles define and specify the scope of these services. The main discussed DGA on the position paper are:

- Article 1 DGA: Matter and scope of the DGA, including a notification and supervisory framework for data intermediation services
- Article 2 DGA: Specifies that these services aim to establish commercial relationships for data sharing between an undetermined number of data subjects, data holders, and data users through various means. Excludes specific services, such as those aggregating data for added value or focusing on copyright-protected content.

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- Article 10 DGA: Describes data intermediation services subject to notification and compliance with Article 12 DGA. Covers services between data holders and potential data users, intermediation services for data subjects, and services of data cooperatives.
- Article 12 DGA: Specifies conditions for data intermediation service providers, including limitations on the use of intermediated data, the format of data intermediated, and requirements for fair access and interoperability. Addresses aspects like fraud prevention, service continuity, cybersecurity, and breach notification.

Some of the issues that can raise is the determination of "openness," which might affect businesses striving to align with DGA regulations. Therefore, the DGA's impact on data intermediaries underscores the need for continuous dialogue and collaborative efforts to address uncertainties in this evolving Data Spaces landscape.

More details from T2.4 discussed in D2.3 is provided in section 6.1. This section covers pilots' legal compliance within Enershare (pilot 4 and pilot 7) and a summary on legislation initiatives.

3.2.5 Standardization

Expectation 19: Monitor existing standards or upcoming standards for alignment.

These standards can be partially used in Enershare pilots and integrated in a roadmap in future energy data spaces.

Expectation 20: Define specific needs in upcoming standards.

The needs will come from Enershare pilots, but also from other energy data spaces use cases, as well as from other domain use cases. These needs may lead to additional standards and or modifications to existing standards.

More details from T2.4 discussed in D2.3 is provided in section 6.2. This section covers the updates on architecture standards, interoperability and networking standards, trustworthiness standards, cybersecurity and privacy standards, and AI standards.

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3.3 Alignment

3.3.1 IDS

Ensuring data sovereignty is a central aspect of data spaces. It can be defined as a natural person's or corporate entity's capability of being entirely self-determined regarding its data. The International Data Spaces Association (IDSA) (8) proposes a Reference Architecture Model (RAM) for this capability and related aspects, including requirements for secure and trusted data exchange in business ecosystems.

In compliance with common system architecture models and standards (e.g., ISO 42010, 4+1 view model), the Reference Architecture Model uses a five-layer structure expressing various stakeholders' concerns and viewpoints at different levels of granularity.

The general structure of the Reference Architecture Model is illustrated in Figure 3. The model is made up of five layers and three perspectives that need to be implemented across the five layers.

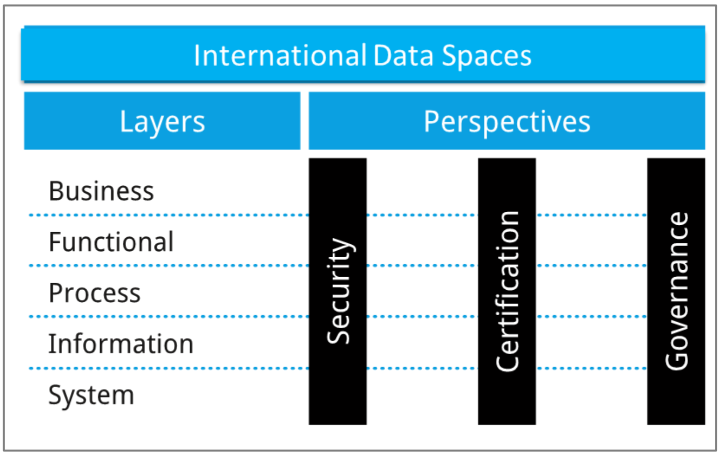

Figure 3: International Data Space (8)

For the ENERSHARE Reference Architecture described in this document, the IDSA RAM is mainly used to provide the process view and the development view for the trust and sovereignty building blocks.

More background on the IDSA and its RAM, data space role model and testbed is described in the first version of the ENERSHARE reference architecture in D2.3.

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3.3.2 Data Space Support Center (DSSC)

DSSC (9) contribute to the creation of common data spaces, that collectively create a data sovereign, interoperable and trustworthy data sharing environment, to enable data reuse within and across sectors, fully respecting EU values, and supporting the European economy and society. It explores the needs of data space initiatives, defines common requirements, and establishes best practices to accelerate the formation of sovereign data spaces as a crucial element of digital transformation in all areas.

The DSSC adopted a so-called asset-based approach to deliver user value. To better comprehend the assets within the DSSC and provide a clear understanding of them internally and externally, the asset model is utilised to depict the interrelationship between these assets (Figure 4). Some assets are part of the Data Spaces Blueprint and range from introductory information to in-depth knowledge about standards and reference implementations.

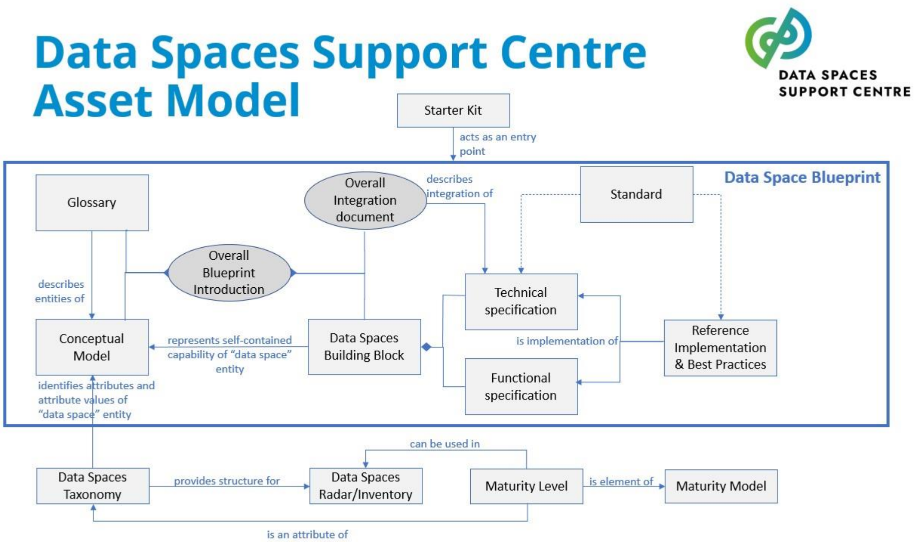

Figure 4: Data Spaces Support Centre Asset Model (9)

The following assets are available which are not specific to a single building block but rather to the overall Data Spaces Blueprint.

- Glossary: is a curated set of terms ('names' of the entities) and definitions ('criteria' enabling to check if something qualifies as an instance of the term).
- Conceptual Model: a model of the data space domain which represents the concepts (entities) and the relationships between them.
- Data Spaces Building Blocks: a basic unit or component that can be implemented and combined with other building blocks to achieve the functionality of a data space. For

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each building block specifications and reference implementations will be identified, especially for technical building blocks.

DSSC adopted the Design Principles for Data Spaces | Position Paper of OpenDEI in which 12 building blocks have been described, ranging from governance, legal, organizational, to technical building blocks on data interoperability, trust and data value. The list OpenDEI data space building blocks is displayed in Figure 5.

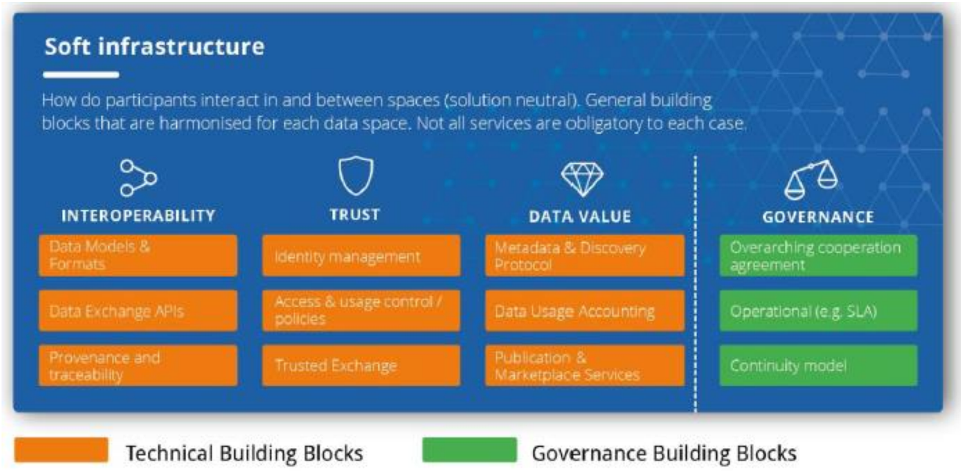

Figure 5: OpenDEI Data Space Building Blocks (10)

As shown in Figure 6, DSSC has further refined the list of building blocks. The full list includes a total of 27 building blocks.

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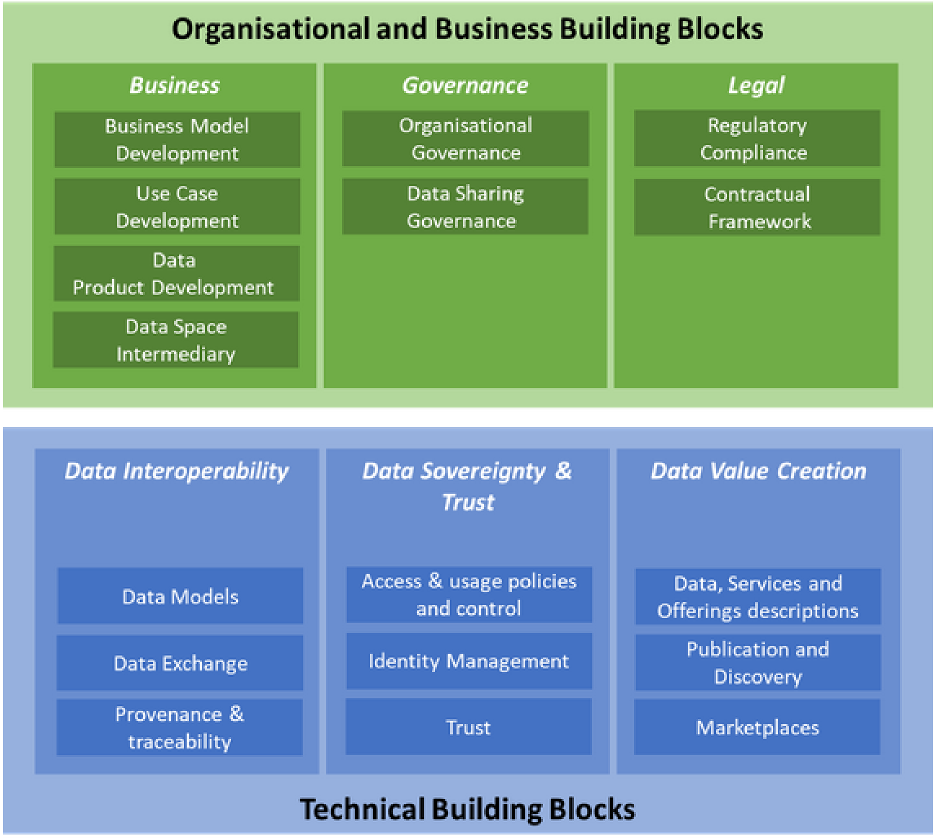

Figure 6: Overview of the Refined Building Blocks (9)

3.3.3 BRIDGE

BRIDGE is a European Commission initiative which brings together research and innovation projects focused on Smart Grids, Energy Storage, Islands, and Digitalization (11). Its primary goal is to create a structured view of cross-cutting issues in these areas. The project is financed by the Horizon 2020 and Horizon Europe programs and involves 155 projects, among which 58 are completed as of 1 July 2023. The work on the project is structured through four working groups: Data Management, Regulation, Business Models, and Consumer and Citizens Engagement; these groups collaborate on addressing key challenges and sharing best practices in their respective areas.

The project plays a significant role in fostering collaboration, knowledge sharing, and policy support in energy innovation and smart grids within the European Union. During the last general assembly, in March 2023, a focus session discussed the concept and developments related to setting up a common European data space for energy, emphasizing its importance and potential contributions.

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BRIDGE collaborates with external initiatives such as ETIP Smart Networks for Energy Transition, Smart Grid Task Force, Clean Energy Transition Partnership, and 2ZERO Partnership, allowing the BRIDGE community to stay informed about their work. Moreover, ENTSO-E and the EU DSO Entity introduced their joint preparatory work for promoting digital twins of electricity grids, emphasizing technological advancements in the energy sector.

3.3.4 GAIA-X

Gaia-X association enables the transition from disjoint data & infrastructure ecosystems, to composable, interoperable & portable cross-sector data sets (or dataspace) and services based on a framework (12). The association covers a large set of services including Energy and is based on three pillars:

- Compliance: for a common digital governance based on European values.
- Federation: enables interoperable & portable (Cross-) Sector datasets (within a dataspace) and services.
- Data exchange: A mean to perform data exchange and anchor data contract negotiation results into the infrastructure.

Gaia-X develops the software components necessary to sets up a federated system that inter-connects several Participants with each other, aiming to develop new services and innovative products.

Such ecosystems consist of joined interconnected data and infrastructure ecosystems, aggregated as 'Federators' by the concept of a Gaia-X Federation, and individually orchestrated and operated by a set of 'Federation Services' (Figure 7).

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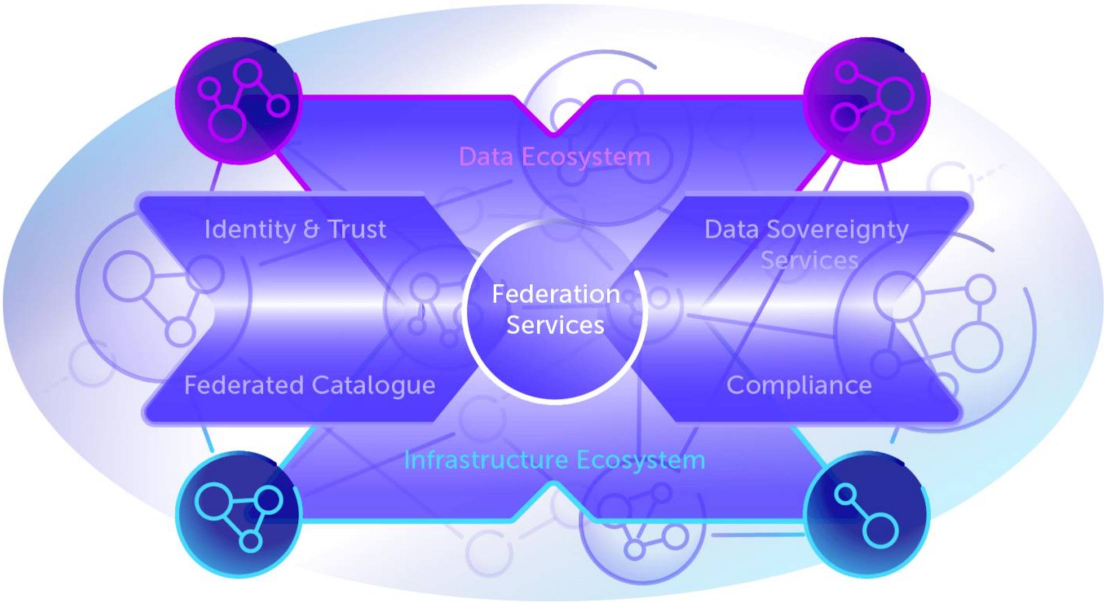

Figure 7: Federation Services (13)

The reference architecture describes concepts and is not focused on specific technologies, required to be compatible with Gaia-X participant to the Data sharing Ecosystem. In other words, Gaia-X explains the Providers, Consumers, and essential Services to interact all togethers to share data. This data space notion is that data are not stored centrally, but rather at the source. Thus, they are only transferred through semantic interoperability as necessary. These Services comprise ensuring identities, implementing trust mechanisms, and providing usage control over data exchange and Compliance – without the need for individual agreements. In term of compatible technologies:

- Identity systems standards supporting federation are OIDC/OAuth2 (draft), SAML, SPIFFE/SPIRE.
- Self-Descriptions are W3C verifiable presentations in Json-LD format. Also, verifiable Credentials themselves contain a set of Claims: assertions about Entities expressed in the RDF data model.

3.3.5 FIWARE

FIWARE Foundation curates a catalogue (14) of more than 60 open-source components for the management of data across multiple sectors including Energy. These components shared a common API, NGSI-LD, which is an open standard evolved by ETSI (15). These components include several functions. From Identity and access management (with full alignment with DSBA and Gaia-X IAM approaches) with keyrock (16), keycloak (17), AuthZForce (18), etc. To the

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gathering of information from heterogenous data sources, the context broker, with Orion-LD (19), Scorpio (20) and Stellio (21). Or for the big data processing of data, Cosmos (22) and the retrieval of information from sensor and IoT devices. The core component, the context broker allows the gathering of this information and its querying in very different ways, geographically, time series and other thanks to the NGSI-LD standard. NGSI standard is a powerful general-purpose API and its full horizontal and vertical scalability. Federation between instances of brokers allows diverse configurations and scalability options.

Besides this alignment, that is related to the implemented mechanisms for the processing of data by using shared standards there is another alignment at the semantic level. FIWARE together with IUDX, OASC, and TMForum curates more than 1000 data models, at the Smart Data Models Initiative[i] most of them in the Energy domain.

The Smart Data Models are also included in the reference architecture. They provide a quick mechanism to create standardized data models, compiling, the attribute names of the object or classes defined, the data types of the information stored in them, the written description about their content and URIs for their use in linked data-based systems. Besides this, these data models are available in a python package, pysmartdatamodels (23), that include all the information for their integration into different systems but also some functions to allow its manipulation, extracting information, validation of payloads or even the insertion of data model compliant information into NGSI-based systems

The Smart Data Models is an initiative that will remain after the end of the ENERSHARE project and therefore, provides actual standardization for the domain.

3.3.6 DSBA

DSBA (24) is the Data Spaces business alliance, an initiative to align the technical mechanisms to use data spaces. The founding members include Gaia-X, IDSA, BDVA and FIWARE. They have released two versions of a technical convergence architecture (25). This architecture is based on the compatibility between the identification and access management systems, it also deals with the trust for the data exchange and its necessary economic transactions. The identification can be done by using verifiable credentials which is compatible with the recent regulation of the EU on European Digital Identity Wallet Architecture and Reference Framework [ii].

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4 4+1 Architectural Model

To describe a software-intensive system such as the Enershare Platform, the 4+1 Architectural View Model is used (Figure 8).

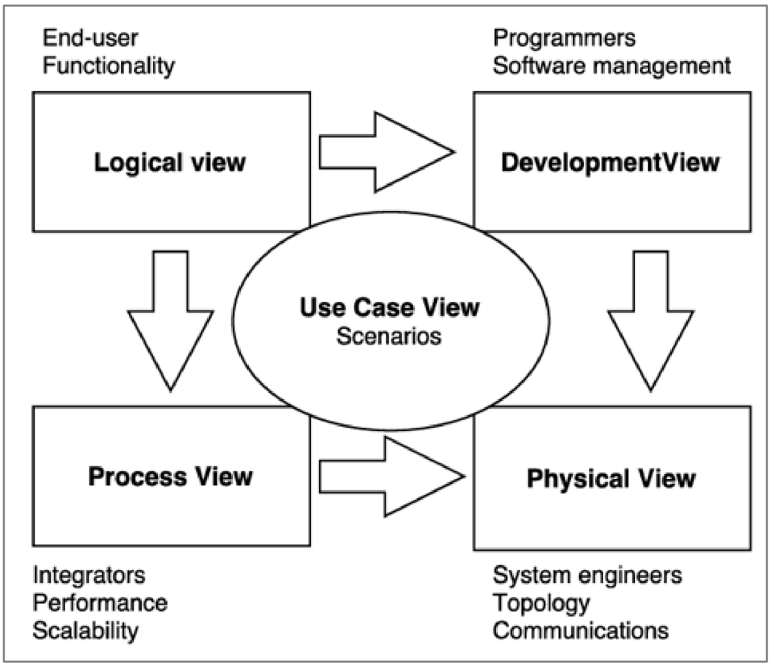

Figure 8: 4+1 View Model (4)

The foreseen stakeholders in this model are end-users, developers, system engineers and project managers.

The foreseen viewpoints include the logical view, the process view, the development view, and the physical view:

- **Logical view:** It is concerned with describing the functionality of the software to the end-user. Model kinds used to represent the logical view include *class, state,* and *object diagrams*.
- **Process view:** It deals with the communication processes of the system. It addresses non-functional concerns such as concurrency, distribution, integration, performance, and scalability. Model kinds used to represent the process view include *message sequence charts, communication diagrams, and activity diagrams.*
- **Development view:** It is also known as the implementation view and describes the system from the perspective of software module organization. Model kinds used to

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represent the development view include the *package diagram* and the *component diagram*.

- **Physical view:** It is also known as the deployment view and takes the system engineer's point of view. It is about non-functional hardware requirements regarding topology and communication. A model kind to represent the physical view includes the *deployment diagram*.
- **Scenarios:** These are a collection of use case descriptions. These use case descriptions illustrate interactions between objects and processes. This viewpoint helps in identifying architecture elements and validating the architecture design.

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4.1 Logical View

The logical view illustrates a system from an end-user's perspective and is concerned with describing the functionality of the software to the end-user. This section covers this approach by defining the Enershare blueprint for organizing components, defining interactions, and aligning functionalities. This is followed by alignment of Enershare with other dataspace models.

4.1.1 Final Reference Architecture

Enershare Data Space Reference Architecture is provided in Figure 9 and is based on BRIDGE DERA 3.0, and the deliverable 2.1 building blocks, which are in turn based on OpenDEI. A description of each building block is also provided in deliverable 2.1.

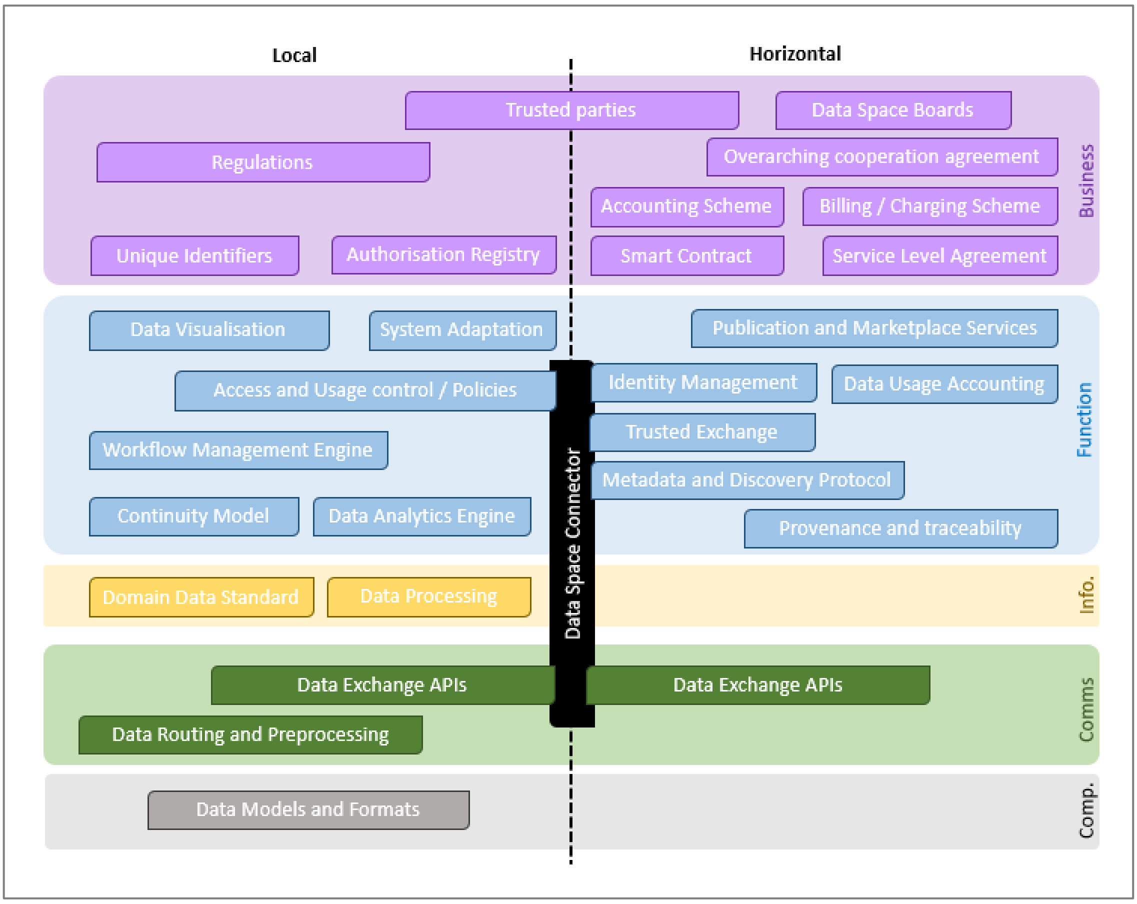

Figure 9: Enershare Data Space Reference Architecture

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The five horizonal layers include the Business, Function, Information, Communication and Component Layers. The vertical split distinguishes between local building blocks that facilitate the functionalities local to a use case, and the horizontal building blocks that allow requirement-abiding participation in the Data Space. The Data Space Connector integrates the local systems with the horizontal domain into the Data Space.

The building blocks are identified based on the use case descriptions and the process described in D2.1 to implement the process steps within the scenarios, information handling or fulfilment of requirements in the pilot use cases. According to the use cases within Enershare, there is a strong focus on data and trusted exchange. Data used in the use cases should include data models and formats, possibly be aligned with domain data standards, and enriched with metadata and discovery mechanisms through publication services and marketplaces.

Trusted exchange makes use of the identity management within the data space and the access and usage control and policies and will be implemented across all use cases. These building blocks form the core of the requirements from the current bottom-up use case perspective.

4.1.2 High-Level Software Architecture

The main aim of this section is to provide a high-level system architecture based on the information regarding the involved subsystems and components as building blocks of Enershare data space, as well as their interdependencies. To achieve this, inputs from WP3, WP4, WP5, WP8 and related deliverables (D3.1, D4.1, D5.1, and D8.1) have been gathered and displayed in Table 5.

Table 5: Enershare Core Components

	Component	Functions	Software details
WP3	**Open Energy Ontology (OEO)**	Data modelling	OWL, Turtle, RDF/XML
	Visualization Portal	Graphical representation of the class hierarchy in ontologies; access and query to data models; documentation	Web UI and triple store with SPARQL endpoint Java
	Vocabulary Hub	Vocabulary registry for overview of existing and used models in the dataspace Wizard for ontology model-driven API design for data exchange use cases.	Web application (PHP+JS+HTML) containerized with DockerTool that exports yaml files Java, Docker

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	IDS based Common Open API specification	OpenAPI specifications to configure a data space connector	Rest services
	Interoperability services	Services for data harmonization and for process scheduling	Java
	Mashup Editor	Data harmonization and data transformation	
	Context broker	Sharing last value data among multiple stakeholders, with real time notifications	Rest services
WP4	**TNO Security Gateway (TSG)**	Secure peer-to-peer data exchange with IAA (Identification, Authentication, Authorization). See IDS RAM 3.5.2	Written in Kotlin, built into Docker images. Default deployment based on Kubernetes & Helm. https://gitlab.com/tno-tsg/core-container https://gitlab.com/tno-tsg/helm-charts/connector
	Identity provider (CA + DAPS)	CA: issues identity certificates for connector instances by signing Certificate Signing Requests (CSRs) that have been handed in by valid connector instances. It revokes certificates that become invalid and, for higher trust levels, assure that private keys are properly stored in hardware modules (such as a TPM or HSM) DAPS: provides dynamic, up-to-date attribute information about Participants and Connectors in form of signed claims and embeds them into Dynamic Attribute Tokens (DATs).	IDS-testbed/CertificateAuthority at master · International-Data-Spaces-Association/IDS-testbed (github.com) International-Data-Spaces-Association/omejdn-daps: Open Source implementation of the Dynamic Attribute Provisioning Service based on http://github.com/Fraunhofer-AISEC/omejdn-server

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WP5	**App Store**	Platform that integrates with the IDS ecosystem to visualize and distribute DApps to be used in IDS connectors. Main functions: - Link with IDS components. - Distribution of DApps; - Federated use of DApps for multi-subdomains. - Dapp registration - Dapp publication - Dapp Metadata publication - TBD: visualization of vocabularies	-Docker Registry and integration with docker engine -One ref implementation of an IDS connector -backend (java) -frontend (angular) -backend database (postgresql)
	TSG Metadata Broker Implementation of IDS Metadata Broker. See [IDS RAM 3.5.4]	Registration, publication, maintenance, and querying of IDS Self-Descriptions. A Self-Description encapsulates information about IDS Connector itself and its capabilities and characteristics. This Self-Description contains information about the offered interfaces, the owner of the component and the metadata of the data offered by the component.	Written in Kotlin, built into Docker images. Default deployment based on Kubernetes & Helm. Acts as Data App on top of a TNO Security Gateway (provided in WP4). Will be provided under Apache 2.0 license.
	Clearing House Module This module will perform any clearing and settlement services considering blockchain-based developments	Clearing & settlement services Data transaction logging Billing or conflict resolution will be available as per demo specifications.	To be defined within architectural concept whether a purely decentralized Clearing house will be rendered or a blockchain based approach (M28)
	Tokenized P2P multi-asset Marketplace	It provides functionalities for the user account management, for publishing and purchasing assets, for auction management. Through the Marketplace GUI, it is possible to register to the ENERSHARE Marketplace and take advantage of the	Web application: JAVA, React Typescript, Bootstrap, Maven

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		functionalities it offers through the Marketplace Core and through IDS ecosystem components (AppStore, Metadata Broker, Clearing House, Connectors).	PostgreSQL Docker
	Blockchain	This module manages the virtual currency of the marketplace and allows the automatic reward to the owner in a distributed way. Moreover, it manages all the transactions that take place between a provider (seller) and a consumer (buyer) in the Marketplace.	Solidity Ethereum

Each of these components will be implemented through the planned releases (Based on release planning mentioned in section Deployment View). Based on the overall system structure and interactions between different components, the following final image (Figure 10) is provided as the high-level software architecture.

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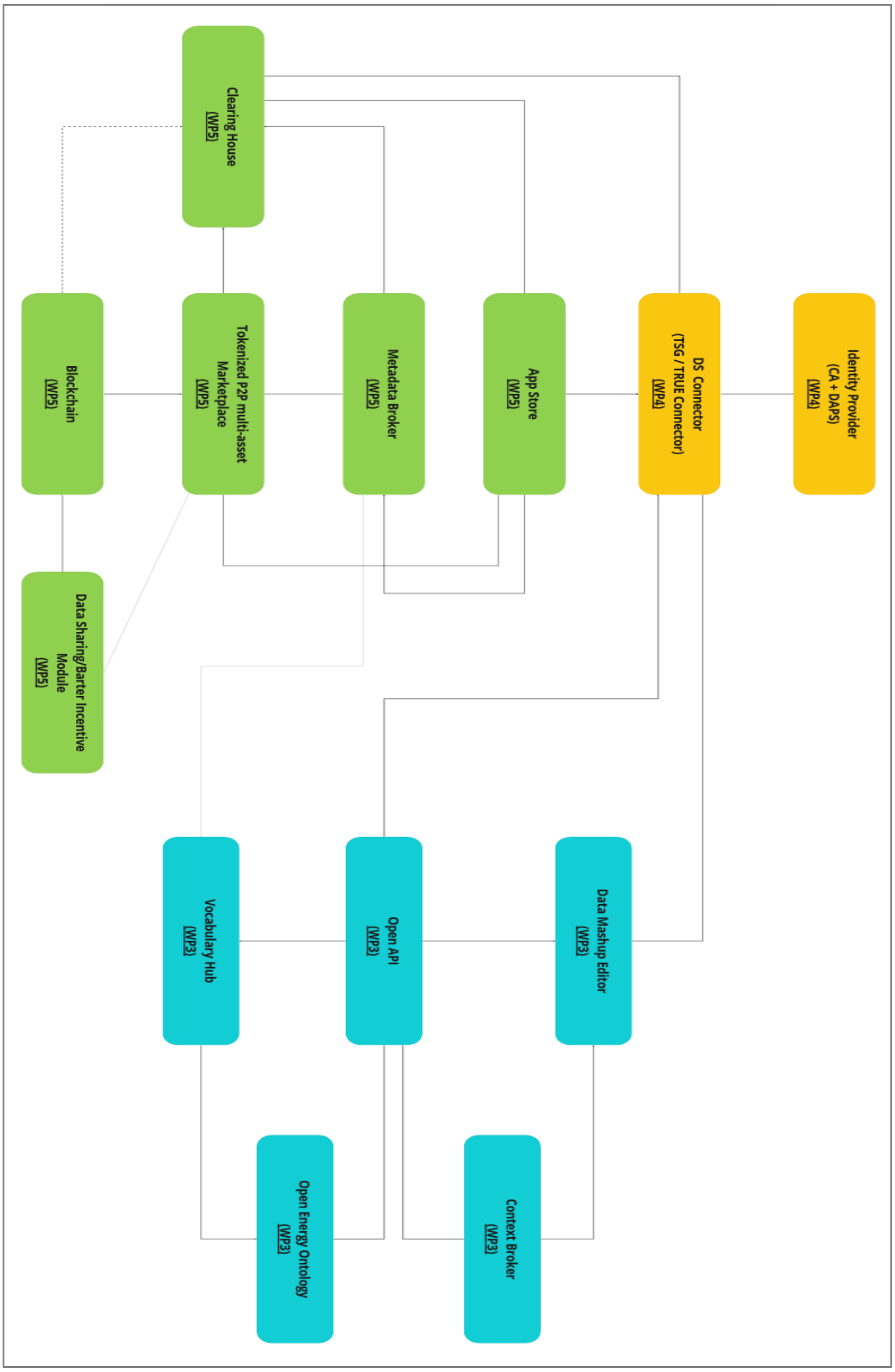

Figure 10: High-level Software Architecture

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4.2 Development View

The development view which is also known as the implementation view illustrates a system from programmers’ perspective and is concerned with describing the software module organization. This section covers this approach by defining the fundamental elements that constitute the core of Enershare. In parallel, the interactions among these core components are elucidated within the development view, providing a comprehensive understanding of the system's evolution.

In addition, a comprehensive table delineating the correspondence between the building blocks and components is presented in Section 6.3. It is imperative to note that the current iteration of this table is not considered final and remains subject to potential revisions as the ENERSHARE system undergoes future development. Continuous refinement and updates to this mapping table are anticipated to align with the evolving nature of the ENERSHARE system.

For additional insights into the content of this section, we recommend consulting the finalized versions of deliverables within WP3, WP4, and WP5, specifically referencing documents D3.3, D4.3, and D5.3. These deliverables are expected to provide comprehensive details and serve as authoritative references for a deeper understanding of the information presented in this section.

4.2.1 Data Space Interoperability

Data Space interoperability deals with the capabilities needed for the exchange of data: (semantic) models, data formats and interfaces (APIs). This also includes functionalities for provenance & traceability.

According to the Data Spaces Support Centre's Blueprint Version 0.5 (26) published in October 2023, the data interoperability pillar consists of the following building blocks (BB):

1. Data Models: capabilities to define and use shared semantics in a data space
2. Data Exchange: capabilities relating to the actual exchange and sharing of data
3. Provenance and traceability: capabilities for tracking the process of data sharing, so it becomes traceable and compliant.

WP3 in ENERSHARE is providing the BBs for data models and data exchange.

Figure 11 shows how these components interact among themselves and with other ENERSHARE components.

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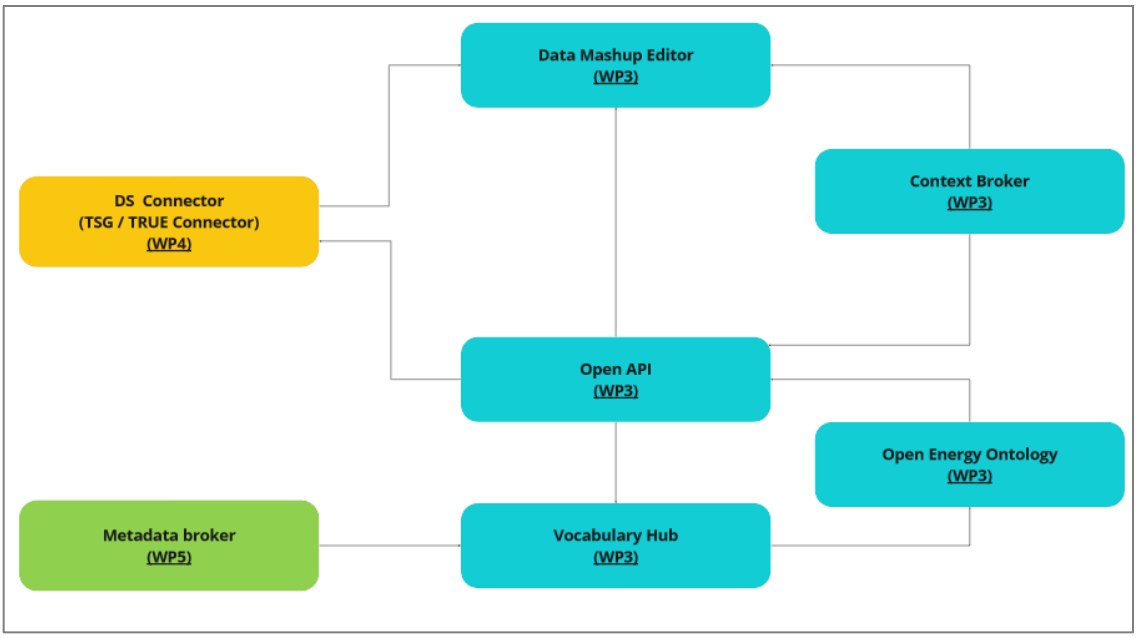

Figure 11: Interoperability Components and Interactions

Data Models and Formats

The Open Energy Ontology provides the common and domain-specific vocabulary to facilitate semantic interoperability in the Energy Data Space.

The Energy Vocabulary Hub component (27), provides facilities for publishing, browsing, and maintaining vocabularies related with the energy domain. One of these vocabularies is the Open Energy Ontology.

In case the ontology is not covering some of the needs of the project an agile standardization will be put in place. This approach allows the creation during project execution of new data models to allocate the new potential needs. Besides this, those models can be curated after project''s end by the Smart Data Models initiative (28).

Data Exchange

The Data Space Protocol distinguishes between a control plane and a data plane. The control plane is responsible for deciding how data is managed, routed, and processed, whereas the data plane is responsible for the actual moving of data.

The data plane is responsible for the actual transmission of data and is coordinated by the data space connectors. The Open APIs are part of this data plane and describe the specific interface specification to share data to foster interoperability. They provide the API methods/operations/calls and the format of the payload.

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For this purpose, the Energy Vocabulary Hub component provides a wizard and editor to facilitate the creation of the Open APIs. These Open APIs define how to formalize the data to be exchanged in the payload of the messages transferred between data providers and data consumers using IDS connectors or through the Context Broker. The Vocabulary Hub enables data space participants to export these Open APIs in various formats, such as e.g., JSON, JSON-LD, or RDF/XML.

The Metadata Broker contains an endpoint for the registration, publication, maintenance, and query of Self-Descriptions. These Self-Descriptions, which can be seen as metadata, encapsulate information about the IDS Connectors and their capabilities and characteristics. Among this information, we have the data model to which the inputs and outputs of the IDS connector need to comply with. These Self-Descriptions are linked to the Energy Vocabulary Hub through the DCAT-AP property "conforms to".

Finally, one of the challenges that the data provider needs to face in order to exchange data in the data space, is that the data format needs to be transformed to comply with the Open APIs specification. The Data Mashup editor allows defining the pipelines that need to be executed to make these transformations. These pipelines are then executed at runtime by the IDS connector or by the client that published data to the Context Broker.

4.2.2 Trust and Sovereignty

To provide for trust and sovereignty in the ENERSHARE dataspace the following components are included in the architecture and displayed in Figure 12:

- A data space connector
- An identity provider
- Usage policy engine (extension of connector)
- A distributed ledger / blockchain

These components are described in full detail in ENERSHARE D4.1 and D4.2. These components are at the core of the data space and part of the first technology release of the ENERSHARE data space as described in D8.2. The components are described at high level in the section below.

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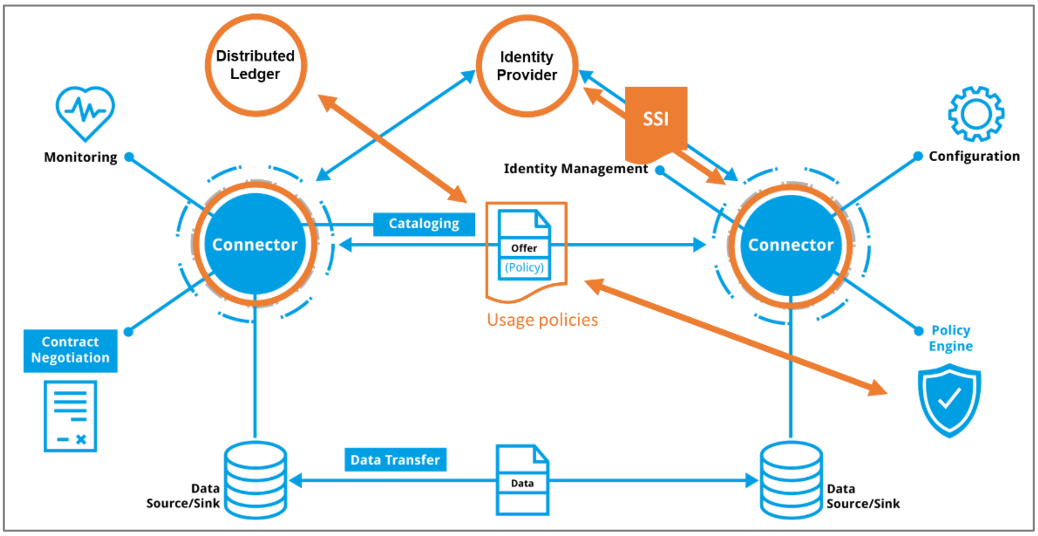

Figure 12: Overview of Trust and Sovereignty Components (picture adapted from Dataspace Protocol v0.8)

Data space connector

A data space consists of a network of parties and IT systems. In the International Data Spaces Reference Architecture Model (IDS-RAM) this network is formed by connectors. In other words, each component or service in a data space is represented by a connector.

A connector allows and enables the exchange of data within a data space. It provides a few core functions that are extended with business logic inside a data app. Among the Connector Core Service(s) are the means for Authentication, Contract Negotiation and Trusted Data Exchange.

Identity provider

To be able to make access control related decisions that are based on reliable identities and properties of participants, a concept for Identity and Access Management (IAM) is mandatory. To access resources in the data space, aspects of identification (i.e., claiming an identity), authentication (i.e., verifying an identity), and authorization (i.e., making access decisions based on an identity) need to be defined.

The Identity Provider consists of three complementary components: Certificate Authorities (CAs) issue and manage technical identities, the Dynamic Attribute Provisioning Service (DAPS) provides short-lived tokens with up-to-date identity claims about connectors, and the Participant Information Service (ParIS) provides business-related information of IDS Participants in machine- and human-readable manners.

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For the first technology release the architecture contains a centralized DAPS to issue and verify identity claims. For later release(s) the project explores the possibility to replace this centralized component by means of Self Sovereign Identity (SSI) concepts and technology.

Usage policy engine

Effective usage control is critical for companies and systems as they protect privacy, maintain data integrity, and guarantee regulatory compliance. Organizations may achieve an appropriate balance between authorizing allowed data usage and protecting individuals' privacy rights by carefully designing and enforcing the policies.

Usage control provides data space participants the ability to enforce architectural designs that respect data sovereignty, ensuring that no violations occur. Furthermore, by implementing usage control mechanisms, data flows are closely monitored, serving as an audit mechanism that generates evidence of compliant data usage. There are specific requirements for data sovereignty that cannot be fulfilled through traditional access control methods

Usage policies are considered part of the data service offering and are agreed upon before the data exchange takes place. This agreement can be stored on the distributed ledger (next paragraph) for compliance and traceability purposes. Policy enforcement is the responsibility of the data space connector.

Distributed ledger

This distributed ledger component provides functionality for the notarization of usage policies. As best practice, the blockchain should be used to register only encrypted data (technically speaking, the digest of a cryptographic function, commonly referred as “hash”), also considering the impossibility of deleting block data once transactions are confirmed. The usage policy can be verified for its integrity by means of the blockchain itself. This provides the necessary level of privacy and anonymity of data, as well as security and reliability of the data exchanged.

The distributed ledger component also facilitates functionalities in the ENERSHARE marketplace, see next section.

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4.2.3 Data Service and Marketplace

The components of the ENERSHARE Marketplace are depicted in Figure 13.

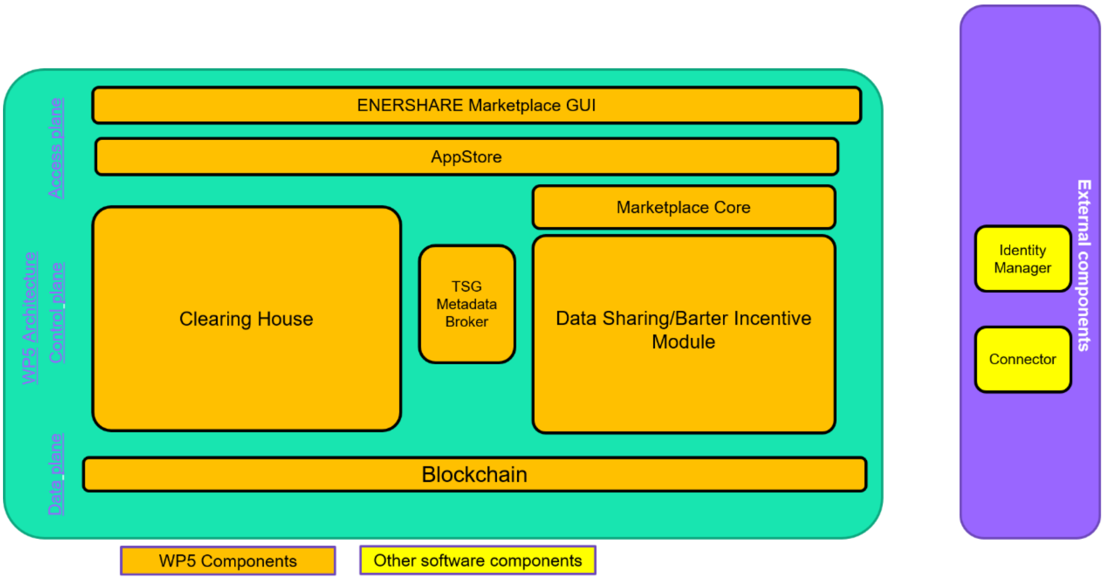

Figure 13: ENERSHARE Marketplace Architecture

Marketplace GUI represents a graphical user interface that provides access to the Marketplace. Through the GUI, users sign up to the marketplace and take advantage of the functions it offers through the Marketplace Core module.

The Blockchain component manages a custom ENERSHARE token and use smart contracts to exploit the functionality offered by the blockchain. The use of smart contracts in conjunction with a custom token would allow token crediting policies to be defined for Marketplace Participants to incentivize asset sharing in the Marketplace. Moreover, smart contracts are used to generate receipts containing the main information attached to the transaction that took place in the Marketplace between provider and consumer.

The Data Monetization and Barter Sharing Incentive Module facilitates precise forecasting of energy production from renewable sources for an efficient energy management and for ensuring grid stability. Collaborative forecasting capabilities based on data Marketplace promote cooperation among various data owners and improve the overall quality of energy forecasting. By leveraging advanced machine learning algorithms, this module facilitates the buying and selling of energy production data indirectly through the application and computation of collaborative forecasting services.

The ENERSHARE Marketplace also includes the following International Data Space (IDS) components:

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- Metadata Broker, which acts as a mediator between providers offering data/data service and users requesting data/data service. It is a data/data service source registry.
- Clearing House: it bases all its functions on a logging service that records information relevant for clearing and billing as well as usage control.
- AppStore, which is a registry for IDS Apps. IDS Apps (mainly Data Apps) are independent, functional, and re-usable software assets that is deployable, executable, and manageable on an IDS Connector. The AppStore also features the capability to search for IDS Apps using different search options.

Data/data service results bought in the Marketplace are exchanged by producers and consumers through their IDS Connectors.

4.2.4 Integration

4.2.4.1 MVP/IDS Testbed Description

According to IDSA specifications the IDS Testbed (29) is a setup with Open-Source IDS components which can be used to verify that a component:

- implements the IDS specifications for establishing connections and communication.
- and, thus, can work interoperable with all IDS components in the testbed setup.

As such, the IDS reference testbed is an open-source setup with IDS components that has been jointly developed by the IDSA open-source community. The testbed enables companies and organizations to develop IDS-compliant components and test them on their interoperability. It is also a preparatory tool for the IDS certification. This capability adheres to the communal goal of the IDSA to unleash the potential of the data economy through data sovereignty and trusted data sharing in data spaces. The testbed enables the large-scale adoption of IDS components needed to bring this reality to fruition.

Testbed advantages

The testbed makes it possible to experience the component's behavior in an IDS infrastructure in real-time. As such, it is the perfect way to put a use-case to the test and prepare component for IDS certification. The testbed is publicly available and contains the essential IDS infrastructure setup (CA, Daps, Meta Data Broker and connectors). Any company or organization that has developed IDS components can employ them in the testbed to check their interoperability and compliance with the IDS Standard (30).

Based on the above we can summarize the IDS testbed scope:

1. Component behavior testing
2. Interoperability testing against IDS components (Connector, DAPS, CA, Metadata Broker)

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3. Preparation for IDS Certification
4. Starting point for creation of Data Spaces

This setup (Figure 14) can also be used as a MVDS (Minimum Viable Data Space) that is a QuickStart to sharing data in a secure and sovereign way.

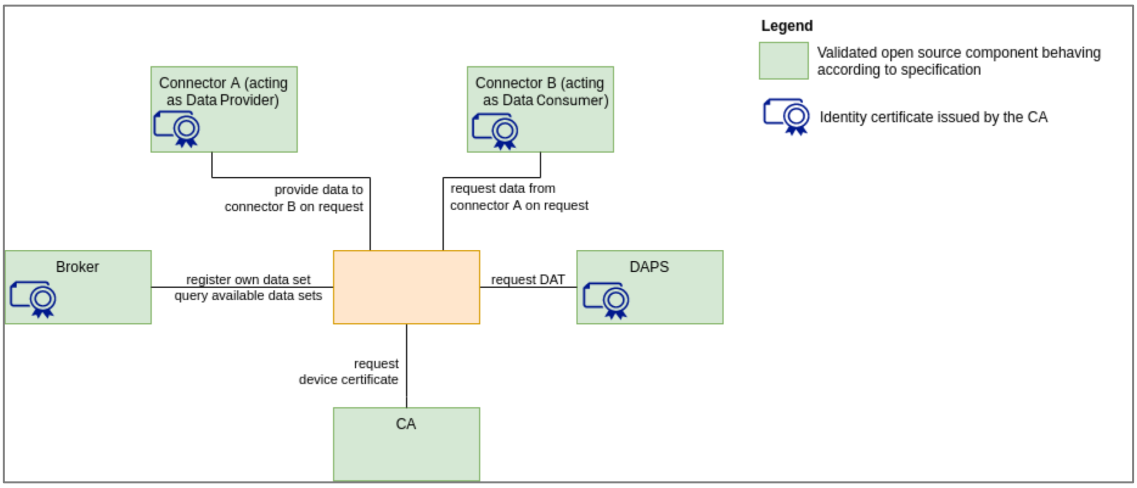

Figure 14: IDS Testbed Current Version (Minimal Setup) (31)

As of January 2024, the current version of the IDS-Testbed is v1.0 and is made up of the following components:

- Certificate Authority (CA)
- Dynamic Attribute Provisioning Service (DAPS) v1.6.0
- Metadata Broker (MDB) v5.0.3
- Dataspace Connector (DSC) v8.0.2 as Connector A
- Dataspace Connector (DSC) v8.0.2 as Connector B

Connectors work as a bridge between data consumers and providers and the Data Space, allowing communication and data transfer between all parties and ensuring that the data exchange is governed by the principles of security, privacy, and trust.

The Metadata Broker acts as a central repository for the publication and discovery of metadata about the data resources available in the Data Space, ensuring that metadata is organised, standardised, and updated appropriately.

The Certificate Authority is responsible for issuing and managing digital certificates, which are used to verify the identities of the participants involved in the data exchange. This ensures the authenticity and integrity of the data.

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Finally, the Dynamic Attribute Provisioning Service works together with the Certificate Authority and provides the necessary protocols and interfaces for secure and controlled data access.

Similarly to what has just been described, an ENERSHARE Testbed setup is under development and will provide support for the integration of the ENERSHARE software components, such as the Marketplace, the Clearing House and the App Store, offering an installation of basic components and features, such as the True Connector, the TSG Connector, the TSG Metadata Broker and the TSG Identity Provider (working as both Certificate Authority and DAPS), with the ultimate goal of ensuring secure and reliable data exchange and compatibility among Data Space components.

4.2.4.2 Integrated UI/UX

User Experience (UX) and User Interface (UI) design are essential tasks which will play a pivotal role in the development of effective digital products and services in the ENERSHARE context. Although UX and UI are frequently discussed in tandem, they encompass separate facets of the design process, each with its unique emphasis and goals. By comprehending UX and UI design processes we aim to shape an outstanding user experience for Enershare.

User Experience design generally revolves around elevating user contentment through the enhancement of a product or service's usability, accessibility, and overall enjoyment during interaction. It embraces a comprehensive perspective that considers the complete user experience journey, spanning from the initial discovery stage to the ultimate interaction.

Enershare UX design and implementation principles:

- User-Centered Approach: UX design will place the user at the core, emphasizing the understanding of user needs, goals, and behaviors.
- Usability: Enershare digital products will be easy to use and navigate, providing intuitive interfaces, and minimizing cognitive load.
- Accessibility: Designing inclusively to accommodate users with varying abilities and providing equal access to information and functionalities.
- Consistency: Enershare will maintain a consistent experience across different touchpoints to create familiarity and reinforce user expectations.
- Delight: Adding elements of surprise, delight, and emotional connection to create memorable experiences.

User Interface design concentrates on the visual and interactive components that users directly interact with, with the goal of fashioning visually appealing and user-friendly interfaces. This entails shaping the visual aesthetics, typography, color palettes, iconography, and interactive features such as buttons, forms, and navigation menus.

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Enershare UI design and implementation principles:

- Visual Hierarchy: Enershare UI will attempt to organize information in a way that guides users' attention, prioritizing content based on importance and relevance.
- Consistency: UI will establish a cohesive visual language with consistent styling, branding, and design patterns throughout the interface.
- Clarity and Simplicity: UI will present information and interactions in a clear and concise manner, avoiding clutter and unnecessary complexity.
- Responsiveness: UI interfaces will adapt seamlessly to different screen sizes and devices, ensuring a consistent experience.
- Feedback and Affordance: Through Enershare user actions will be assisted by visual feedback and familiar visual cues which will communicate functionality and interactivity.

While Enershare UX and UI design have different goals, they will be interrelated and rely on each other to deliver a unified user experience. UX design serves as the foundation, shaping the product's structure, flow, and functionality, while UI design breathes life into it by ensuring an aesthetically pleasing and user-friendly interface. Enershare UX design process involves a series of activities such as user research, the creation of user personas, defining user flows, wireframing, prototyping, and usability testing. These activities establish a robust groundwork for crafting user interfaces that effectively cater to user needs and align with their thought processes. Conversely, Enershare UI design transforms the UX design into visual elements, encompassing aspects like typography, color schemes, and interactive components. It requires meticulous attention to detail, maintaining visual consistency, and a profound understanding of the brand identity to construct an engaging and visually coherent interface.

By seamlessly integrating UX and UI design, Enershare implementation will create exceptional user experiences that not only fulfill user expectations but also elicit positive emotions, instill trust, and boost user engagement. Recognizing the roles and significance of both UX and UI design is crucial for aspiring designers as it equips them to collaborate efficiently, iterate on design solutions, and ultimately forge impactful and delightful digital products and services.

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4.3 Process View

The process view illustrates a system from an integrator's perspective and is concerned with the dynamic behavior of the system. This section covers this approach by providing a sample communication process within IDS RAM. This is followed by the process view that deals with the dynamic aspects of the ENERSHARE Marketplace and explains the system processes, and how they communicate.

4.3.1 IDS RAM

The IDS Reference Architecture Model uses a five-layer structure, as depicted in Figure 15:

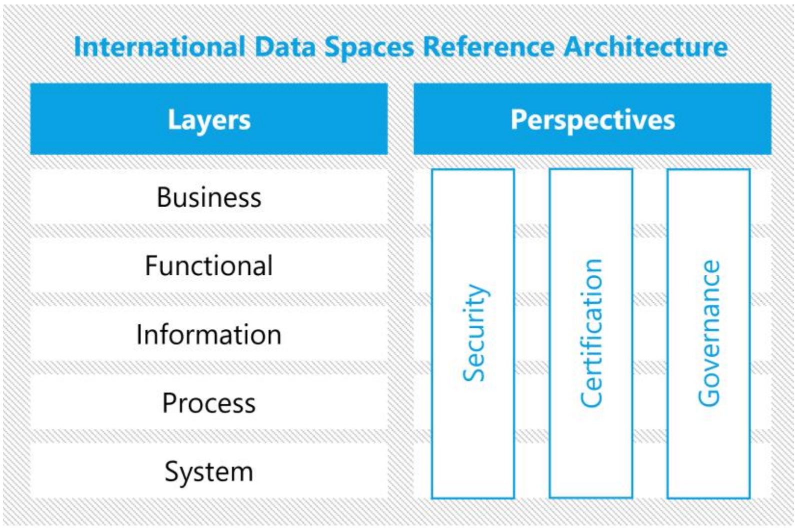

Figure 15: General Structure of the IDS Reference Architecture Model (8)

The process layer provides a dynamic view of the IDS RAM, by specifying the interactions between the different components. The following processes are relevant for ENERSHARE, as they describe the interactions of some of the components that will be implemented by the technical work packages (32).

4.3.1.1 Onboarding

The 'Onboarding' process encompasses two preliminary steps that an organization must complete to function as either a Data Provider or Data Consumer within the International Data Spaces:

1. Registration and certification of the organization.
2. Procurement of a certified IDS connector.

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Once these prerequisites are met, an organization can establish multiple IDS connector instances through the following actions:

1. Provisioning and configuring the connector.
2. Setting up its availability.

A visual representation of these essential steps is presented in Figure 16.

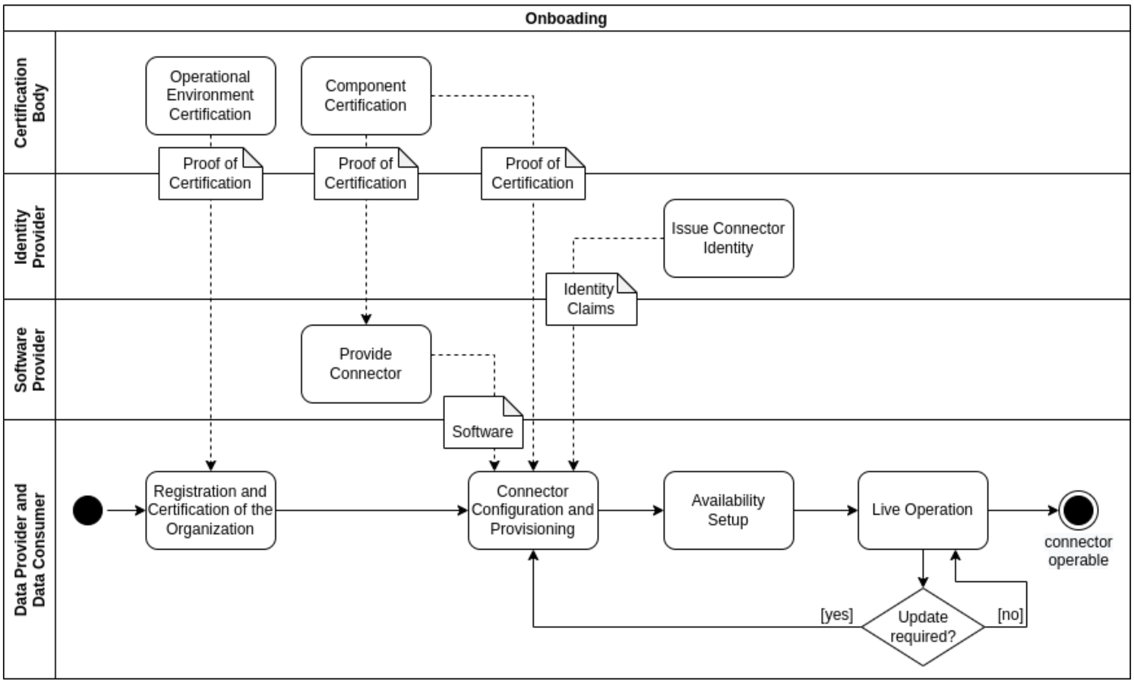

Figure 16: Onboarding Process

4.3.1.2 Data Offering

This process explains how data artifacts are made available to potential Data Consumers within the International Data Spaces (IDS). It outlines two scenarios: one where the Data Provider knows the Data Consumer from the outset and directly shares information about data assets, and another where the Data Provider doesn't initially know the Data Consumer. In the latter case, proper description and advertisement are crucial. The IDS offers a solution by defining a technology-agnostic language for data Self-Descriptions and the necessary infrastructure for hosting and searching these descriptions. The Data Provider remains the authoritative source of information, and any changes to Self-Descriptions are limited to specific cases such as correcting errors or complying with regulations. The IDS Information Model provides a schema for Self-Descriptions and their components, promoting semantic interoperability in Data Spaces through domain-specific vocabularies and application profiles. The Data Provider can send Self-Description documents to an IDS Metadata Broker. Usually, representations of the RDF classes

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ids:Connector and ids:Resource are used. The IDS Metadata Broker then checks the Self-Description syntactic correctness and persists it in its local database, as shown in the Figure 17:

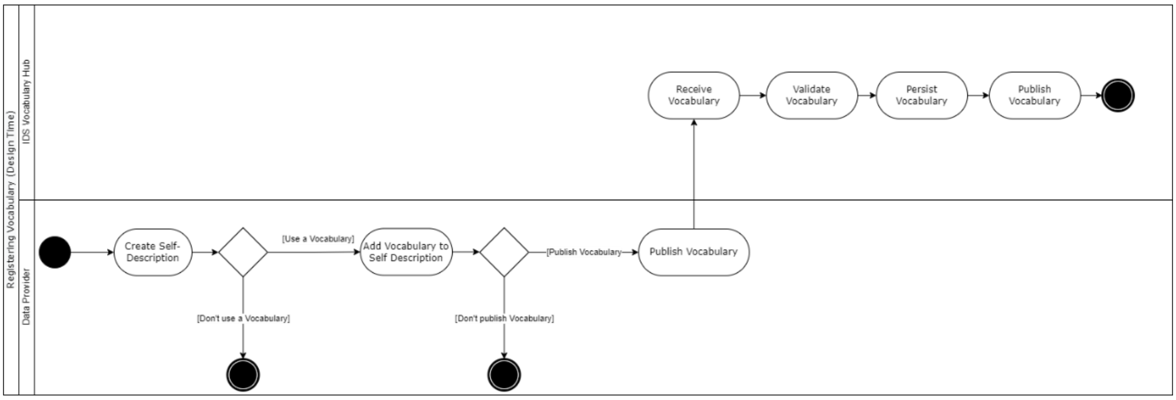

Figure 17: Register Self-Description at IDS Metadata Broker

To locate a Data Provider, a Data Consumer can search within IDS Metadata Brokers, selecting one based on thematic coverage and query capabilities. As depicted in Figure 18, the broker provides query results, potentially filtered based on usage policies, and the Data Consumer must interpret these results to identify suitable data sources. Each result includes information about IDS Connectors, enabling the Data Consumer to access their Self-Descriptions and choose an appropriate data offering from the Data Provider, which may offer the same data in different formats or pricing options.

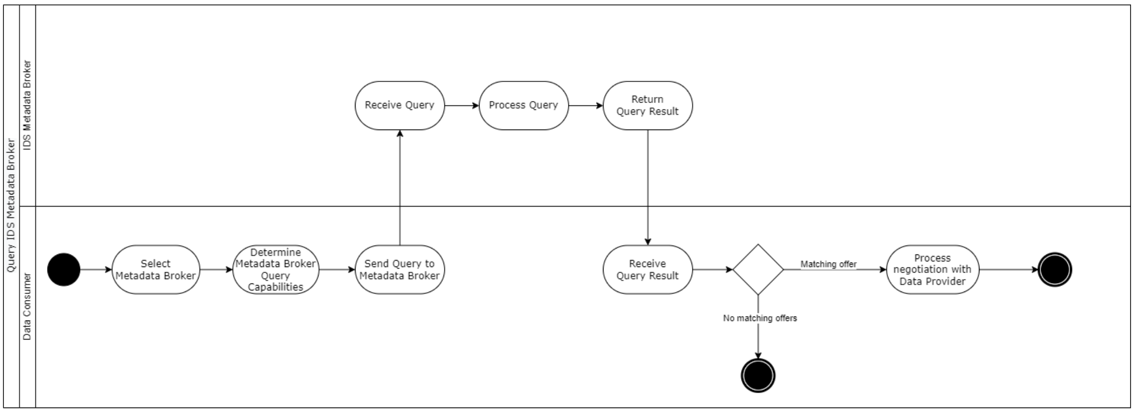

Figure 18: Query IDS Metadata Broker

4.3.1.3 Contract Negotiation

Connector Self-Descriptions provide information about available data assets, including Usage Control details within a Contract Offer, specifying the conditions under which the Data Provider shares data. The negotiation involves an automated process within IDS Connectors, leading to

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a Data Usage Contract (or Contract Agreement) between the Data Consumer and Data Provider. The sequence diagrams elaborate on this negotiation process (Figure 19).

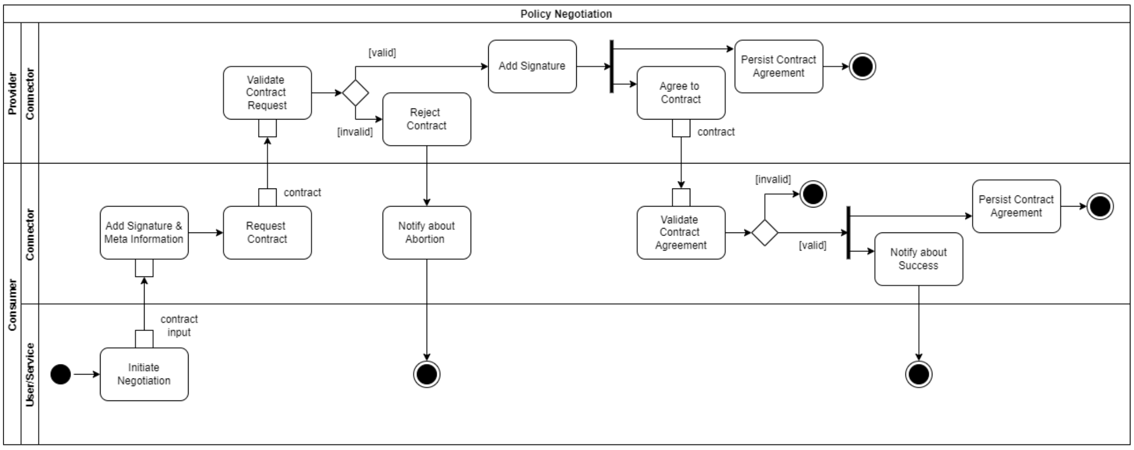

Figure 19: Simple Contract Negotiation

In some data spaces, Contract Requests or Offers may require Clearing House approval for added trust or compliance. Upon successful validation, the Data Provider stores the Contract Agreement and sends it to the Clearing House. The Clearing House verifies both signatures and adds its own before returning the triple-signed Contract Agreement to the Data Consumer for content verification. This process is depicted in the Figure 20:

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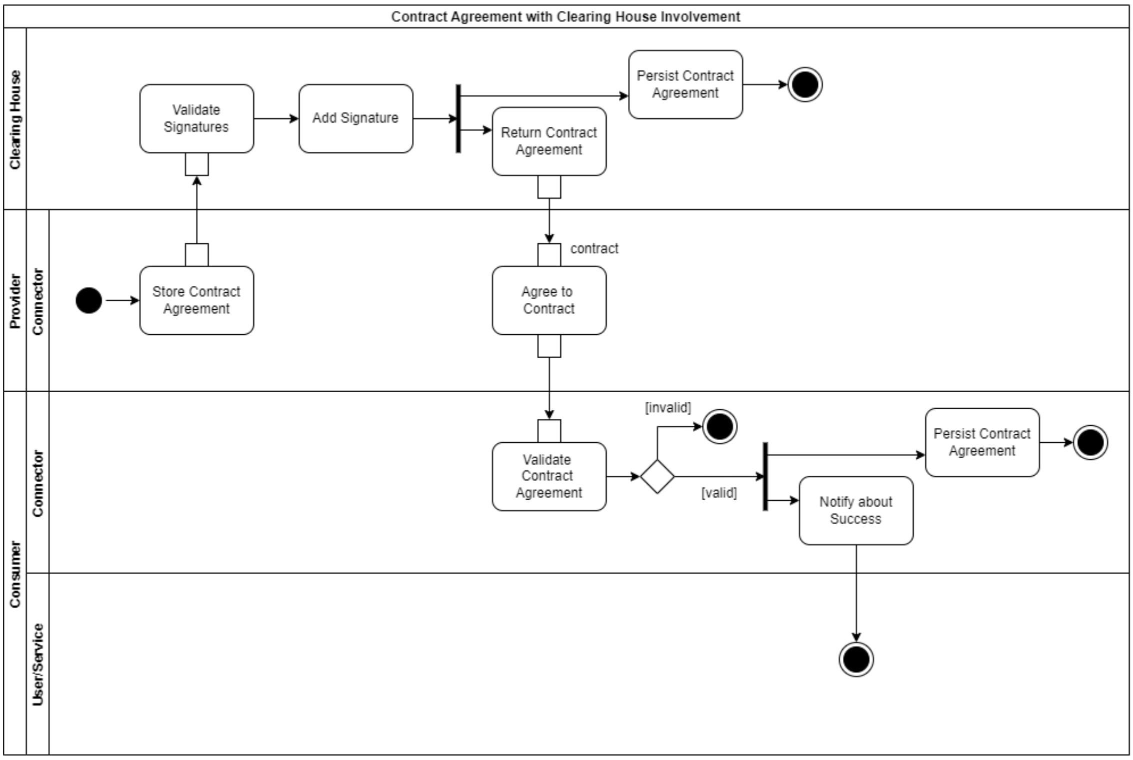

Figure 20: Contract Agreement with Clearing House Involvement

4.3.1.4 Exchanging Data

Following successful Onboarding, a Data Consumer or Provider's operations consist of the Control Phase and the Transfer Phase. As displayed in Figure 21, in the Control Phase, both parties go through processes like Data Offering and Contract Negotiation using an IDS-specific communication protocol defined in IDS-G. In the Transfer Phase, if these processes are successful, they can commence data exchange by invoking Data Operations (e.g., data upload or download) via their IDS Connectors, with details described subsequently.

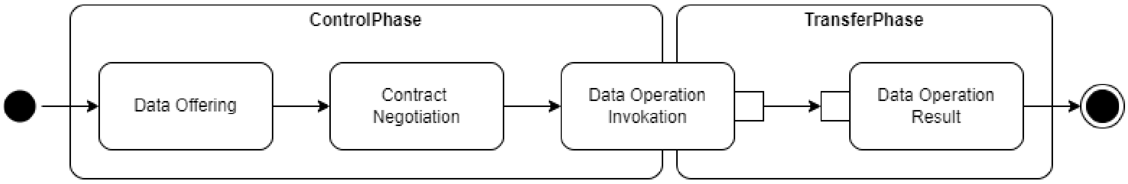

Figure 21: Communication Phases

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4.3.2 ENERSHARE Marketplace

The process view deals with the dynamic aspects of the ENERSHARE Marketplace, explains the system processes, and how they communicate.

Use case diagrams are a powerful tool for process modeling, as they help you visualize the interactions between the users and the system. As an example, Figure 22 represents the main processes the seller (provider) and the buyer can do in the Marketplace respectively for selling or buying an asset. The Seller, who has already an account on the Marketplace, publishes the asset she/he wants to sell, namely dataset, data service, Apps, charging station availability, and then, the buyer may buy the asset he needs. The buyers may rate the assets, or the sellers and the sellers may visualize the ratings for their assets or the rating for herself/himself. Both seller and buyer may visualize their transactions.

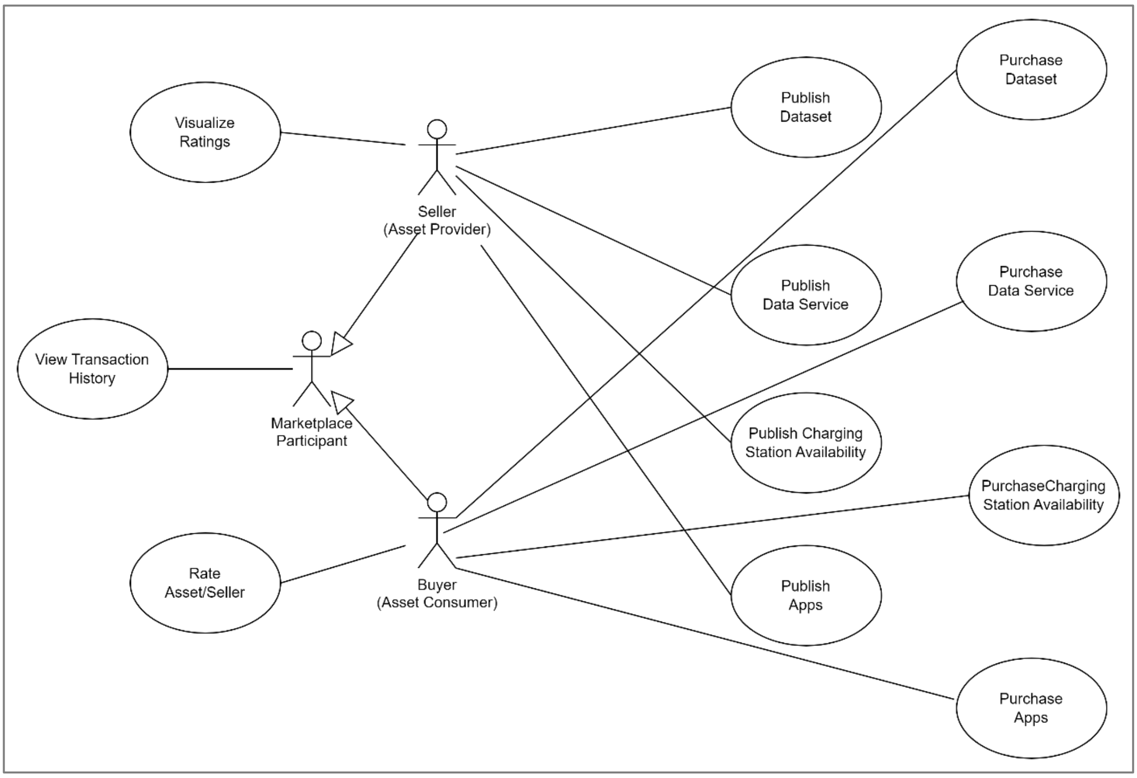

Figure 22: Publishing/Purchasing Asset

UML sequence diagrams are used to represent the process view. Some examples of main processes of the are represented in the sequence diagrams below. The sequence diagram depicted in Figure 23 describes the (Marketplace Participant as Seller) publishing dataset. The sequence diagram depicted in Figure 24 describes the (Marketplace Participant as Buyer) purchasing dataset.

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All the use case diagrams, and sequence diagrams related to the ENERSHARE Marketplace will be presented in the deliverable 5.2.

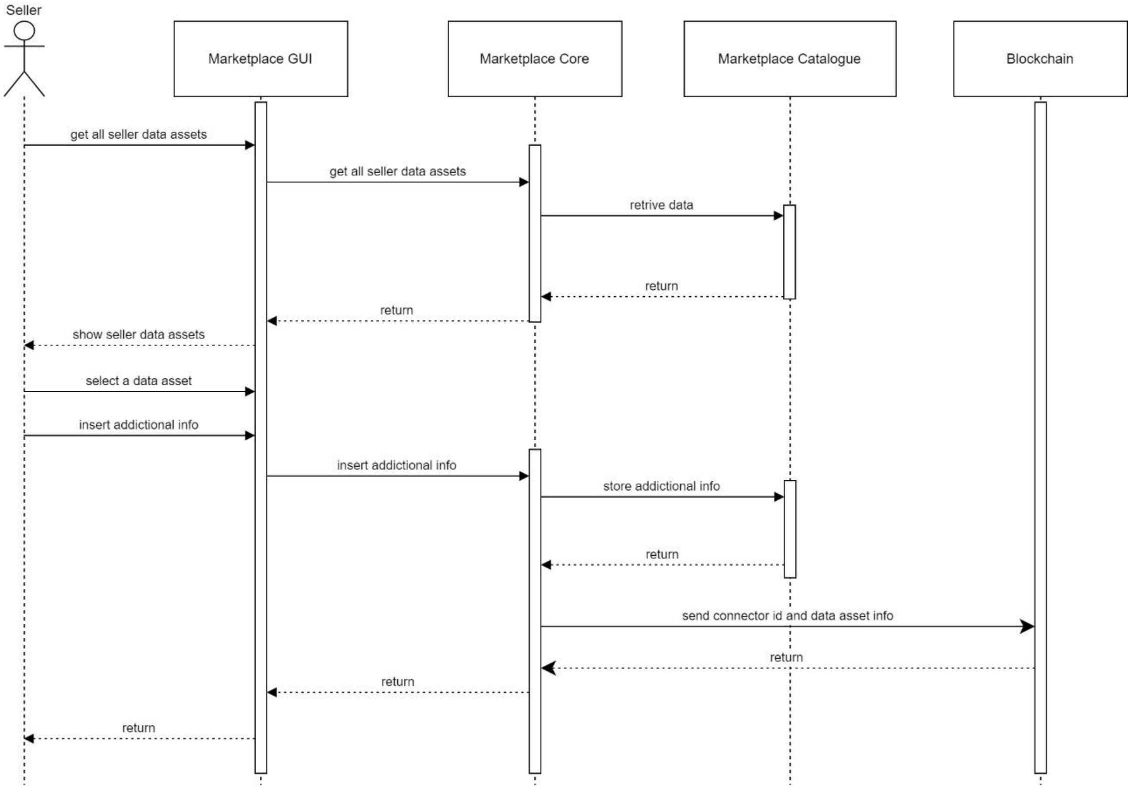

Figure 23: ***Publish Dataset*** **Sequence Diagram**

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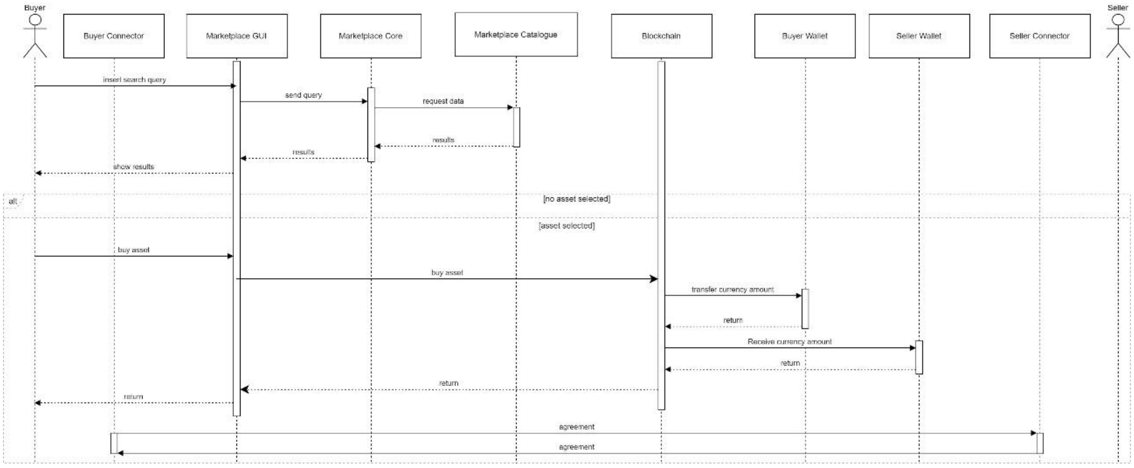

Figure 24: *Purchase Dataset* Sequence Diagram

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4.4 Deployment View

The deployment view illustrates a system from a system engineer's perspective and is concerned with the system structure. This section covers this approach by providing the current state of Enershare system with a list of deployed functionalities based on MVP. The components of MVP were selected based on the identified building blocks in ENERSHARE deliverable 2.1 – "Use cases' descriptions and list of minimum Data Space building blocks required for pilots" and also the architecture radar which defines the set of functionalities that need to be implemented through different releases. More details on this are provided within WP8 (D8.2). The rest of functionalities will be deployed based on release planning.

Based on MVP planning, WP4 provides two essential building blocks for the energy data space: a data space connector implementation and an identity provider. Together with the vocabulary hub (WP3) and metadata broker (WP5), these components allow for a minimal viable data space (Table 6).

Table 6: MVP Components

Nr.	Component	Based on	WP	Responsible Partner
1	Vocabulary Hub (Reference Semantic Model)	Semantic Treehouse	WP3	TNO
2	Connector	TSG Connector	WP4	TNO
3	Identity Provider (CA+DAPS)	TSG DAPS	WP4	TNO
4	Metadata Broker	TSG Broker	WP5	TNO

Component implementations:

1. **Vocabulary Hub (Reference Semantic Model)**
   The Vocabulary hub is the Vocabulary registry for overview of existing and used models in the dataspace Wizard for ontology model driven API design for data exchange use cases (Table 7).

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Table 7: Vocabulary Hub

Vocabulary Hub (Reference Semantic Model)	
Description	For wizard: Input: standard vocabularies like OWL ontologies or JSON schemas (e.g., Smart Data Models) Output: customized JSON Schema, XML Schema, Open API Specification (OAS), or SHACL that is still aligned with standards. Includes example data formats: data models Output: JSON, JsonLD, RDF, Yaml
Software details	Web application (PHP+JS+HTML) containerized with DockerTool that exports yaml files Java, Docker
URL	• https://www.semantic-treehouse.nl/

2. **TSG Connector**

The TNO Security Gateway (TSG) is a project developed by TNO (Netherlands Organization for Applied Scientific Research) that focuses on developing a secure and trusted data exchange ecosystem (Table 8). It intends to make it possible for companies to safely communicate and collaborate on data while maintaining data sovereignty, privacy, and security. It is composed of up of several components:

- **Authentication and Authorization:** TSG verifies user identities and authorizes access, ensuring only authorized individuals can interact with the gateway and access shared data.
- **Encryption and Data Protection:** TSG encrypts data during transmission and storage, safeguarding its confidentiality and integrity from unauthorized access and tampering.
- **Access Control:** TSG regulates data access by allowing organizations to define specific access rights and permissions, ensuring that only authorized users can retrieve or modify data.
- **Privacy-Preserving Protocols:** TSG employs protocols to protect sensitive information, enabling data sharing while preserving individual privacy and confidentiality.
- **Data Governance and Policy Enforcement:** TSG enforces data governance policies, enabling organizations to define usage conditions, data protection policies, and consent management rules to comply with regulations and principles.

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- **Integration and Interoperability:** TSG seamlessly integrates with existing systems, allowing organizations to leverage their infrastructure while benefiting from enhanced security and data sharing capabilities.
- **Monitoring and Auditing:** TSG provides monitoring and auditing features to track data usage, access patterns, and security breaches, ensuring accountability and compliance.

Table 8: TNO Security Gateway

TNO Security Gateway (TSG)	
Description	IDS-based HTTP Multipart communication (See: Message Flows, Deployment), and the Playground to play around with the connector
Software details	Written in Kotlin, built into Docker images. Default deployment based on Kubernetes & Helm.
URL	• https://tno-tsg.gitlab.io/ • https://gitlab.com/tno-tsg/core-container • https://gitlab.com/tno-tsg/helm-charts/connector

3. **TSG DAPS**

The TSG DAPS is an implementation of an IDS Dynamic Attribute Provisioning Service (DAPS) v2, combined with certificate authority capabilities to sign certificate signing requests (CSR) (Table 9).

The management interface is a multi-user interface that can set certification statuses for entries in the DAPS. Participants in the dataspace can login to the DAPS and make a Certificate Signing Request for themselves and a Component. The admin of the DAPS can verify the Participants and Component certificates and grant them a Trust level. The Trust levels of Participants can be Entry, Member and Central. The Trust levels of Components are Base, Trust, and Trust+.

Initial support for federation of DAPS instances is included, by sharing JSON Web Key Sets of other DAPS instances to allow connectors connected to their primary DAPS to validate tokens of other DAPS instances by retrieving the public key of that remote DAPS from its primary DAPS. This feature is experimental.

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Table 9: TSG DAPS

TSG DAPS (includes CA)	
Description	Implementation of an IDS Dynamic Attribute Provisioning Service (DAPS) v2, combined with certificate authority capabilities to sign certificate signing requests (CSR)
Software details	Written in Typescript. Both backend and generic frontend application.
URL	• https://gitlab.com/tno-tsg/daps • https://tno-tsg.gitlab.io/docs/daps/

4. **TSG Metadata Broker**

The TSG Metadata Broker is implemented as a TSG Connector. The key function of the Metadata Broker is to enable publication and discovery of services by providing the metadata of connectors within the dataspace (Table 10).

Providers of services publish metadata about their services in the TSG Metadata Broker. Once published, consumers can query the TSG Metadata Broker to find best-matching services. The metadata also contains the information required for the consumer to connect to the provider and initiate the data transaction. In other words, the TSG Metadata Broker provides the consumer with the necessary information to discover and select a service and to set up a data transaction using that service. The TSG Metadata Broker does not play a role in the actual data transaction.

The connectors in the dataspace are responsible for making sure the self-descriptions in the TSG Metadata Broker are up to date. The self-descriptions can be accessed by connectors via querying (e.g., via SPARQL). The TSG Metadata Broker uses a triple store as its backend to enable the SPARQL query functionality. The IDS Information Model is used for the messages format.

Table 10: TSG Metadata Broker

TSG Metadata Broker	
Description	IDS-based HTTP Multipart communication. See: Message Flows - Broker
Software details	Written in Kotlin, built into Docker images. Default deployment based on Kubernetes & Helm. Acts as Data App on top of a TNO Security Gateway (provided in WP4). Will be provided under Apache 2.0 license.

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URL	• https://tno-tsg.gitlab.io/

ENERSHARE Live Demo based on MVP-Setup:

In Table 11, Enershare live demo based on MVP-setup is provided:

Table 11: Enershare Live Demo

Identity Provider (CA+DAPS)	**Description**	The Enershare IDS Identity Provider contains a live overview of the identities used in the Enershare data space, for both organizations as the technical components.

	Process	Onboarding + identity provisioning
		• TSG Identity provider (DAPS + CA)
		• 2 participants in MVP
		  ○ ENERSHARE Authority (provides the IDP, broker and vocabulary hub) => that is currently we as a project
		  ○ TNO-Sample
		• 3 connectors in MVP, for the:
		  ○ Broker, Data provider and Data consumer
		• All involved data space participants (pilot partners) need to be registered. Not every participant needs its own connector. This can be provided by a service provider.

	Live Demo	https://daps.enershare.dataspac.es/
Metadata Broker	**Description**	The IDS Metadata Broker is a service for publishing and searching metadata of Connectors and resources between International Data Spaces Participants. To ensure the necessary interoperability and general interactions, an IDS Metadata Broker (like the App Store) is also defined as a specialized IDS Connector. The communication between an IDS Connector and an IDS Meta Data Broker is based on the same principles as any other Connector-Connector communication within the International Data Spaces. Still, an IDS Metadata Broker provides a collection of additional functionalities: • Indexing services to respond to queries and present known Connectors and other resources effectively and efficiently. • Interfaces for Users or IDS-Messages to ensure access to the stored information.

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	Process	Data Offering
		• TSG Metadata broker
		• Self-description of the data service is registered in the broker by the connector of the data provider
		• A data service is represented by an API agent in the connector. In this release, the agent is an implementation of an OAS data app in the connector.
		• This self-description includes
		  ○ Endpoint/access url to the connector
		  ○ API specification of the data service
		  ○ Basic metadata like temporal and spatial coverage of the data service

	Live Demo	https://broker.enershare.dataspac.es/
Vocabulary Hub (Reference Semantic Model)	**Description**	The Energy Vocabulary Hub is the place where data models in the Energy domain can be viewed and published.

	Process	Data model and API schema
		• Energy ontologies
		• Vocabulary Hub implementation
		  ○ The Schema wizard to design API schemas
		• Input ontologies used:
		  ○ SAREF v3.1.1
		  ○ Heat pump specific vocabulary (project specific)
		  ○ SOSA - A lightweight ontology for sensors, observations, samples, and actuators
		• Resulting schema published and referenced in self-description (previous step)

	Live Demo	https://energy.vocabulary-hub.eu/
Data Consumer	**Process**	Data consumer – REST client app • Simple UI to consume and show response of a data query • Implemented/integrated as data app • You start by querying the broker • Select the recipient agent (the data service you want to connector to) • API version is automatically filled • Enter the path '/measurements' (based on the API specification)

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		• Hit send to receive the data
	Live Demo	https://meter-consumer.enershare.dataspac.es/consumer-ui/

As per the WP8 integration process timeline, the remaining components are slated for deployment in subsequent iterations as integral components adding the initial release. In Table 12 to Table 15, a template of the release planning process containing the software components, their associated functionalities and implementation activities across release 1 to release 4, aligned with MS releases are presented.

Table 12: MVP

Components & Functionality	
	Reference Data Set TSG Connector Deployed Metadata Broker Identity Provider (CA+DAPS) Initial set of services (for TSG Connector) Vocabulary Hub (Reference Semantic Model)
Activities	
1	Finalisation of Functional Requirements
2	Definition of MVP Components
3	Implementation
4	Pilot Deployment
5	Pilots Test & validation
D8.2	ENERSHARE Data Space (1st technology release)
MS4	1st technology development cycle completion

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Table 13: 2nd Release

Components & Functionality	
	Integration of actual pilot datasets
	True Connector
	Metadata Broker - update
	Identitiy provider - update
	2nd set of services (focus on True Connector)
	Fiware Context Broker
	OpenAPI Interfaces - 1st version
	Semantic Models (Open Energy Ontologies)
	Marketplace [GUI/User Entry Point]
	Clearing House [Intitial Logging Service]
	AppStore [Intitial Service]
Activities	
1	Finalisation of Functional Requirements
2	Definition of Release Components
3	Implementation
4	Pre-integration testing
5	Integration to release 1
6	Deployment (Central)
7	Pilots Test & Validation
D8.3	ENERSHARE Data Space (2nd technology release)
MS5	Pre-pilot phase completion
MS6	2nd technology development cycle completion

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Table 14: 3rd Release

Components & Functionality	
	Integration of actual pilot datasets Integration between connectors Final set of services Data Mashup Editor Blockchain [Initial Service] Usage Control & Rules enforcement Integration of WP5 components
Activities	
1	Finalisation of Functional Requirements
2	Definition of Release Components
3	Implementation
4	Pre-integration testing
5	Integration to release 2
6	Deployment (Central)
7	Pilot deployment
8	Pilot test & validation

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Table 15: 4th Release

Components & Functionality	
	Integration of WP3 final components Integration of WP4 final components Integration of all WP6 services Integration of WP7 models Tokenised Marketplace [Final version] Clearing House [Final version] AppStore [Final version] Enershare Final Data Space
Activities	
1	Finalisation of Functional Requirements
2	Definition of Release Components
3	Implementation
4	Pre-integration testing
5	Integration to release 3
6	Full Deployment
7	Pilot test & validation
D8.4	ENERSHARE Data Space (Final technology release)
MS7	Full Pilot Operation Phase completion
MS8	Final technology development cycle completion

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5 Conclusion

In this deliverable, the primary objective has been to establish a comprehensive Reference Architecture for the Enershare project. The Enershare Reference Architecture serves as a standardized template, encapsulating best practices, design patterns, and guidelines. It can be used as a blueprint for the development of specific software architectures within the Enershare energy UCs and the broader energy domain. The elicited requirements underscore key aspects such as standardization, interoperability, privacy protocols, incentivizing data sharing, and fostering trust through effective communication, while ensuring compliance with legal and regulatory requirements.

The methodology employed in crafting this Reference Architecture draws on various approaches. The theoretical foundation is rooted in ISO 42010 for Architecture Description, providing a solid framework. The 4+1 view model and the adaptation of existing software components contribute to a practical and pragmatic approach. The incorporation of existing initiatives, including BRIDGE, IDSA, FIWARE, OpenDEI, and DSSC Blueprint, ensures alignment with industry standards. The Architecture Radar and collaborative work associated with the Miro Board facilitate a dynamic and collaborative design process.

The methodology employed comprehensively fulfills various aspects. The expectations and requirements elicitation and logical view address standardization, reusability, and quality assurance. The development view focuses on consistency, efficiency, and knowledge sharing, while the process view encompasses performance, scalability, and risk reduction. Together, these elements form a robust and adaptable Enershare Reference Architecture poised to meet the project's evolving needs.

It is important to note the preliminary nature of this document. As the Enershare project evolves, more up-to-date and technical information will be available in respective documents. The ongoing deployment of new releases building on the MVP signifies the practical testing and evolution of the proposed architecture.

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6 Appendix

6.1 Complementary Information on Legal and Regulatory Aspects

6.1.1 Feedback from Enershare Pilots

A survey was prepared and summited to the pilots to submit feedback under voluntary bases, we have received detailed answers for two of them which are explained here:

I. **Pilot 4 (Greece):**

Application: DIGITAL TWIN FOR OPTIMAL DATA-DRIVEN POWER-TO-GAS OPTIMAL PLANNING

- Jurisdiction plays an important role in the implementation and operation of the digital twin for optimal data-driven power-to-gas planning. Legal rules should primarily provide protection from the risks associated with the use of digital twins, with particular attention required regarding cybersecurity, intellectual property, allocation of risk and the modelling risk. However, working closely with legal and regulatory experts and engaging with local stakeholders will help ensure compliance and maximize the benefits of the digital twin platform within the specific jurisdiction.
- Regulatory Framework: Different jurisdictions have varying regulatory frameworks governing the energy sector, including power-to-gas technologies. The digital twin platform must comply with applicable regulations related to data privacy, cybersecurity, energy markets, and grid integration. Understanding and adhering to these regulations is crucial to ensure legal compliance and gaining the necessary approvals for deployment.
- Data Governance and Privacy: Jurisdiction-specific data governance and privacy laws dictate how data can be collected, stored, processed, accessed, and shared. When implementing a digital twin platform, it is essential to comply with these regulations and protect the privacy of sensitive data, such as energy consumption patterns or market information.
- Grid Interconnection Standards: Jurisdictions often have specific grid interconnection standards and requirements for integrating renewable energy technologies, including power-to-gas systems. The digital twin platform should consider these standards to ensure seamless integration with the existing grid infrastructure.

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Regulations to follow

- The implementation and operation of the digital twin for optimal data-driven power-to-gas planning should adhere to various regulations, which may vary depending on the jurisdiction.
- Data Privacy: Ensure compliance with data privacy regulations, such as the General Data Protection Regulation (GDPR) in the European Union or other local data protection laws. Protect personal and sensitive data collected and processed by the digital twin platform and obtain proper consent from users for data usage.
- Cybersecurity: Implement robust cybersecurity measures to safeguard the digital twin platform from unauthorized access, data breaches, and cyber threats. Follow industry best practices and standards for data encryption, access controls, network security, and incident response.
- Intellectual Property and Licensing: Respect intellectual property rights and licensing agreements when utilizing third-party technologies, software, or data within the digital twin platform. Adhere to copyright laws, licensing terms, and any specific intellectual property regulations relevant to the jurisdiction.
- Jurisdiction-Specific Regulations: Research and understand any jurisdiction-specific regulations or guidelines that may apply to power-to-gas systems and digital twin technologies. This may include local energy policies, incentives, or specific requirements related to renewable energy integration and data management.

II. Pilot 7 (Latvia):

Application: DIGITAL TOOL FOR PRIVATE HOMEOWNERS TO ASSESS ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSIONS.

- Regulatory Framework: Different jurisdictions have varying regulatory frameworks governing energy efficiency, including solar panel systems. The digital toll must comply with applicable regulations related to data privacy, cybersecurity, energy efficiency calculation methods. Understanding and adhering to these regulations is crucial to ensure legal compliance and gaining the necessary approvals for deployment.
- Data Governance and Privacy: Jurisdiction-specific data governance and privacy laws dictate how data can be collected, stored, processed, accessed, and shared. When implementing a digital tool, it is essential to comply with these regulations and protect the privacy of sensitive data, such as names, surnames, personal identification codes of the owners of private houses.

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Regulations to follow

- Data Privacy: Ensure compliance with data privacy regulations, such as the General Data Protection Regulation (GDPR) in the European Union or other local data protection laws. Sensitive data will be protected during data collection. It will be monitored in accordance with the regulations that establish the procedure for calculating primary energy and greenhouse gas emissions.

6.1.2 Summary on Legislation Initiatives

Note the following section is taken from D2.3 which was provided in April 2023.

Cybersecurity

NIS directive	Directive on Security of Network and Information Systems (the NIS Directive) went into effect in August 2016.
	• Affects digital service providers (DSPs) and operators of essential services (OESs)
	• OESs include any organizations whose operations would be greatly affected in the case of a security breach
	• DSPs and OES are now held accountable for reporting major security incidents to Computer Security Incident Response Teams (CSIRT), even if they outsource the maintenance of their information systems to third parties
	• Each member state required to create a NIS directive strategy, which includes the CSIRTs, National Competent Authorities (NCAs) and Single Points of Contact (SPOCs)
	  ○ Responsibility of handling cybersecurity breaches in a way that minimizes impact
	  ○ Encouraged to share cyber security information
	• DSP and OES obligations:
	  ○ Information to allows assessment of their information systems and security policies
	  ○ Notification of all significant incidents must be notified to CSIRTs

NIS2 directive	Directive (EU) 2022/2555 (known as NIS2) (33) entered into force on 16 January 2023. Member States have 21 months to transpose NIS2 to their national legislative framework. Replaces directive (EU) 2016/1148 (NIS) Additional aspects to NIS: • Creation of cyber crisis management structure (CyCLONe - European Cyber Crises Liaison Organization Network) • Enhanced harmonization on security requirements and reporting obligations • New areas of interest: supply chain, vulnerability management, core internet and cyber hygiene

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	• Peer reviews for enhancing collaboration and knowledge sharing amongst Member States
	• covering a larger share of the economy and society
	
	Role of ENISA:
	
	• European vulnerability registry
	• Secretariat of CyCLONe
	• Publication of annual report on state of cybersecurity in the EU
	• Support organization of peer reviews between member states
	• Registry of entities providing cross-border services (DNS (domain name servers service providers, TLD (top level domain) name registries, entities providing domain name registration services, cloud computing service providers and data centre service providers)
	• Assistance to NIS2 transposition
	• Support cooperation
	  ○ Identification of good practices
	  ○ Support reporting process for cybersecurity incidents (thresholds, templates, and tools)
	  ○ Common approaches and procedures
	  ○ Addressing common cybersecurity issues
	
	• Secretariat CSIRTs Network and organization of CyberEurope Exercise

Cybersecurity Act	The Cybersecurity act (34) establishes an EU-wide cybersecurity certification framework for digital products, services, and processes. It complements the NIS Directive. The set-up and maintenance of the framework will be led by ENISA.
Enershare contribution	Identifying needs for conformity assessment on energy data center service providers.

Data and privacy

Data act	The Data Act is a European Union legislative proposal (35) to create framework which encourages data sharing. It will ensure fairness by setting up rules regarding the use of data generated by Internet of Things (IoT) devices. Measures and means are proposed 1) to increase legal certainty for companies and consumers who generate data on who can use what such data and under which conditions, 2) to prevent abuse of contractual imbalances that hinder fair data sharing, 3) to allow public sector bodies to access and use data held by the private sector, and 4) to enable customers to effectively switch between different providers of data-processing services.
Data governance act	The data governance act (36) aims to make more data available by regulating the re-use of publicly/held, protected data, and boosting data sharing through the regulation of novel data intermediaries and by encouraging the sharing of data for altruistic purposes. In addition to the GDPR, further safeguards are included to increase trust in data sharing and re-use.
AI act	The AI Act is a proposed European law proposed in April 2021. It identifies three risk categories: • Applications and systems that create an unacceptable risk, e.g., government-run social scoring

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	• High-risk applications, e.g., CV-scanning tool that ranks job applicants • Low-risk application The first two categories of systems will be subject to compulsory conformity assessment. A standardization request is underway with the objective to provide standards by early 2025 supporting trustworthy AI processing.
European health data space proposal for regulation	While this proposal is for the health domain, it is worth monitoring because it may have an impact on the way data space ecosystems are implemented. The European health data space (37). It includes rules, common standards, practices, infrastructures, and a governance framework for two data purposes: • Empowering individuals through increased digital access to and control of their electronic personal health data, supporting free movement in the EU and a single market (primary use of data) • Providing a consistent, trustworthy, and efficient set-up for the use of health data for research, innovation, policy-making and regulatory activities (secondary use of data)
Enershare contribution	Enershare will monitor the compliance of its use cases w.r.t. the potential regulations, possibly providing feedback and proposals.

Clean energy package

Clean energy package	The package (38), adopted in 2019, will help to decarbonize EU's energy system in line with the European Green Deal objectives, with the following legislative initiatives: • The Energy Performance of Buildings Directive (EU 2018/844) outlines specific measures for the building sector • The revised Renewable Energy Directive (2018/2001/EU) has set an ambitious, binding target of 32% for renewable energy sources in the EU's energy mix by 2030 • The Directive on Energy Efficiency ((EU) 2018/2002), in place since December 2018, sets out a target of increasing energy efficiency over current levels by at least 32.5% by 2030 • The Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999 – has been in force since December 2018 (39). Each EU country is required to establish integrated 10-year national energy and climate plans (NECPs) for 2021-30. • The electricity market design is the last part of the packages. It has 4 strands - 2 new laws on electricity, 1 on risk preparedness and 1 outlining a stronger role for the Agency for the Cooperation of Energy Regulators (ACER).
Enershare contribution	Check in the use cases contributions to the package, identify resulting needs and requirements for energy data spaces.

Code of conduct on energy smart appliances

Code of Conduct on energy management related	This Code of Conduct is under discussion within the JRC. It covers the following energy smart appliances (ESA): • White goods: washing machines, tumble driers, washer-driers, dishwashers.

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interoperability of Energy Smart Appliances	• Heat pumps (delivering heat/cold through air or water), local space heaters, water heaters (electric storage, heat pump storage, electric instantaneous), ventilation. And the following use cases from EN 50631 (40) • Flexible start for White Goods (or other devices) • Monitoring of Power Consumption • Limitation of Power Consumption • Incentive Table based Power Consumption Management • Manual operation (provisioning of necessary information in case of user driven manual operation of ESA)
Enershare contribution	Contribute to interoperability profiles that follow the code of conduct.

6.2 Complementary Information on Standardisation

Except for the section on architecture standards the other parts are taken from D2.3 which was provided in April 2023.

This section benefited from the following engagement work

- Trialog presented a keynote in Comforen 2023 on March 16th, 2023, entitled “Keynote: the challenge of energy systems integration and interoperability” (41). This keynote points out the following needs
  - Have a standardization practice, where, architecture profiles are defined, Interoperability profiles are defined, and Trustworthiness profiles are defined
  - Ensure that profiles include generic, domain independent architecture artefacts, generic, domain dependent architecture artefacts and solution specific architecture artefacts
- Trialog presented a status on digital twin standardization on July 6th, 2023, during the ETSI IoT week (42) mentioning the progress of the work on data spaces.
- Trialog was invited to make a presentation on privacy standards on September 12th, 2023, in London (43) entitled “Critical New Data Privacy Standards: Achievements and obstacles”
- Trialog was invited to a panel chaired by JTC1 chai during the ISO annual meeting 2023 (September 19th, 2023) (44) where the notion of profiles was presented.

Reference	**Best practices and guidelines for reference architectures (RA)** - ISO/IEC JTC1/AG8 Draft standing document.

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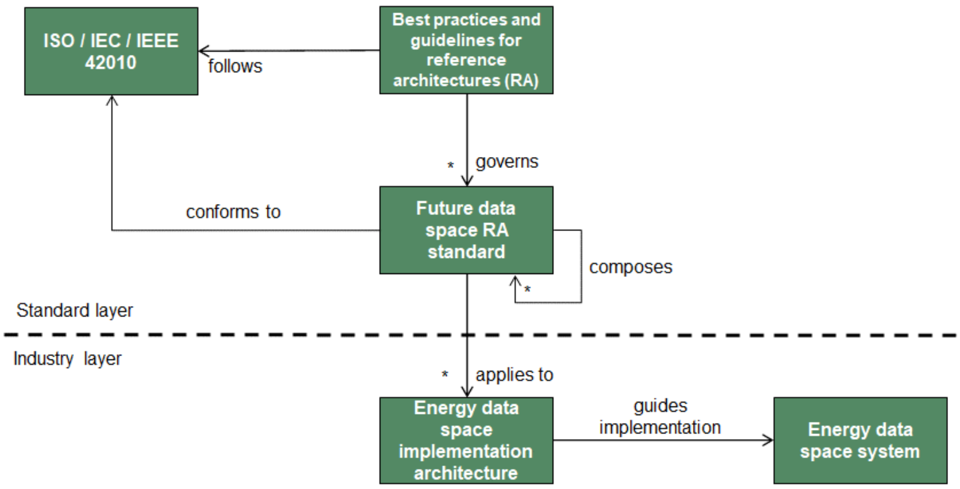
Scope	This standing document provides guidance to facilitate the integration of Reference Architectures (RA) used in standards created by different organizations, by providing conventions and rules on RA standards. The intent is to promote a degree of commonality among JTC 1 RAs to address problems that dissimilar RAs create for standards and their constituents. This document provides a unified approach for using ISO/IEC/IEEE 42010 (45) and its related standards to characterize reference architecture development. This document also provides initial guidance for consistent application of those RAs by using an integrated approach when developing domain specific standards.
Status	The document is prepared by ISO/IEC JTC1/AG8: Meta Reference Architecture and Reference Architecture for Systems Integration. It will be submitted for adoption at the next JTC1 plenary, to be used by all future RA standards. AG8 was established in 2019 with the objective of enabling the integration of multiple RA standards. The EC has a specific liaison with AG8 (Frank Boissière initially, and Svet Mihaylov now). The work carried out by AG8 was influenced by the Create-IoT support action (Antonio Kung, Emmanuel Darmois). Antonio Kung is the editor of this standing document.
Impact on data space architecture	Figure 25 shows the approach proposed by the standing document: • The development of a data space reference architecture (note that there is a preliminary work item on data spaces in ISO/IEC JTC1/SC38, and a report being prepared in ISO/IEC JTC1/SC41/AG31 on data spaces and the integration of digital twins). • The creation of energy data space implementation architecture  **Figure 25: Construction an Energy Data Space Implementation Architecture** The standard document also suggests the use of the foundational RA pattern to construction a reference architecture as shown in Figure 26. Future data space reference architecture could also use the foundational RA pattern.

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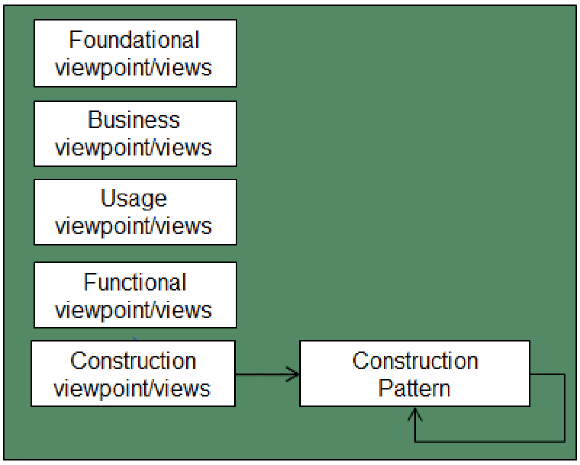
<table>
<tr><td></td><td>

Figure 26: Foundational RA Pattern

The study made by openDEI included an aligned construction approach as shown in Figure 27. The study was the result of a working group which included data space stakeholders from EC projects as well as standardization experts (46).

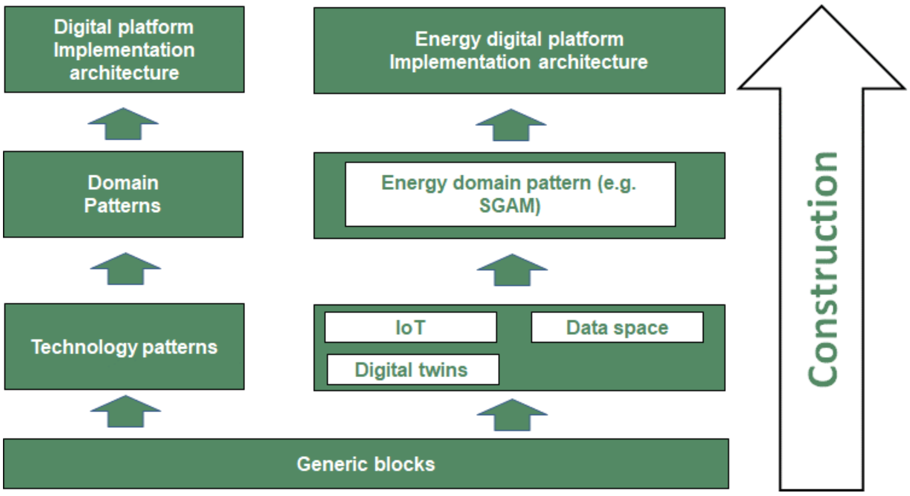


Figure 27: Constructing an Energy Data Space Implementation Architecture</td></tr>
<tr><td>Enershare contribution</td><td>Enershare external contributions on reference architecture will follow this standing document</td></tr>
</table>

Reference	ISO/IEC 30141 IoT reference architecture Edition 2 - ISO/IEC JTC1/SC41 document (47).
Scope	This document specifies an Internet of Things (IoT) reference architecture (IoT RA) as a generalization of existing practice that includes the distinguishing characteristics of IoT systems and other fundamental characteristics exhibited by IoT systems. This document addresses stakeholder concerns related to the business value of IoT systems, the interactions occurring between the IoT system, the users and the physical environment, and the implementation of IoT systems. Among the characteristics specified are the abstract functions within IoT systems and a variety of structures that are used to construct IoT systems.

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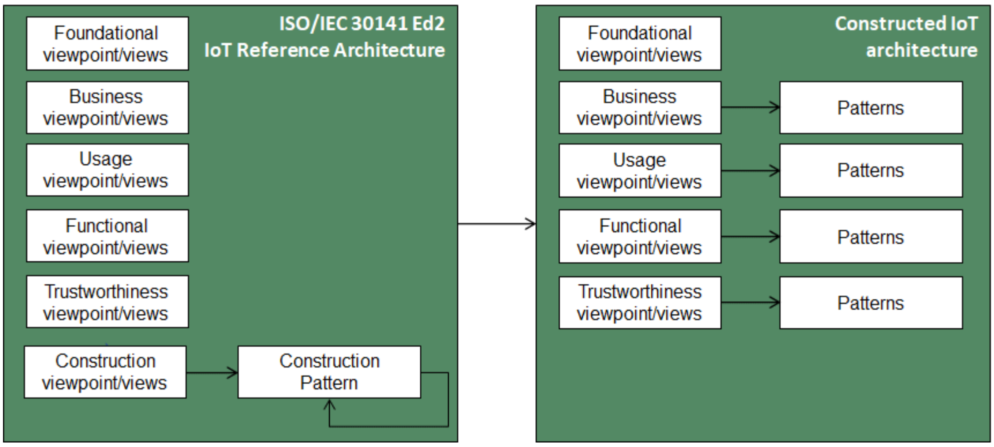
Status	The document will be published in 2023 or early 2024. It follows the AG8 standards document. Figure 28 shows how dedicated IoT architecture can be constructed, through patterns.  **Figure 28: Construction View of ISO/IEC 30141 Edition 2**
Impact on data space architecture	The following options are possible: • Constructing an IoT architecture which supports energy data spaces by integrating smart grid architecture patterns (e.g., SGAM) and data space patterns. • Constructing an energy data space by integrating in a generic data space architecture (e.g., defined by the Data space support center (support action on data spaces) specific energy data space patterns, and IoT patterns (i.e., the IoT reference architecture can be considered as a pattern)
Enershare contribution	The same approach can be applied for a data space reference architecture.

1. Update on Architecture Standards *

Below is a list of standards of interest to Enershare:

Reference	ISO/IEC 42024 Concepts and characteristics - ISO/IEC JTC1/SC7 (48).
Status	Just started
Impact on data space architecture	This will clarify some of the terms and concepts to be used in the long run.
Enershare contribution	Monitoring of the work. Trialog will be active on that standard.

Reference	**ISO/IEC 42042 Reference architecture** - ISO/IEC JTC1/SC7.
Status	Just started

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Impact on data space architecture	Will provide guidance on how to describe a data space reference architecture
Enershare contribution	Monitoring of the work. Trialog will be active on that standard

Reference	**ISO/IEC 30188 Digital twin reference architecture** - ISO/IEC JTC1/SC7 (49).
Status	Just started
Impact on data space architecture	Is one of the main approaches to implement data processing capabilities for data spaces. Trialog will be co-editor.
Enershare contribution	Monitoring of the work

Reference	**NP 20151 data space concepts and characteristics** - ISO/IEC JTC1/SC38[1].
Status	Just started
Impact on data space architecture	Will ensure that everyone has the same understanding. Trialog, IDSA and ECLIPSE follow and will contribute to this standard.
Enershare contribution	Monitoring of the work

Reference	**PWI JTC1-SC41-17 Guidance on the integration of IoT and digital twins in data spaces** - ISO/IEC JTC1/SC41 (50).
Status	Has been running for one year, leveraging contributions from OpenDEI and AIOTI. A proposal has been made to start the development of a standard. This will be done when NP 20151 is approved.
Impact on data space architecture	Will provide guidance on how to integrate IoT and digital twin
Enershare contribution	Check if Enershare results can be used for contributions (use cases, building blocks)

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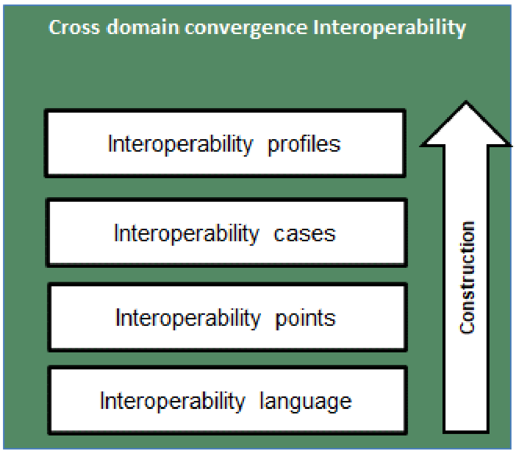
2. Interoperability and Networking Standards

An interoperability profile can include many standards focusing on separate layers (physical, semantic, transport, …). With the advent of complex systems, there is a need to include higher levels standards such as ISO/IEC 21823-5.

Reference	ISO/IEC 21823-5 Policy and behavioural interoperability – ISO/IEC JTC1/SC41 document (51)
Scope	Based on ISO/IEC 21823-1, this document provides the basic concepts for IoT systems and digital twin systems behavioural and policy interoperability. This includes: • Requirements • Guidance on how to identify points of interoperability • Guidance on how to express behavioural and policy information on capabilities • Guidance on how to achieve trustworthiness interoperability • Use cases and examples
Status	ISO/IEC 21823-1 (interoperability framework) was published in February 2019 as a framework. This was followed by ISO/IEC 21823-3 (semantic interoperability) which was published in September 2021. It is expected that ISO/IEC 21823-1 will be extended to add considerations on the principles to build an interoperability profile as shown in Figure 29: • Define the interoperability language • Define the interoperability point (where – spatial, when – temporal) • Define the interoperability points (why) • Define the interoperability profiles (how)  Figure 29: Construction Interoperability Profiles
Impact on data space architecture	• Data space architecture should identify the interoperability points • Interoperability profiles should be structured in alignment with architecture profiles
Enershare contribution	Enershare will undertake a description of architecture profiles, interoperability points and interoperability profiles in its use cases. If appropriate, contributions could be made to this standard.

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3. Trustworthiness Standards

References	The following standards are published and/or developed within ISO/IEC WG13 (Trustworthiness): • ISO/IEC 5723 Trustworthiness – vocabulary (52) • ISO/IEC PWI 5957 Trustworthiness — Reference architecture (53) • ISO/IEC PWI 9814 Trustworthiness – Overview and concepts (54) • ISO/IEC PWI 18149 Trustworthiness — Ontology (55)
Definition	ISO/IEC 5723 defines trustworthiness as follows: • Ability to meet stakeholders' expectations in a verifiable way ISO/IEC 5723 adds 4 further notes: • Depending on the context or sector, and on the specific product or service, data, technology, and process used, different characteristics apply and need verification to ensure stakeholders' expectations are met. • Characteristics of trustworthiness include, for instance, accountability accuracy, authenticity, availability, controllability, integrity, privacy, quality, reliability, resilience, robustness, safety, security, transparency, and usability. • Trustworthiness is an attribute that can be applied to services, products, technology, data, and information as well as to organizations. • Verifiability includes measurability and demonstrability by means of objective evidence.
Status	The following analysis can be made on the status of standardization work in trustworthiness: • Guidance on how to address dependencies between trustworthiness characteristics is not available. These dependencies depend on the context (e.g., the standards of a vertical domain). For instance, in the automotive sector, the approach is first to address safety (ISO 26262), and then see the impact of security (ISO 21434). • Standardization experts have not yet agreed on the following: • Difference between trust and trustworthiness, • Objective and subjective aspects of trustworthiness and resulting assurance requirements • Impact of context on trustworthiness characterization • Danger of inconsistency between generic trustworthiness and IoT trustworthiness (56), AI trustworthiness (57), Cloud trustworthiness (58) • Need to define trustworthiness profiles that consider vertical domain needs (e.g., energy), or technology needs (e.g., AI).
Impact on data space architecture	The support of different contexts in data space can justify the definition of trustworthiness profiles. Figure 30 shows a possible conformity assessment approach: • A trustworthiness profile follows requirements that are verified in a first conformity assessment scheme. • A system that implements a trustworthiness profile follows requirements that are verified in a second a conformity assessment scheme.

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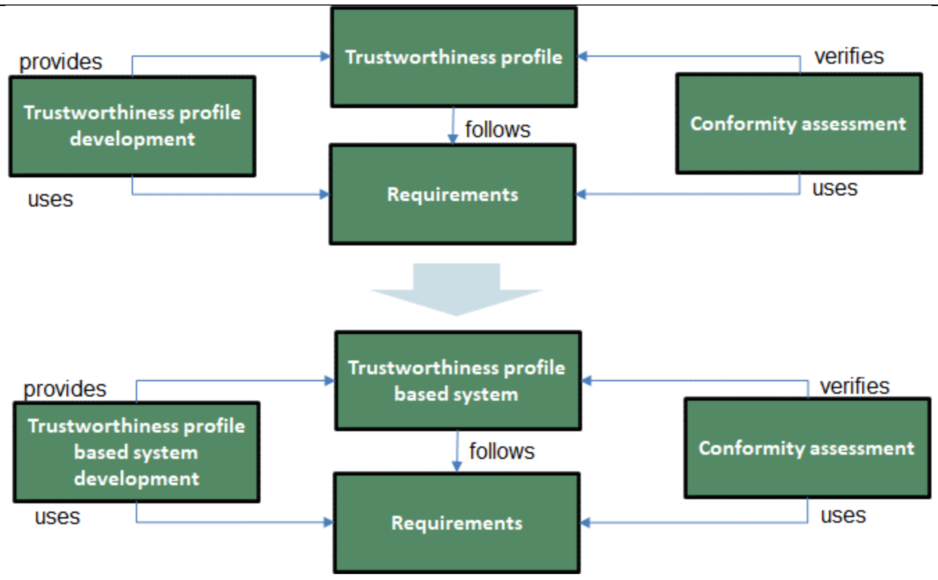

Figure 30: Trustworthiness Profiles

Enershare contribution	Depending on use cases, Enershare will: • identify potential trustworthiness profiles, or • Identify requirements for potential trustworthiness profiles

4. Cybersecurity and Privacy Standards

While there are many cybersecurity and privacy standards, data spaces need standards that focus on the ecosystem. One example is ISO/IEC 27570 (privacy guidelines for smart cities). This section focuses on standards initiatives that can influence Enershare work, or that would benefit from Enershare contributions.

CEN-CENELEC standards on RED	Cybersecurity delegated act to the radio equipment directive (RED) (59). Three standards are being developed by CEN-CENELEC JTC13: • Common security requirements for internet connected radio equipment • Common security requirements for radio equipment processing data, namely internet connected radio equipment, childcare radio equipment, toys radio equipment and wearable radio equipment • Common security requirements for internet connected radio equipment processing virtual money or monetary value Those standards are planned for the end for 2023. They will have an impact on IoT devices using wireless communication.
Enershare contribution	Enershare will verify the impact of such standards in energy data spaces.

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ISO/IEC 5181 **Data provenance**	This project has started in early 2023. Here is the scope: This document provides guidelines, methodology and techniques for deriving securely information called meta-data, from sources, intermediaries and users creating, manipulating, and transforming data. The meta-data derived from data creations and transformations serves for earning trust in entities and stakeholders during the whole lifecycle of data use and data manipulations. By referring to provenance meta-data an information respectively a decision base is provided to processes or, to individuals. Provenance meta-data of data records can also be applied from both, processes, or individuals when they must decide which one of their data, they want to make voluntarily available to the public as a common good and which one not. This standard could influence metadata on provenance to be used in data spaces.
Enershare contribution	Enershare will investigate requirements on data provenance and contribute to the development of this standard

ISO/IEC 27568 **Security and privacy of digital twins**	This preliminary work item started in November 2022 with Antonio Kung (Trialog) acting as editor. The current work is of landscaping nature. The following opinion is provided: • Additional security and privacy frameworks are needed to support the digital twins, the integration of capabilities (IoT, AI), and the collaboration between digital twins (federation) • Digital twins will be a key concept in ICT ecosystems. Guidance on digital twin security and privacy plans are needed. They can be considered as an extension to ISO/IEC TS 27570 (Guidelines for privacy in smart cities)
Enershare contribution	Enershare will investigate requirements on digital twins in data spaces and contribute to the development of this standard.

5. AI Standards

CEN-CENELEC JTC21 work item on AI trustworthiness characterisation	This new work item was approved on January 21st , 2024 to address the EC standardisation request to address the AI act. The request is asking for the publication of standards in early 2025. This work item will focus on the definition of (1) a methodology to define trustworthiness profiles, and (2) trustworthiness characteristics.
Enershare contribution	Enershare will check whether some of its use case require AI trustworthiness characterization. If this is the case, it will contribute the use cases as input to the standard development.

ISO/IEC 27090 **Guidance for addressing security threats and failures in artificial intelligence systems**	This project has started in 2022. It focuses on the cybersecurity of machine learning systems.

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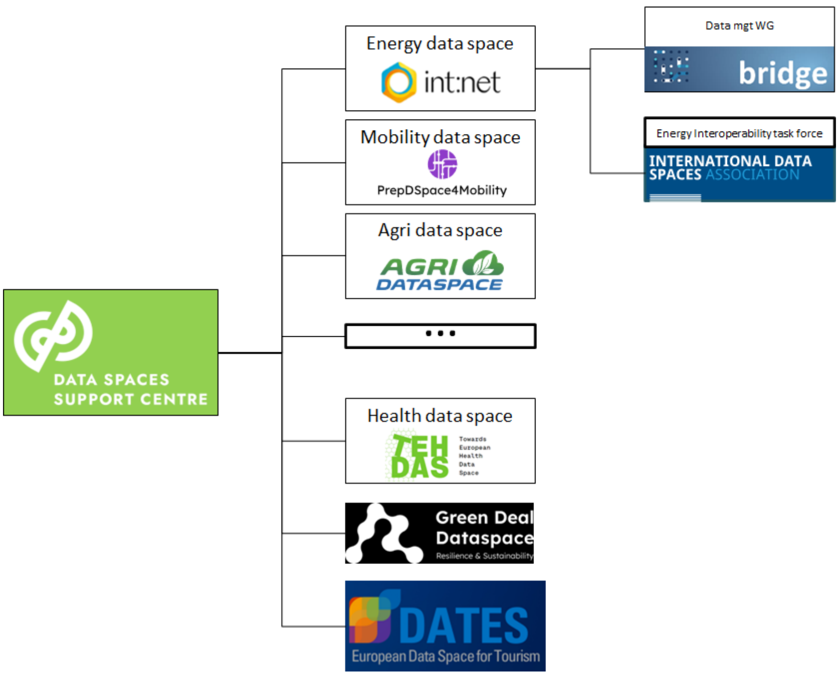
ISO/IEC 27091 AI – Privacy protection	This project has started in 2023 as the result of a preliminary work item. It will cover all types of AI systems (data driven, and knowledge driven).
Enershare contribution	Enershare will check whether some of its use case require AI cybersecurity or privacy. If this is the case, it will contribute the use cases as input to the standard development.

6. Context of Data Spaces

Enershare contribution	Enershare is part of a community of energy data space projects, e.g., Omega-X (60), EDDIE (61), Synergies (62), DataCellar (63), supported by Int:net (64). As shown in Figure 31, there are similar projects in other domains, such as PrepDSpace4Mobility (65) for mobility, Great (66) for the green deal data space, Dates (67) for the tourism data space, Agridataspace (68) for agriculture data spaces, or Tehdas (69) for health data spaces. Finally, there is an overarching data space support action DSSC (Data Space Support Centre) (70). The position of Enershare is to ensure a structuring of (1) its reference architecture, (2) interoperability capabilities, and (3) trustworthiness aspects are structured according to common aspects, cross domain aspects and domain specific aspects.  Figure 31: Data Spaces Research Ecosystem (Partial View)

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6.3 Mapping between Building Blocks and Components

BBs \ Comps	Open Energy Ontology	Vocabulary Hub	Open API	Data Mashup Editor	Context Broker	Virtualization Portal	Identity Provider (CA+DAPS)	DS Connector	App Store	Clearing House	Metadata Broker	Blockchain	Tokenized P2P multi-asset Market Place	Data Sharing/Barter Incentive Module
Data Space Boards														
Overarching cooperation agreement														
Continuity Model														
Data Models and Formats	X	X												
Data Exchange APIs		X	X		X			X	X					
Identity Management							X	X	X					
Trusted Exchange							X	X						
Domain Data Standard		X												
Access and Usage control / Policies								X						
Metadata and Discovery Protocol		X						X	X		X			
Data Processing														
Publication and Marketplace Services									X		X			
Regulations														
System Adaptation				X										
Service Level Agreement														

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Comps / BBs	Open Energy Ontology	Vocabulary Hub	Open API	Data Mashup Editor	Context Broker	Virtualization Portal	Identity Provider (CA+DAPS)	DS Connector	App Store	Clearing House	Metadata Broker	Blockchain	Tokenized P2P multi-asset Market Place	Data Sharing/Barter Incentive Module
Provenance and traceability														
Data Visualisation														
Data Analytics Engine														
Data Routing and Preprocessing														
Workflow Management Engine														
Unique Identifiers														
Data Usage Accounting										X				
Accounting Scheme										X				
Billing / Charging Scheme										X		X		
Smart Contract												X	X	

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