Enershare

The Energy Data Space for Europe

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

enershare.eu

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D3.1 ENERSHARE interoperability building blocks

Alpha version

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List of Acronyms

API	Application Programming Interface
BD4NRG	Big Data for Next-Generation Energy
CIM	Common Information Model
CSV	Comma-Separated Values
CSVW	CSV on the Web standard
DE	Digital Enabler
DFIG	Doubly-Fed Induction Generator
DSBA	Data Spaces Business Alliance
DSO	Distribution System Operator
EC	European Commission
EO	Earth Observation
EPES	Electrical Power and Energy System
ePO	eProcurement Ontology
GUI	Graphical user Interface
HTTP	Hypertext Transfer Protocol
IDS	International Data Spaces
IDSA	International Data Spaces Association
JSON	JavaScript Object Notation
JSON-LD	JavaScript Object Notation for Linked Data
MQTT	Message Queuing Telemetry Transport

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NGSI	Next Generation Service Interfaces
OAS	Open API Specification
OEO	Open Energy Ontology
P2P	Peer-to-Peer
PM	Permanent Magnet
PV	Photovoltaic
RAM	Reference Architecture Model
RAMI	Reference Architecture Model Industry
RDF	Resource Description Framework
RML	RDF Mapping Language
SHACL	Shapes Constraint Language
SHBERA	IoT Smart Home/Building and Smart Energy Reference Architecture
SIF	Semantic Interoperability Framework
SAREF	Smart Applications REFerence
SSA	Service Specific Adapter
TSG	TNO Security Gateway
TSO	Transmission System Operator
WP	Work Package

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Executive summary

The EU Strategy for Data acknowledges that Data Spaces should be interconnected and interoperable. Although data sharing and exchange within specific domains and sectors is already happening in existing initiatives, each of these initiatives follows its own approach, and therefore they are not always interoperable.

Creating the basis for the Energy Data Spaces primarily is not so much a technological challenge, as there are plenty of technical solutions and standards available. The main challenge hence is to move towards an Energy Data Space which offers: (i) Full intra-Data Space interoperability for cross-sector data sharing across energy sectors (electricity, heat, etc.) and with other energy (es. buildings/homes) and non-energy data hubs (es. EO-based observation, weather data, energy efficient financial risks); (ii) Multiple use inter-data space interoperability for cross-domain data space data sharing, exchange, and reuse. The horizontal focus on the use of standards and interoperability will make it possible to scale up the European Energy Data Spaces and facilitate the single market for energy data.

This deliverable, which is the first of a series of 3 (alpha, beta and final version), will present the preliminary results of the work in WP3, whose focus is on the design and development of the intra-energy and cross-sector Data Space interoperability building blocks, concretely: i) semantic data models (ontologies) specific for the energy sector and for other synergic cross domain sectors, ii) data exchange APIs that guarantee the interoperability of energy centred data driven services.

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1 Introduction

1.1 About the project

The overall vision of ENERSHARE is to develop and demonstrate a European Common Energy Data Space which will deploy an 'intra-energy' and 'cross-sector' interoperable and trusted Energy Data Ecosystem. Private consumers, business (energy and non-energy) stakeholders and regulated operators will be able to access, share and reuse, based upon voluntary agreements (or legal obligations where such obligations are in force): (a) Large sources of currently fragmented and dispersed data; (b) Data-driven cross-value chain (energy and non-energy) services and Digital Twins for various purposes.

1.2 About this document

This deliverable, which is the first of a series of 3 (alpha, beta and final version), presents the preliminary results of the work in WP3, whose focus is on the design and development of the intra-energy and cross-sector Data Space interoperability building blocks, concretely: i) semantic data models (ontologies) specific for the energy sector and broaden with others for other synergic cross domain sectors, ii) data exchange APIs that guarantee the interoperability of energy centred data driven services defined in WP6.

In more detail, this report provides a comprehensive overview of the methodology employed to establish the semantic data model, which addresses the requirements of 12 use cases across seven pilots. Additionally, it outlines the architecture and scope of the building blocks designed to facilitate semantic interoperability in both one-to-one and one-to-many data exchange communications. This architecture is part of ENERSHARE's Data Space Reference Architecture defined in WP2 D2.3.

1.3 Intended audience

The intended audience for this deliverable is two-fold. On the one hand, all involved stakeholders of the project, the technical work packages and especially the partners

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developing connectors and services in the different use cases. On the other hand, any external partner to the project that would like to be part of the European Common Energy Data Space which will deploy an 'intra-energy' and 'cross-sector' interoperable and trusted Energy Data Ecosystem.

1.4 Reading recommendations

This document is divided into 7 chapters.

- Chapter 1 is this introduction.
- Chapter 2 provides an analysis of how several EU projects and initiatives have addressed the challenges of semantic interoperability and how their results could be used and enhanced in the ENERSHARE project.
- Chapter 3 describes the architecture and the scope of the main functional components for data interoperability which have been identified in WP3.
- Chapter 4 explains the four steps of the methodology used to define the semantic data model, as well as the status of development of the ENERSHARE ontology to cover the specific needs of the twelve use cases.
- Chapter 5 addresses the list of software components that make up the Alpha version and the proposed message sequence for data exchange in one-to-one communications using IDS connectors.
- Chapter 6 presents some conclusions and the future work planned for the beta version.
- Finally, chapter 7 includes the list of references.

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2 Analysis of existing EU projects and initiatives addressing semantic interoperability in the energy domain

As described in IEC's "Guide and Plan to develop Smart Energy Ontologies" [1], one of the steps is to assess existing ontologies in order to reuse whenever possible and detect limitations and lessons learned. This section provides an analysis of how several EU projects and initiatives have addressed the challenges of semantic interoperability and how their results could be used and enhanced in the ENERSHARE project.

2.1 PLATOON

2.1.1 Description and main goal

Ensuring the semantic interoperability issues between heterogeneous systems is a very challenging task. Considering the use of a common semantic data model is a central element to ensure this semantic interoperability. A common semantic data model allows heterogeneous systems to share the same meaning of entities that enables them to interoperate when they come to use them in their different processes and services. The work done in PLATOON aims to propose a common semantic data model to meet the needs of the pilots' use cases. Semantic Data Models or more known as Ontologies are recognized as the cornerstone element to build a common semantic data model. Indeed, an ontology allows the description of domains in an unambiguous manner enabling experts to reach a consensus in a specific domain. Furthermore, ontologies could be shared and reused by different actors. SAREF [2] and CIM [3] are examples of ontologies in the energy domain that are considered reference frameworks. Reusing standardised ontologies fosters interoperability between systems. However, existing ontologies (like SAREF, CIM,

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etc.) in the energy domain did not cover yet all needs assessed by the different pilots of the PLATOON project. Consequently, there was a need to design a new ontological module to cover the PLATOON project needs.

2.1.2 Relevant results

To achieve semantic interoperability between pilots through the handling of data heterogeneity, a specific methodology to create harmonized semantic data models was developed in task T2.3 of PLATOON project, led by ENGIE, including all the needs of the PLATOON project use cases. Please refer to PLATOON's deliverable D2.3 for more information.

However, we should notice that the design of the semantic data model in the PLATOON project is use-cases oriented. That means that for each new module designed, the goal was restricted to meet only the needs of the use cases and not to cover all the concepts that could exist in the domain of discourse of the module. The main steps of this methodology, after studying the existing semantic data models (ontologies/taxonomies) of the energy sector, are:

1) Ontology requirements specification: it aims to analyse each use case to: (i) assess and define the scope of the ontology according to the application domain, (ii) extract the relevant terms that need to model the use case (concepts and relationships), and (iii) specify a list of natural language questions that the ontology should answer to.

2) Ontology analysis: the goal of this step is to reuse well-known ontologies or to design new ontological modules by respecting the practices for ontology design patterns.

3) Overview of ontological modules: it targets a consolidation of all conceptual modules together and providing an example for each pilot.

4) Interaction with stakeholders and ontology formalization: the purpose of this step is to: (i) discuss with the stakeholders to check if their needs are designed, and (ii) formalize all ontological modules by using an ontology editor and a standard language and integrate all modules into an ontology system.

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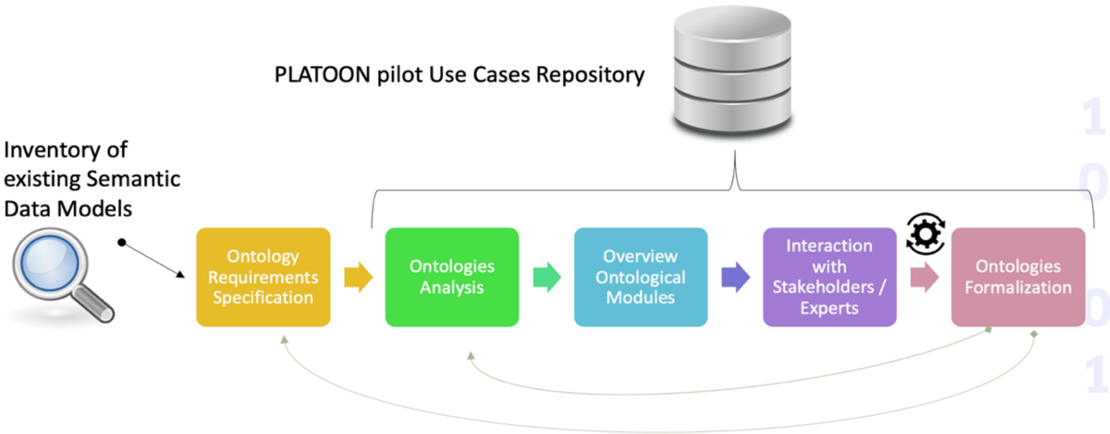

Figure 1: Overview of PLATOON Semantic Data Models methodology

To facilitate reusing existing semantic data models, ENGIE provided an inventory of these semantic data models of the energy domain. This inventory contains the different ontologies and their information (format, link, name, domain, number of concepts and properties, update date).

ENGIE also defined common templates to follow the methodology steps. These templates are provided to partners to correctly define the scope of the domain ontology and to easily exchange with the stakeholders. In the common template of the step 1, for example, each pilot responsible briefly described the goal of the use case that needs to be designed, the main mission of the ontology design, and proposed a set of questions that the ontology should be able to answer.

PLATOON project also provided some ontology diagrams describing the different use cases that are used to interact with stakeholders. From the diagrams, the PLATOON ontology modules are formalized in OWL and examples of knowledge graphs are instantiated.

2.1.3 Potential use and added value in ENERSHARE

There are several added values in ENERSHARE that can be capitalized from PLATOON project. The major one, in our opinion, is the reuse of the PLATOON Semantic Data Model. In fact, because PLATOON covers 7 Pilots and 19 use cases in the Energy domain, there is obviously some overlap with the ENERSHARE use cases. As an

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example, we can cite the wind turbine domain, the energy consumption and production, weather, meter, etc.

Another important added value is the methodology applied to create the semantic data model that reaches the need of the PLATOON use cases. This methodology is reused to design and create the ENERSHARE semantic data models.

Furthermore, a one stop portal for semantic data models is provided to access to internal and reused ontologies of the PLATOON project. This portal contains aggregated statistics across 21 ontologies, and it provided a first view of ontologies. Concepts and properties can be searched across ontologies. This portal also offers the possibility to visualize the relations graph between concepts. This portal has an ontology page specific to the referred topic (Building, HVAC, Wind Turbine, Grid, etc.). It includes ontology metadata, statistics of supported entity types and namespaces. In this portal, ENGIE offers a SPARQL endpoint to query ontologies and extract knowledge graphs related to three pilots (Wind Turbine, Building Office and Smart Grid).

In addition, as previously noted, the inventory of existing ontologies addressed by ENGIE in PLATOON, could be reused and updated to cover the need of ENERSHARE use cases. Moreover, several templates can be reused to follow the steps of the methodology.

However, we must notice that, about the reuse of existing ontologies, one needs to be vigilant with the meaning because different modelling points of view about the same concept can be proposed. This point is very challenging and requires more attention to make decisions that could be a matter of discussions.

Finally, the experience that ENGIE had in the PLATOON project might be considered as a significant added value. In fact, ENGIE had the experience to design heterogeneous and a large scope of use cases covering different domains. It had the opportunity to manage a complex and challenging project by organizing workshops for each teamwork and different follow-up meetings that helped to communicate with stakeholders (non-semantic experts) in order to describe their needs.

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2.2 BD4NRG

2.2.1 Description and main goal

BD4NRG stands for Big Data for Next-Generation Energy. One of the project's goals is to develop a semantic and business interoperability framework for cross domain edge-level analytics applications, cross-context learning and datasets spanning entire EPES (Electrical Power and Energy System) value chains.

As the BD4NRG project's aim is to facilitate the sharing of very large amounts of data from diverse sources, the issue of semantic interoperability has been crucial to the project. One of the goals of the BD4NRG Reference Architecture is to facilitate interoperability between data suppliers, data consumers and data service providers in BD4NRG.

The work on semantic interoperability in the BD4NRG project has been influenced by data space design principles from initiatives like GAIA-X, DSBA, Open DEI and IDS. The decentralized and distributed nature of data spaces has important consequences for semantic interoperability. Data providers must be able to describe and publish their data sources in such a way that these become easily findable and reusable for (potential) data consumers, even without prior knowledge of the specific consumers.

Another source of the BD4NRG design principles applied on semantic interoperability came from the BRIDGE Data Management working group. They warned that the proliferation of semantic standards is a major obstacle to the advancement of semantic interoperability in the energy domain, and in general. Making more standards is said to only exacerbate the problem (the problem being the lack of semantic interoperability).

These design principles led to a focus of the BD4NRG work on semantic interoperability on creating innovations that help boost the adoption of existing semantic standards in distributed data sharing networks. The main innovation result is an implementation of the IDS Vocabulary Hub component, in line with IDS RAM 4.

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2.2.2 Relevant results

From the perspective of semantic interoperability, there are two relevant results from the BD4NRG project: the Energy Vocabulary Hub implementation and the reported experience [2] with applying the five-star model for vocabulary use.

The Energy Vocabulary Hub is a web application developed and deployed by TNO and available at https://energy.vocabulary-hub.eu/. It is actively maintained and under continuous development. The reason for choosing a more general scope (Energy) instead of a narrower scope (BDN4RG project) as reflected by the URL was to combine the shared need for such a vocabulary hub functionality for both BD4NRG and other European energy data space projects, like ENERSHARE, into a single deployment. This aligns with the aim of ENERSHARE Task 10.1, which is to achieve interoperability and synchronization with the other projects of this call and initiative. That means that these projects can benefit from published vocabularies using shared models for pilots and use-cases. This also extends the service beyond the project lead time as the BD4NRG project is nearing its end while other projects are still beginning. TNO expects that other projects will join in years to come, enabling even more synergies on semantic interoperability across projects.

The Energy Vocabulary Hub runs on the Semantic Treehouse software developed by TNO. Its codebase is expected to be published as open source by the end of June 2023, allowing other projects like ENERSHARE to build on it as seen fit.

The Energy Vocabulary Hub drives adoption of existing standards by allowing users to take these standards (i.e., ontologies) as a starting point and create data models, schema's and Open API specifications with them. This functionality is also referred to as the 'wizard within the Vocabulary Hub, because it provides the users with a series of steps. For example, in BD4NRG, one data provider used this wizard to create a JSON Schema for their oscillography timeseries data based on the SAREF ontology. Another data provider used the wizard to create an Open API specification for their data on energy-efficiency projects funded by a governmental investment fund, based on a combination of SAREF and the European eProcurement Ontology (ePO).

The second relevant result is the experience gained with applying a five-star framework for vocabulary use [5] to encourage data providers to add as much semantic metadata as they can. The framework defines five milestones on the journey towards better semantic interoperability (i.e., vocabulary use). Each milestone is defined by a number of stars, the first being one star, the second being two stars, up until the complete five stars for the last milestone. The framework is simple, but powerful in communities involved in distributed data sharing, for a few reasons. First, through clever definitions of the milestones/stars, it is much clearer what the next step towards better semantic interoperability requires from the data provider. Secondly, it's easy to keep score: with the five-star model we can compare the vocabulary use of two datasets, e.g., one has only one star and the other has three. This also allows the semantic task force of the project to clearly communicate expectations within the project consortium: perhaps they require all data providers to achieve three stars at the minimum. Finally, although the first milestone is feasible for all (since it is simply providing a description of your dataset in natural language), the model leaves room for the reality of different capabilities and maturity of data providers. Perhaps one data provider can achieve four stars, while for another it is more reasonable to expect two. Regardless of these differences, in BD4NRG it was found that framing the challenge of semantic interoperability using the five-star model resulted in increased levels of vocabulary across the project.

2.2.3 Potential use and added value in ENERSHARE

The Energy Vocabulary Hub was initiated by the BD4NRG project with the express intention of reuse by and interoperability with other European data space projects like ENERSHARE. It is also an implementation of the IDS Vocabulary Hub component of the IDS RAM, and reusing it is thereby an act of adopting IDS in this project.

For ENERSHARE, the use of the Energy Vocabulary Hub could bring its interoperability goals closer. It provides a single registry for both standardized data models and pilot specific data models, and ways to integrate these. It allows for pilot partners to generate practical artifacts based on these data models: standardized schemas and API specifications. Additionally, as ENERSHARE pilot partners define the alignment of their data to these vocabularies, they have access to the work done by data providers from other projects such as BD4NRG, possibly leveraging the alignments they made at an earlier time. This is facilitated by the Vocabulary Hub as it keeps track of which pilot data models reuse which vocabularies.

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Next to the benefits of leveraging what the Energy Vocabulary Hub currently has to offer, there are three opportunities for the ENERSHARE project to extend its range of functionalities. Figure 2 provides a visual summary.

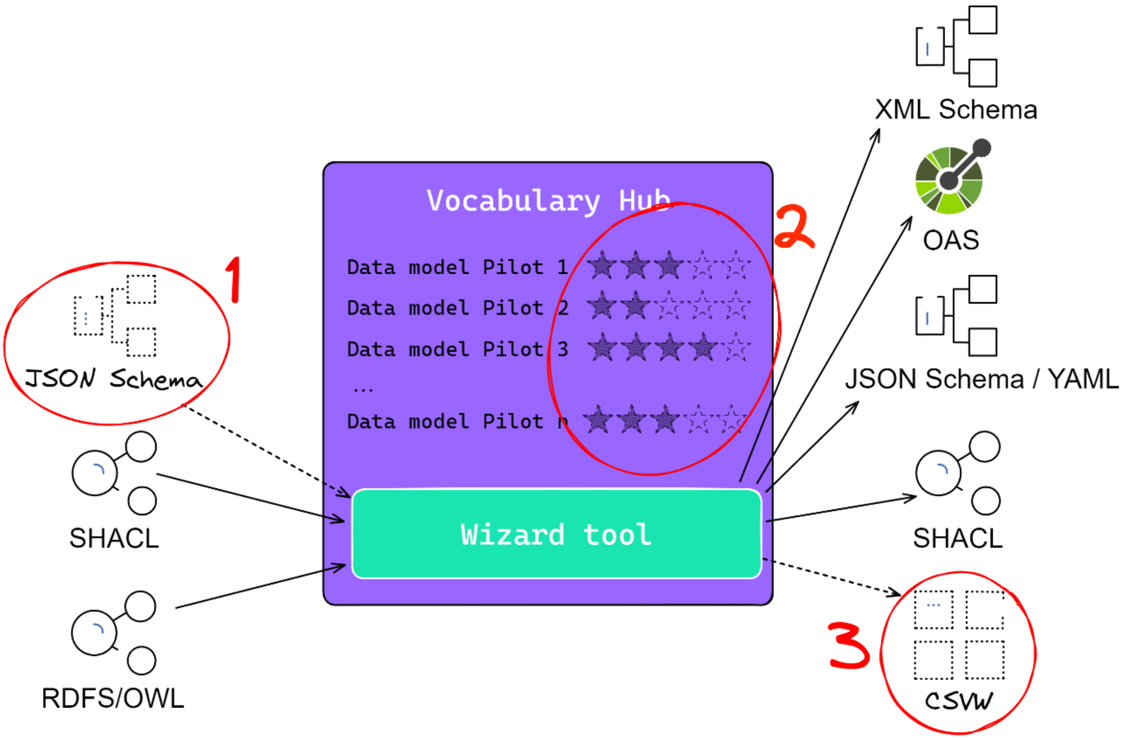

Figure 2: Overview of three opportunities to extend the Vocabulary Hub that help to achieve ENERSHARE goals

The first involves extending the wizard to support standardized vocabularies that are built without RDFS/OWL and SHACL, for example vocabularies that use JSON schema (e.g., formalized as JSON, JSON-LD or NGSI-LD). While it's good that data providers can currently use the vocabulary hub to leverage standardized ontologies identified and developed in earlier projects such as PLATOON and InterConnect, it's unfortunate that the same does not hold for semantic models formalized in JSON-LD or NGSI-LD, such as Smart Data Models. There are clear signs that some of these non-ontology standards are popular. For example, in both BD4NRG and ENERSHARE the pilots/use cases are considering to reuse some (subset of) standard JSON schemas, in particular Smart Data Models. Since the purpose of the vocabulary hub is to promote reuse of popular vocabularies, removing this limitation is an important opportunity for ENERSHARE.

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The second opportunity concerns the beforementioned five-star framework for vocabulary use. The opportunity is to implement support for such a framework into the Energy Vocabulary Hub. Until now the five-star framework has been tested in BD4NRG only as a way to carry out bilateral communication between semantic experts and use case owners. It proved to be an effective communication tool that led data providers to increase their vocabulary reuse. But vocabulary reuse could be increased further and on a bigger scale if the registry of data models in the Vocabulary Hub would leverage this framework in its interface by clearly indicating for each data set which semantic milestones have been reached. It could provide help to users to reach the next milestone as well. This would bring clarity about the degree of semantic interoperability of data sets within the data sharing network as a whole. After all, if every dataset had an indicator of their degree of vocabulary use, data customers would be able to see at a glance which datasets are most likely to become reusable with minimal effort required. An Energy Vocabulary Hub that keeps the score while providing ways for data providers to achieve the next milestone/star as easily as possible would create positive incentives for data providers that benefit the semantic interoperability in the ENERSHARE project and beyond.

The third and final opportunity is based on the observation that a lot of data providers offer tabular data, in particular CSV. Best practices for creating schemas and linking CSV data to existing vocabularies make use of CSVW [6] (CSV on the Web (CSVW) standard to add metadata to describe the contents and structure of comma-separated values (CSV) data files). However, the current Energy Vocabulary Hub doesn't support creating schemas for CSV. More exploration is needed to see if adding CSVW support next to the current support for JSON Schema, XML Schema, RDF/SHACL and Open API is feasible and worthwhile the effort.

2.3 Interconnect

2.3.1 Description and main goal

The fundamental concept driving the project is Semantic Interoperability, which refers to the capability of digital systems to exchange data with a shared, unambiguous, and agreed-upon meaning. This is a crucial building block for realizing the Digital Single Market. By leveraging ontologies like SAREF and employing knowledge exchange mechanisms, the project takes a significant step beyond

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Syntactic Interoperability. This advancement enables the interconnection of diverse ecosystems through swappable components, empowering different providers and companies to offer competitive and cost-effective solutions while avoiding vendor lock-ins or closed vertical technology implementations. The main innovation of the project is to deploy the concept of semantic interoperability into practice on a large scale, at a maturity level.

Semantic interoperability is under establishment at a large scale. From the Interconnect consortium composed by 50 plus partners and with solid manufacturers of IoT and white good appliances, a majority remains on using syntactic interoperability approaches, or none at all. The contributions from the InterConnect project show that large-scale adoption is technically possible, desirable, and long-term competitive with positive impacts on the offering of modular services and technologies.

To fulfil the objective of deploying semantic interoperability on a large scale and cross-domain, InterConnect defined a reference architecture for the project, that resulted from a detailed state of the art analysis of relevant IoT related reference architectures, extending the well-established concepts to allow a wider coverage necessary to cover ICT processing, ontology mapping and semantic interoperability. The result was the establishment of the Secure interoperable IoT smart Home/Building and smart Energy system Reference Architecture (SHBERA), that ensures compatibility with other well-established initiatives like Reference Architectural Model Industry (RAMI). The reference architecture enables the implementation of digital services, which can be clustered, according to the context and requirements, supporting multiple implementations focused on devices and systems as well as cloud-based infrastructures. This is what allows different corporate digital ecosystems to be built in a completely modular approach and to take advantage of synergies and developments that can be leveraged by several entities.

2.3.2 Relevant results

The SHBERA reference architecture is designed departing from the requirements to establish a common ground between two domains, IoT and Energy. The democratization in the access and share of knowledge between these planes will uncover the ecosystem for the creation and co-creation of interoperable, data

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driven energy and non-energy services. Unlocking interoperability between them is materialized in Interconnect via two *key exploitable results*, that embody the necessary developments that support the concept for the SHBERA. These transversal outcomes provide the base ground to the realization of use-cases in pilots, supporting a vision of interoperable and interchangeable services, namely the *cross-domain semantic interoperability* and the *smart grid and DSO interface*. A concrete description of each one of these *key exploitable results* follows.

- The Cross-domain semantic interoperability is the transversal and core innovation of the project -- through the Semantic Interoperability Framework (SIF) [7][8][9] -- upon which all the developments concerning the semantic interoperability are made. It covers the domain of buildings and homes, where different devices and systems are made interoperable allowing energy and non-energy services to be exploited in a modular way.

The SIF considers from the same proven concept of distributed *connectors*, i.e., Service Adapters, but considers SAREF as ground to bring meaning to data in favor of considering a fixed data model as the interoperability agreement between stakeholders. Becoming semantically interoperable goes beyond the ability of systems to exchange information with correct syntax (syntactic interoperability) to the automatic, correct interpretation of the meaning of information (semantic interoperability). Ultimately, the SIF unlocks a semantically interoperable interface that allows stakeholders' services to share and query knowledge represented according to SAREF, instead of using syntactic interfaces with strict integration and querying options limited by the chosen data model. This means that ANY question, that fits the knowledge can be used to interact with a component, without relying on a matching API that was defined and implemented by the component.

The SIF concept bundles a set of tools to enable interoperability up to the semantic level, namely: the *Service Adapter* as the *connector* adopted by digital platforms via a Service Specific Adapter (SSA); the distributed *Semantic interoperability layer*, handling knowledge exchange and querying between adapters; the *Service Store* providing a catalogue of interoperable services, knowledge explorer and certification of services; the *P2P marketplace* for the instantiation of services devoted to fully distributed applications; and a set of tools to ensure security, privacy and governance transversal capabilities.

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- Enclosed as part of the former Key Exploitable Result are the extensions to the SAREF family of ontologies that resulted from the use-cases in the Interconnect project. The evolution of SAREF is publicly available [10]. At the time of editing this deliverable, InterConnect's contributions to SAREF are currently under evaluation to be formally included in ETSI.

- The Smart grid and DSO interface is also a transversal contribution made on creating innovative interoperable mechanisms to be applied to the grid domain, where flexibility service providers can interact with system operators to be able to provide support to the grid operation and contribute to the efficient exploitation of energy assets.

2.3.3 Potential use and added value in ENERSHARE

The SIF (Figure 3) shares common architectural principles with the IDS RAM v3.0 on the overall mission, but also when considering components with equivalent role to IDS building blocks, This is clear for the case of the SIF's Generic Adapters and the IDS connectors or the SIF's Service Store and IDS Metadata Brokers and Vocabulary hub. Data and Metadata exchange in Interconnect's SIF is handled by a brokering component that can set data exchange between connectors, including the possibility to reason on top of exchanged data, and discovering new links between data representations.

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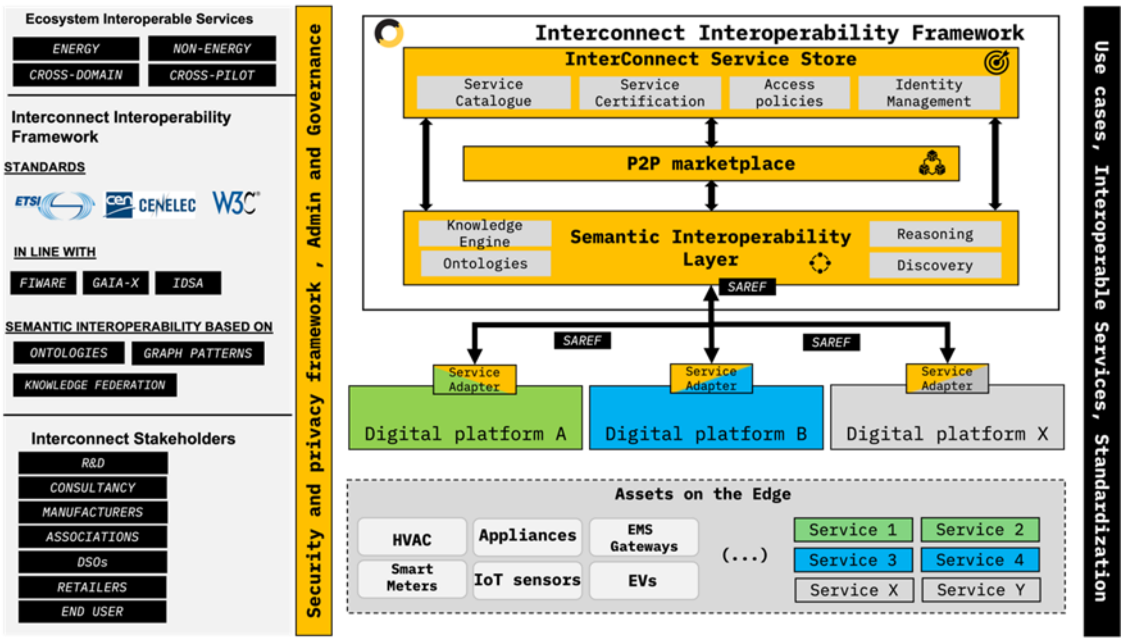

Figure 3. InterConnect's Semantic Interoperability Framework.

Despite being modeled with the same rationale, Interconnect does not directly adopt IDSA's Reference Architectural model. This means that some of the logical building blocks of IDSA RAM exist in Interconnect, but they might be spread in different technological components of the SIF. Nevertheless, a seamless integration is possible, where InterConnect (SIF, ontology, and services) can be used as facilitator for establishing semantically interoperable ecosystems on top of which data spaces can be organized. While the SIF is stronger in terms of the semantic data representation and what it can unlock (as data producers and data consumers directly consider a strictly semantic data model), IDSA's RAM v3.0 adopted in ENERSHARE is stronger in the provision and the assurance of sovereignty and data governance as part of deploying new data space ready value-chains.

Part of the SIF, the Knowledge Engine component is of particular interest to ENERSHARE in complement to IDSA's Metadata Broker or even the Vocabulary Hub. The reasoning capabilities of Knowledge Engine could facilitate the discovery of new relationships among the metadata on data models provided by the Metadata Broker.

Finally, Interconnect's ontologies including the extensions to SAREF (currently under review for formal inclusion in ETSI) and others are directly applicable. The work leading to Interconnect's ontologies, namely SAREF considered from the use-cases

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and services in Interconnect's 7 large scale pilots that include a total of plus 60 energy and non-energy services from IoT devices, including manufacturers of smart home appliances, providers of digital services for optimization and comfort control and Grid stakeholders covering mostly energy flexibility-centric services.

2.4 OneNet

2.4.1 Description and main goal

OneNet is primarily focused on providing an open and flexible architecture for transforming the European electricity system into a smarter and more efficient one. The project is designed to enable cross-platform market and network operation services by integrating various platforms such as DSO platforms, Market platforms, and Data Exchange platforms, in a fully decentralized manner.

The OneNet Connector, which is IDSA compliant [11] (IDS Info Model 4) and powered by TRUE Connector that is part of the FIWARE Catalogue, is a comprehensive platform designed to enable secure and efficient communication between devices, applications, and services. It offers a range of functionalities that can be tailored to meet the needs of various stakeholders, including developers, businesses, and end-users.

Developers can use OneNet to build robust and scalable IoT solutions with ease. The platform supports a wide range of devices and protocols, making it easy to integrate new devices into existing systems. OneNet also provides developers with a suite of tools for managing data, monitoring devices, and automating workflows.

Businesses can leverage OneNet to improve their operations and drive growth. The platform's real-time data analytics capabilities enable businesses to gain valuable insights into their operations, which can be used to optimize processes, reduce costs, and increase productivity. OneNet also enables businesses to streamline communication between teams, departments, and customers, improving collaboration and customer satisfaction.

End-users benefit from OneNet's seamless and intuitive interface, which makes it easy to interact with connected devices and services. OneNet's security features

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protect user data and ensure that only authorized devices and users can access sensitive information.

2.4.2 Relevant results

The OneNet project has been implemented in 12 pilots across four clusters, addressing significant cross-DSO business models and use cases. The project has successfully demonstrated the feasibility of using OneNet for different scenarios, including procurement and activation support, bidding for balancing services, congestion management, and flexibility trading.

One of the key highlights of the project is the successful implementation of the OneNet Connector in various use cases across different countries, demonstrating the scalability and interoperability of the infrastructure. For instance, in the Northern Cluster, the OneNet Connector was used to support procurement and activation, bid optimization, and preparation for flexibility trading. In Spain, the OneNet Connector was utilized for the Local Market platform - Market Session. In Cyprus, it was used for the evaluation of flexible service providers' response and coordination of distributed flexible resources, while in Slovenia, it was utilized for congestion management in distribution grids under market conditions. In Poland, the OneNet Connector was used for bidding for day-ahead balancing services, congestion management, and voltage control services, and in the Czech Republic, it was utilized for non-frequency services. In Portugal, the OneNet Connector was used to meet day-ahead and intraday flexibility needs for DSO/TSO within the OneNet system. In the Eastern Regional Cluster, it was used for flexibility market data aggregation, while in the Western Regional Cluster, it was utilized for cross-SO grid pre-qualification.

2.4.3 Potential use and added value in ENERSHARE

The OneNet project results can be leveraged in the ENERSHARE project in several ways. ENERSHARE is focused on developing and deploying innovative solutions for energy sharing and optimization in buildings, which aligns with OneNet's goal of enabling smart building solutions.

One way in which OneNet results can be reused in ENERSHARE is by utilizing the same data integration and communication protocols developed in OneNet to enable seamless data exchange between different components and systems within the

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buildings. This can help to reduce development time and costs for ENERSHARE, as well as enhance the scalability and interoperability of the overall system. Additionally, ENERSHARE can leverage OneNet's advanced analytics and machine learning capabilities to develop more accurate and reliable energy optimization models. By feeding OneNet data into the ENERSHARE models, the accuracy and effectiveness of the optimization algorithms can be improved, resulting in better energy efficiency and cost savings for building owners and occupants.

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3 In-depth architecture of the semantic interoperability building blocks

As explained in deliverable D2.3 "Description of Reference Architecture for the European Energy Data Space", the main objective of ENERSHARE WP3 is the development of the necessary building blocks to facilitate data interoperability, so that data can flow seamlessly between parties and domains. More in detail, WP3 will provide two types of building blocks:

- Data Models and Formats (i.e., common formats) for model specifications and representation of data in data exchange payloads.
- Data Exchange APIs for facilitating the sharing and exchange of data, i.e., provisioning and consumption of data, between the data space participants.

3.1 Architecture

Figure 4 depicts the main functional components for data interoperability, which have been identified in WP3.

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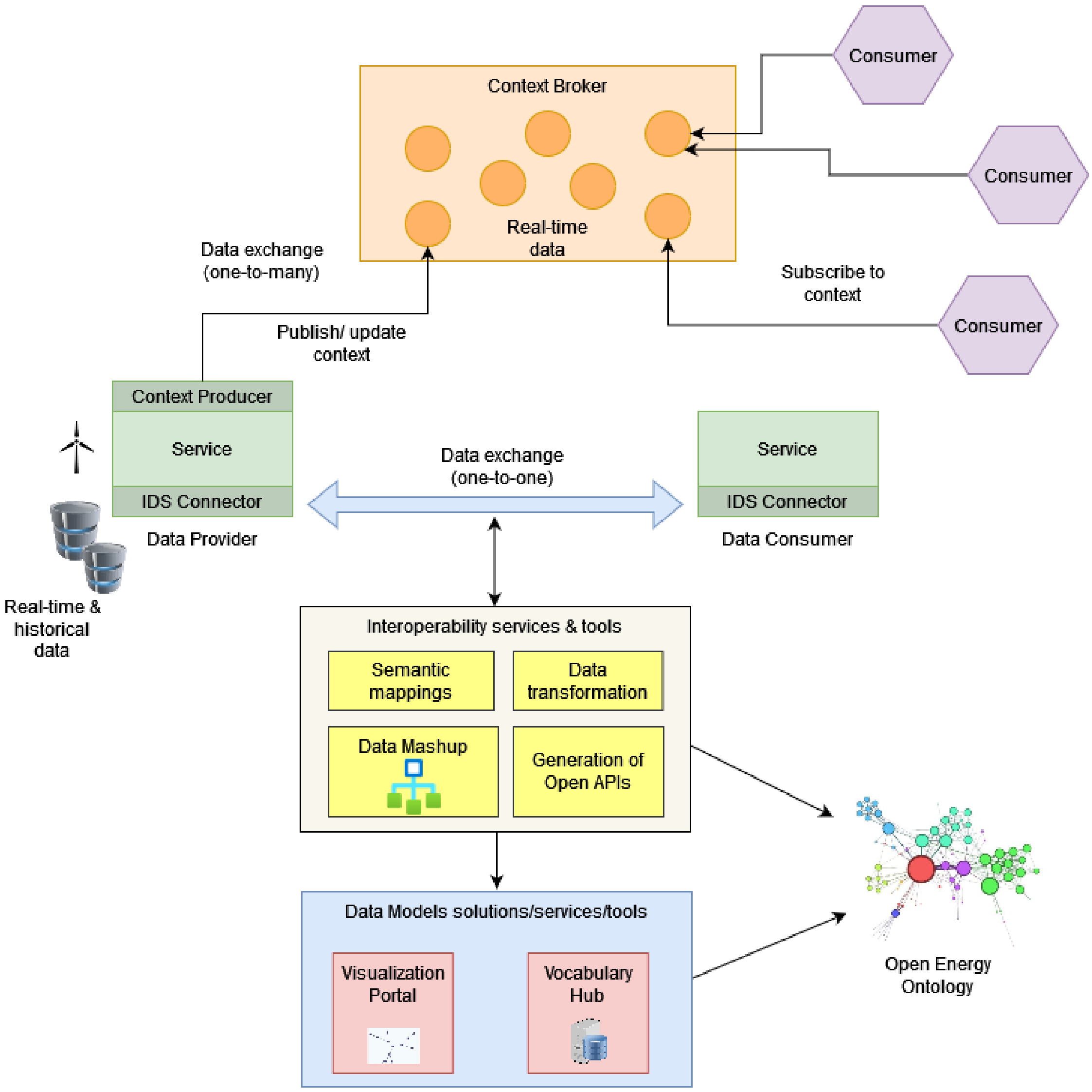

Figure 4: Functional components for data interoperability

3.2 Data Models and Formats

The purpose of the building blocks under this category is two-fold. On the one hand, to provide a semantic model to represent the energy domain that will allow to unambiguously interpret all the concepts and the data exchanged in the ENERSHARE pilots. On the other hand, to provide the mechanisms or tools to query, interact with and foster the adoption of these semantic models.

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The Open Energy Ontology (OEO) is the set of interconnected ontologies that are being developed to semantically model the energy data landscape (renewables, energy communities, flexibility and electromobility). Section 4 explains the methodology that is being followed to define the OEO ontology and the current status of the model.

The tool to query and interact with data models will offer two functionalities:

- A Vocabulary Hub or web-based vocabulary registry where all project stakeholders can find the data vocabularies relevant to the project. This includes both *standard vocabularies* (i.e., ontologies like OEO but also others like Smart Data Models) and *non-standard vocabularies* (i.e. data models specifically for a certain pilot use case).

- A Visualization Portal or web-based GUI for the interactive visualization of ontologies. The user will be able to interact with the ontologies, check the available properties and metadata information, and make queries on the model through a SPARQL endpoint.

3.3 Data Exchange APIs for the sharing and exchange of data

Two alternatives are considered for data exchanging between services: one-to-one and one-to-many.

In the first case (one-to-one), secure and trusted data exchange is guaranteed between provider and consumer using IDS connectors. Using IDS connectors, the consumer can access or exploit both last-value data and historical data. From the different implementations of data connectors listed in the Data Connector Report [12], the TRUE Connector [13] and the TNO Security Gateway (TSG) [14] are being considered to be used in ENERSHARE pilots. Currently, these connectors are not interoperable among them. However, the Dataspace Protocol Specification, currently in version 0.8 and based on W3C standards, is defining the convergence to a common framework for data spaces which guarantees intra and inter data space interoperability.

For one-to-many data exchange, a publish/subscribe paradigm using the Context Broker is proposed. The Context Broker is recommended for sharing right-time data

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(i.e., near real-time data) among multiple organizations. Its main functions are the context management and the context availability management. Context information refers to the values of attributes characterizing entities relevant to the application. Using this mechanism, a provider can publish data to which several consumers can subscribe. As new data is published, consumers receive a notification of the context updates.

Besides, a set of interoperability services and tools will be provided to facilitate data exchange including data transformations, semantic mappings, the generation of Open APIs and a data mashup editor to combine data from different data sources. Section 5 contains a detailed description of these services and tools.

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4 Methodology and advances for the ENERSHARE data model

4.1 Proposed methodology definition for ENERSHARE semantic data models

To design the semantic data model for the ENERSHARE project, we reuse the methodology defined in the PLATOON EU project. The methodology is divided into the four steps detailed below. Each step is applied to each use case to cover all the specified needs (see Figure 5). This section details all the steps based on the deliverable of Common Data Models in the PLATOON project [15].

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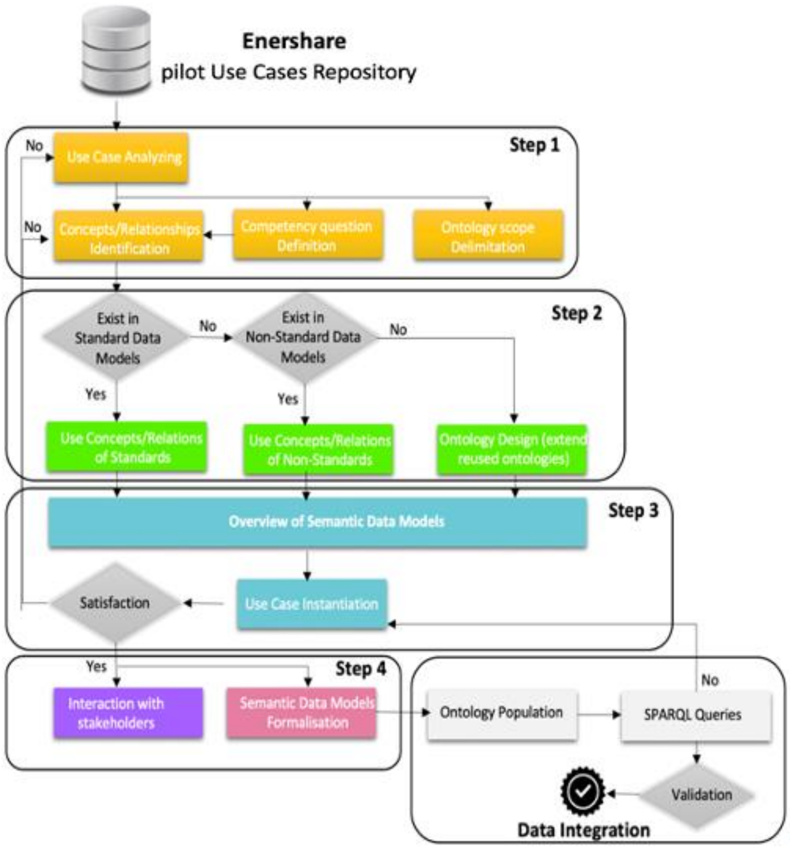

Figure 5: Design methodology steps for ENERSHARE use cases

4.1.1 Step 1: Ontology Requirement Specification

Before creating an ontology, it is important to start to analyse the need and the specification expected from the semantic data model. The step 1 is composed of different tasks to meet the ontology requirements. These tasks are presented as follows:

a. Use case analysis: in this task, a deep analysis of the use case requirements is mandatory. In the ENERSHARE project, each use case is described according to the IEC 62559-2 template [22].

b. Ontology scope delimitation: in this task, we define the scope of the ontology to design an ontology module. This scope is defined according to

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the application domain. An example of scope limitation could be a Wind Turbine failure and maintenance.

c. Competency questions definition: in this task, we define natural language questions that domain experts want the ontology to help to answer. The list of competency questions will also be useful to evaluate the final ontology.

d. Term elicitation: in this task, the knowledge experts analyse the IEC-62559 documents that describe the use cases and identify and extract all relevant terms for a specific domain. They also analyse the list of competency questions to extract key terms to be included in the semantic model (e.g., wind turbine, generator, flexibility, forecast, system, sensors, etc.)

The outcome of the step 1 is a document that contains the scope of the ontology, a list of competency questions and a tab with a list of extracted relevant terms. These terms will be validated or not by the business experts to be considered or not in the ENERSHARE semantic data models.

4.1.2 Step 2: Ontology Analysis

The goal of the step 2 is to start creating the semantic data model. Following the principle of ontology domain, the reuse of existing ontologies is recommended before starting a new design of a new ontology module. According to this principle, we define several tasks detailed as follows:

a) Identification of concepts and relationships, from the list of relevant terms, we associate for each term, a concept name or a relation name that will be used in the semantic datal model. For example, we associate a concept *WindTurbine* to the term wind turbine, and the concept *HydraulicSystem* to the term hydraulic system.

b) Reusing Ontology, for each identified concept in the previous task, we identify the concept in the existing ontology if it is already defined. If several concepts are available in different ontologies, our strategy is to propose a mapping between these equivalent concepts to ensure the interoperability.

c) Extending Ontology, if the ontology module in the domain exists and covers a part of the use case but the concept doesn't exist in these modules, we extend the existing ontology with the new concept.

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d) Ontology construction in the third case, if the existing ontologies don't cover the use case domain, we create new ontology modules that cover the use case; we extend or add equivalent concepts when it is relevant to increase the interoperability.

The outcome of this step 2 is: (i) a list of identified existing ontology modules, (ii) a list of reused concepts and relations and (iii) a list of concepts that need to be designed in a new ontology module to cover the scope of the use case.

4.1.3 Step 3: Overview of ontological modules

The goal of the third step is to integrate all modules together into a harmonized semantic data model and producing an example for each pilot. This step consists of the following procedures: diagrams integration, ontology evaluation (scoping of Use Case, consistency, competency) and pilot instantiation with an illustrative example.

This step takes as input: (i) a list of identified ontology modules, (ii) a list of concepts and relations coming from the list of ontology modules, and (iii) a new designed ontology module.

a) Diagrams integration: the knowledge engineer puts different modules together in a schema diagram to check all classes, properties and possibly to improve them. This task is important to join the different schema diagrams of the modules with semantic relations (e.g., subsumption, equivalence, etc.). A global overview schema of all used modules should be provided.

b) Ontology evaluation (scoping of Use Case, consistency, competency): the knowledge engineer will evaluate the ontology modules to ensure that its definitions correctly implement the use case requirements and competency questions. The goal of the ontology evaluation is to prove compliance of the world model with the world modeled formally.

c) Use Case instantiation with an illustrative example: the knowledge engineer instantiates scenarios of the use case with an illustrative diagram.

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4.1.4 Step 4: Interaction with stakeholders and ontology formalization

The objective of this step is to interact with stakeholders and to formalize all ontology modules by using an ontology editor and a standard language (e.g., RDF, OWL) and integrate all modules into an ontology system. This step consists of the following tasks:

a) Discussion with stakeholders: if the stakeholder is unsatisfied, the knowledge engineer lists a set of issues and returns to Step 1.

b) Ontology formalization process: if the stakeholder is satisfied, the knowledge engineer proceeds to the formalization process:

- provide an owl file for each new ontology module if created in Step 2.
- provide an RDF file for each use case, describing how the overview model is instantiated.

4.2 Overview of main pilots' topics

In ENERSHARE project, seven pilots are involved. Each pilot can have its specific needs and use cases covering overlapping topics.

Indeed, these pilots share several common notions in different domains. For these use cases design to be harmonized, we need to determine the overlapping concepts that are similar in meaning and are unique to each of the use cases. This step is important in our process to create harmonized semantic data models that include the information of all the use cases.

From the analysis of these pilots, we have roughly identified several topics (see Figure 6):

- Topic 1 (yellow circle) concerns the renewable energy domain (wind turbine, wind farm, hydraulic pitch system, PV system, PV modules, etc.). This topic is found in several ENERSHARE use cases of pilots such as pilot 1, pilot 7 and pilot 3.
- Topic 2 (green circle) concerns the flexibility domain (behavior for flexibility, flexibility of EV, flexibility of end-users, etc.). We identified in this topic, the

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different use cases of pilot 5 (use cases 5a, 5b and 5c), the use cases of pilot 2(use cases 2a, 2b), the use case of pilot 3 and pilot 6.

- Topic 3 (blue circle) concerns the building, its energy consumption and appliances. The use cases 2c and 2d of the pilot 2 are associated to this topic.
- Topic 4 (orange circle) concerns the energy community (energy community, community size, community type, etc.). This topic is related to the use case 2b of the pilot 2 and the use case 5a of the pilot 5.
- Topic 5 (purple circle) concerns the grid domain, and it is related to these use cases 2a, 3 and 4.
- Topic 6 (grey circle) concerns common notions that will be shared by the different use cases such as sensors, weather, forecast, etc.

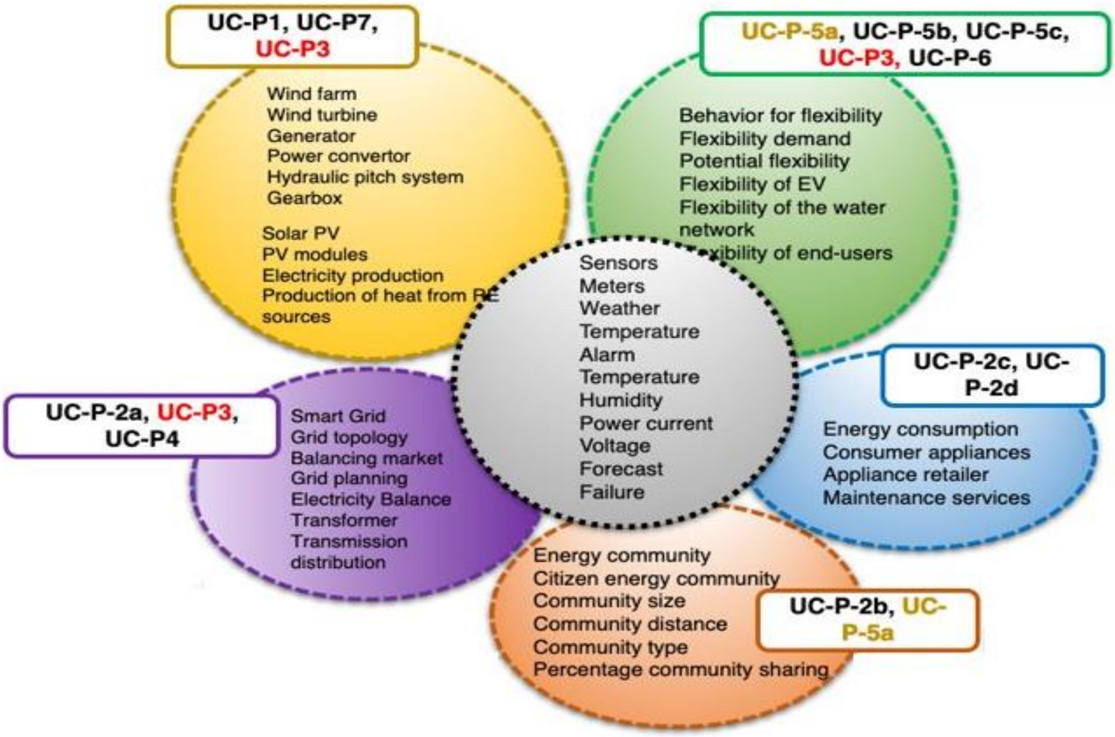

Figure 6: Overview of main topics

The use cases of pilots 3 and 5 are found in several topics such as renewable energy, the flexibility domain, the energy community, and the grid domain.

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In the next section, we present the progress status of the different pilots to apply the methodology to create the semantic data models. We also show some examples of the application of the proposed semantic data models methodology.

4.3 Proposed methodology application

The goal of this section is to describe the application of the proposed methodology for all the use cases of presented pilots in the ENERSHARE project. We defined a common template document that is provided to the different partners to easily define the scope of the domain ontology and exchange with stakeholders.

Different meetings with stakeholders and T3.1 participants are done to follow the steps of the methodology.

In this first period, the current progress status of the pilot use cases is as shown in Table 1.

Teamwork	Pilots	Use Cases	STEP 1				STEP 2	STEP 3	STEP 4
			Use Case Analysis	Ontology scope	Competency questions	Extraction of relevant terms			
Teamwork 1	**Pilot 1:** Wind farm integrated predictive maintenance and supply chain optimisation [**Spain**] - TECN, ENGIE, ACE, HINE	Wind farm integrated predictive maintenance and supply chain optimization							
Teamwork 2	**Pilot 2:** Cross-value chain smart buildings/smart mobility/smart grid services for Local Energy Communities and power network operators [**Portugal**] - INESC TEC, SEL , NESTER	Use Case A - Smart Services in energy communities to support transmission grid operation and planning							
		Use Case B - Instantiation of energy communities and digital simulation of business models							
		Use Case C - Detect irregularities in energy consumption in households with seniors living							
		Use Case D - Suggest maintenance of appliances based on NILM data							
Teamwork 3	**Pilot 3:** Optimal multi-energy vector planning -electricity vs heat [**Slovenia**] - COMS, ENVIRODUAL, ELES, KPV, EKL	Optimal multi-energy vector planning -electricity vs heat							
Teamwork 4	**Pilot 4:** Digital Twin for optimal data-driven Power-to-Gas optimal planning [**Greece**] - NTUA, DEPA	Digital Twin for optimal data-driven Power-to-Gas planning							
Teamwork 5	**Pilot 5:** Cross-value chain data community-centered services for optimising DSO-level grid operation while coordinating with e-mobility and water sectors [**Italy**] - ASM, EMOT, ENG	Use Case A –Cross-sector Flexibility Services for aggregators and DSO							
		Use Case B -Services for e-mobility CPOs, EVs							
		Use Case C - Flexibility provision for electricity grid with water pumps and predictive maintenance of							
Teamwork 6	**Pilot 6:** Aggregation of available flexibility from the behind-the-meter consumers **(Sweden)** - FORTUM	Aggregation of available flexibility from the behind-the-meter consumers							
Teamwork 7	**Pilot 7:** Cross-value chain services for energy-data driven green financing [**Latvia**] - LEIF, NTUA	Cross-value chain services for energy-data driven green financing							

Table 1. Progress Status of ENERSHARE use cases.

In Task 3.1, almost all use cases have finished step 1 and 2 of the proposed methodology. We also have started working in step 3 for several use cases in

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different pilots such as pilots 1, 2, 3, 4, and 7. The following subsections present all the steps (1,2,3) except the step 4, which is not yet started.

4.3.1 Application of Step 1 – Ontology Requirements Specification

As we mentioned above, the step 1 aims, from the list of use cases defined in WP2, to (i) analyse each use case of pilots, (ii) delimit the scope of the ontology, (iii) define the competency questions, and (iv) extract the relevant terms.

From a common template document, each business expert of a pilot described the goal of the use case, the objective to design the ontology and proposed a list of questions that the ontology should be able to answer.

Table 2 shows an example of a use case specification related to the pilot 1 “Wind farm integrated predictive maintenance and supply chain optimization”. The use case aims to design the wind turbine with all components, the maintenance, damages and failures. After discussing with business experts, several natural language questions are defined to validate the semantic data model such as:

- What is the kind of the wind turbine?
- What is the location of the wind turbine?
- What is the typology of the turbine, in terms of speed?
- What are the subsystems of the wind turbine?
- What are the sensors related to a wind turbine, where are they located and what do they measure?

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STEP 1: 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 of 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 subsystems: generator, gearbox, pitch system and power converter: a) wind turbine ontology with all components b) Ontology to represents damages, failures and failures modes related to wind turbine (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 turbine?

Table 2. Example of use case specification in T3.1

In this first step, a list of important terms is extracted. A relevant term can be a list of nouns and/or verbs. A noun represents a candidate concept in the ontology modules and a verb is the relation between concepts. This list of terms should be validated or not by the stakeholders in order to be considered in the semantic data model.

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Table 3 shows an example of the relevant extracted terms from the IEC template of the pilot 1 use case. Different terms are detected such as wind turbine, wind farm, generator, sensors, etc.

Term
Wind farm terms
Wind farm
wind farm name
wind farm location
onshore wind farm
offshore wind farm
Wind Turbine terms
Wind Turbine
wind turbine id
wind turbine manufacturer
wind turbine model
wind turbine power production
wind turbine efficiency (of power production)
Type of existing sensors
Location of existing sensors
frequency sensor (kHz)
vibration (sensor value)
wind turbine nacelle temperature
wind turbine failures
wind turbine controller
pitch control
wind turbine SCADA System
wind turbine manufacturer
wind turbine manufacturer platform
wind turbine manufacturer model
wind turbine power production
Generator terms
electric generator
induction generator (generator type)
Doubly fed induction generator (generator type)
synchronous generator (generator type)
permanent magnet (PM) generator (generator type)
generator manufacturer
generator model
generator bearing

Table 3. Example of term elicitation for the use case of Pilot 1.

4.3.2 Application of Step 2 – Ontology Analysis

The step 2 aims to identify the relevant concepts to be modelled or reused or extended in the semantic data model. For each extracted term in the previous step,

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we associate a concept name (Concept column) or a relation name (Relation column) that will be used in the semantic data model. If the concept already exists in a well-known ontology, we put the existing concept in the column "Reusing Ontology" and if the concept exists in several ontologies, we put all the concepts in the same cell to prepare the mapping between these concepts. Otherwise, if the concept doesn't exist yet in other ontologies, we will see for the concept that could be extended with our new concept and put it in the "Extending ontology" column.

For example, in the Table 4, we have the term *wind turbine*. The concept associated to this term is *WindTurbine*. This concept exists in *ontowind* (*ontowind:WindTurbine*) and *platoon (plt:WindTurbine)* ontologies. In this case, we can reuse existing ontologies for this concept.

Term	is-it considered in the semantic data model ? (YES/NO)	Concept	Concept definition	Relation	Reusing Ontology	Extending Ontology
Wind farm terms						
Wind farm	YES	WindFarm	(wikipedia)A wind farm or wind park,		ontowind:WindPowerPlant, plt:WindFarm	
wind farm name	YES			sch:name, ontowind:name	ontowind:OnshoreWindPowerPlant ontowind:OnshoreWindPowerPlant	
wind farm location	YES		Location where a group of turbines are	geo:location (lat, long, alt)		
onshore wind farm	YES				ontowind:OffshoreWindPowerPlant	
offshore wind farm	YES					
Wind Turbine terms						
Wind Turbine	YES	WindTurbine			ontowind:WindTurbine,plt:WindTurbine	
wind turbine id	YES		Term that identifies each wind turbine	sch:identifier		
wind turbine manufacturer	YES			sch:manufacturer		
wind turbine model	YES			sch:model		
wind turbine power production	YES	PowerProperty	Nominal power of a wind turbine. Units:	producedElectricPower	saref:Power=seas:ElectricPowerProperty	
wind turbine efficiency (of power production)	YES	EfficiencyProperty		seas:efficiency	seas:EfficiencyProperty	saref:Property, seas:Property
Type of existing sensors	YES	ontowind:Anemometer,			Ontowind	
Location of existing sensors	YES	Location		s4bldg:isContainedIn	WGS84 Geo Positioning RDF vocabulary	
frequency sensor (kHz)	YES	FrequencyProperty			seas:FrequencytProperty	
vibration (sensor value)	YES	VibrationProperty			plt:VibrationProperty	
wind turbine nacelle temperature	YES	TemperatureProperty			seas:TemperatureProperty, saref:Temperature	
wind turbine failures	YES	Failure			cim:FailureEvent	
wind turbine controller	YES	WindTurbineController	wind turbine control software designed to maximize production		s4bld:Controller (but it is building controller than not windturbine controller.)	
pitch control	YES	PitchControl			plt:PitchControl	
wind turbine SCADA System	NO		minutes intervals.			
wind turbine manufacturer	YES			sch:manufacturer		
wind turbine manufacturer platform	YES					
wind turbine manufacturer model	YES			sch:model		
wind turbine power production	YES	ElectricEnergyProductionProperty			plt:ElectricEnergyProductionProperty	
Generator terms						
electric generator	YES	Generator	component that transform mechanical power into electrical power		OntoWind:Generator	
induction generator (generator type)	YES	Induction Generator	electric generator type		plt:InductionGenerator	OntoWind:Genrator
Doubly fed induction generator (generator type)	YES	DoublyFedInductionGenerator	electric generator type, included in induction generator		plt:DoubleFedInductionGenerator	OntoWind:Genrator
synchronous generator (generator type)	YES	SynchronousGenerator	electric generator type			OntoWind:Genrator
permanent magnet (PM) generator (generator type)	YES	PermanetMagnet	electric generator type, included in synchronous generator			OntoWind:Genrator
generator manufacturer	YES			sch:manufacturer		
generator model	YES			sch:model		
generator bearing		GeneratorBearing			plt:GeneratorBearing	

Table 4. Example of ontology analysis.

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4.3.3 Application of Step 3 – Overview of ontological modules

This step aims to harmonize all diagrams proposed for each pilot and provide an illustrative example for some semantic data models. The harmonization plays an important role in pilots that present different diagrams for each use case.

But, before the harmonization process, we started working in the ontology diagrams modelling in order to check and validate the design with stakeholders and all T3.1 participants.

Figure 7 shows an extract of the ontology diagram of the wind turbine (pilot 1) that represents the hydraulic system and its components.

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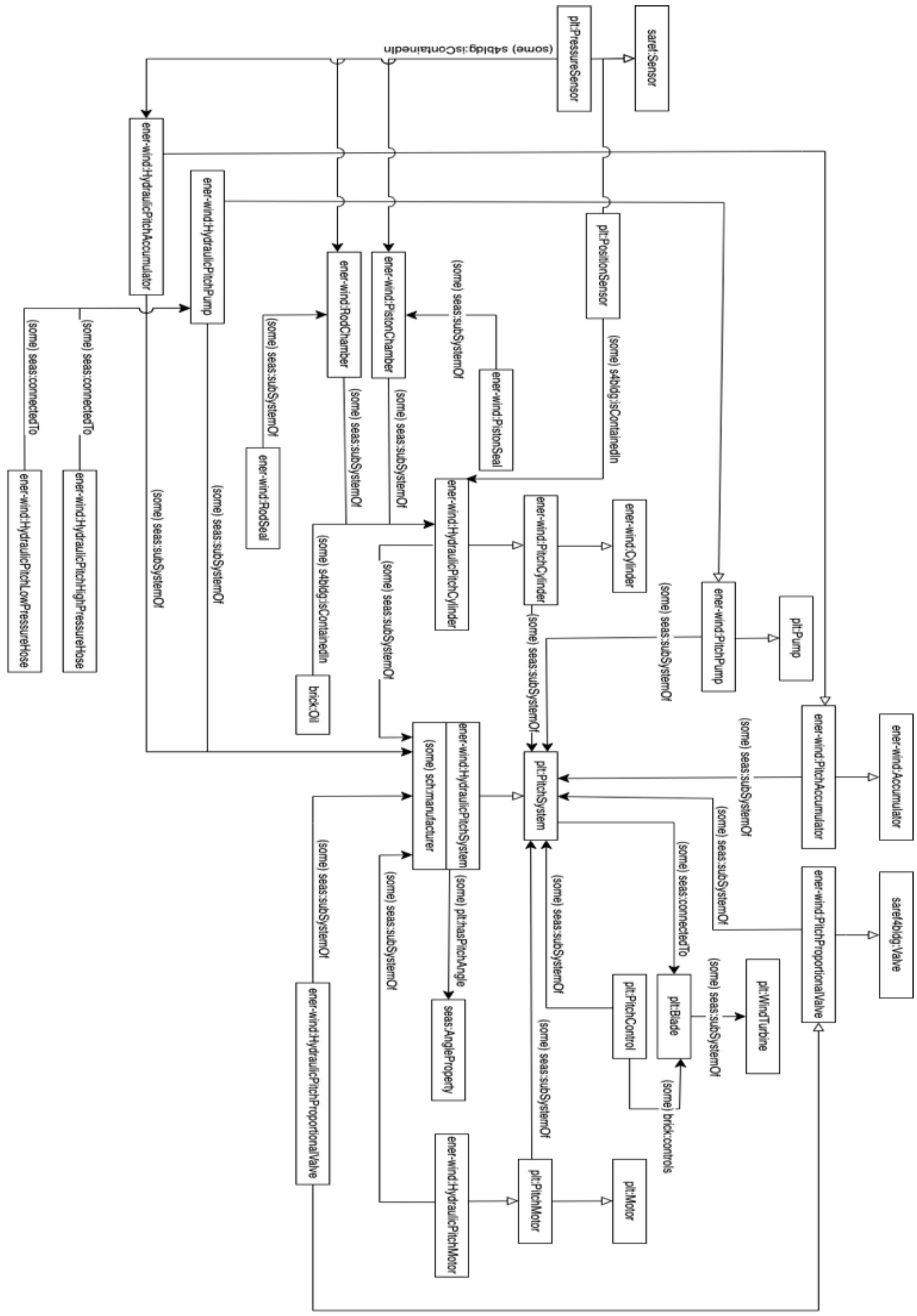

Figure 7. Extract of wind turbine ontology diagram - Hydraulic System (version 1)

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5 List of components conforming the Alpha version

This chapter describes the status of the components of the semantic interoperability building blocks, in this Alpha version.

5.1 Vocabulary Hub & Wizard for generation of Open APIs

5.1.1 Description

The purpose of the Vocabulary Hub in general is to increase semantic interoperability by facilitating data space participants in using standardized vocabularies. In other words: its focus is on adoption of vocabularies by a community of users.

The Vocabulary Hub is intended to be utilized during the *design phase*, when data providers and consumers are creating and configuring their data sharing interfaces. The more emphasis placed on achieving semantic interoperability during this phase, the higher the quality of the metadata. Consequently, the data becomes more discoverable, interoperable, and reusable.

The wizard is part of the Vocabulary Hub and provides users with an easier way to create schemas or even API specifications that are aligned to standardized ontologies. It's a type of wizard because it provides the user with a sequence of steps in their web browser where they:

1. identify and select any appropriate ontology for their use case, e.g., SAREF or OEO; (It can be more than one.)
2. create a data model of their dataset in the Vocabulary Hub by selecting all the classes/properties from the ontology selected at step 1;
3. let the Vocabulary Hub generate a schema or API specification for the data model they created in step 2. At the time of this writing, the Energy Vocabulary Hub supports XML Schema, JSON Schema, RDF/SHACL and Open API Specification (OAS).

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Next to a schema or API specification, the wizard also generates in step 3 an RDF Mapping Language (RML) specification that anyone could use to transform any data that conforms to this data model into a knowledge graph with links to the original ontology selected in step 1.

5.1.2 Current developments in ENERSHARE

As explained in section 2.2, the Energy Vocabulary Hub developed in the ENERSHARE project and its wizard are built on the Semantic Treehouse, i.e., TNO's implementation of the IDS Vocabulary Hub. The platform is implemented as a web application, deployed at https://energy.vocabulary-hub.eu, and available to all ENERSHARE project partners.

Readers can find more documentation of the wizard functionality on the documentation page of Semantic Treehouse.

As mentioned in 2.2.3, three opportunities for the ENERSHARE project to extend its range of functionalities have been identified:

1. Extending the wizard to support standardized vocabularies in other formats or serializations in addition to RDFS/OWL and SHACL.
2. Implement support for the five-star framework for vocabulary use into the Energy Vocabulary Hub
3. Adding CSVW support in the wizard

In this alpha version, the work is focusing on the first point. The wizard is being extended to support vocabularies that use JSON schema (e.g., formalized as JSON, JSON-LD or NGSI-LD).

5.2 Data Exchange in one-to-one communications

As explained in section 3.3, secure and trusted data exchange in one-to-one communications is guaranteed between provider and consumer using IDS connectors.

IDS connectors need to deal with both the control plane and the data plane. The control plane manages contract negotiation and the data transfer process, whereas the data plane performs the actual data transfer.

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One of the goals of WP3 is to define the data exchange APIs of the data plane. When two parties exchange data, one of them plays the role of Data Provider (by making the data technically available for being transmitted) and the other plays the role of Data Consumer (by receiving the data from a Data Provider).

Taking into account the services that are being defined in task 6.2 and task 6.3 and the needs of each of the pilots, there will be two possible ways to exchange data: synchronously or asynchronously. In the first case, the consumer requests data to the provider and receives an answer immediately. In the second case, the provider needs some time to prepare the response data (e.g., some machine or deep learning algorithms need to be executed which might take minutes or even hours). Once the data is ready, the provider will notify the consumer.

According to the IDS architecture, the communication is always started by the consumer using IDS Messages. The most common way to exchange these IDS-Messages in an IDS data ecosystem between the participants are multipart messages. IDS multipart messages consist of two parts, a header and a payload. The header part contains the actual IDS-Message, such as a ConnectorUpdateMessage, a DescriptionRequestMessage or ArtifactRequestMessage. A payload may be required for some IDS multipart message types, but it does not always have to be [23].

From the complete list of IDS Messages, the subset of messages that are involved in a scenario of data exchange are the following:

- ArtifactRequestMessage: Message asking for retrieving the specified Artifact as the payload of an ArtifactResponse message. This message doesn't have a payload.
- ArtifactResponseMessage: Message that follows up a ArtifactRequestMessage and contains the Artifact's data in the payload section.
- NotificationMessage: Notification messages are informative, and no response is expected by the sender. May be used for scenarios, which are not covered by the core IDS messages.

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5.2.1 Message sequence for synchronous data exchange

The first message that needs to be sent by a consumer when asking for a given artifact is of type ArtifactRequestMessage.

The consumer connector with endpoint, e.g., https://enershare-pilot-1:8084/proxy, sends an HTTP POST request to the connector's endpoint of the provider. For messages of type ArtifactRequestMessage, the following data needs to be provided in the body of the message:

```
{
        "multipart": "form",
        "Forward-To": "https://enershare-windturbine:8889/data"
        "messageType": "ArtifactRequestMessage",
        "requestedArtifact":
"http://companyA.com/enershare/resource/windturbine"
 }
```

"Forward-to" points to the connector's endpoint of the provider and "requestedArtifact" identifies the artifact and the data to be retrieved.

If the requested data is available, the provider will respond with an ArtifactResponseMessage.

The payload will contain the requested data which will be formatted according to the ENERSHARE ontology either in JSON-LD or NGSI-LD format. To define these specifications, the Vocabulary Hub's wizard will be used.

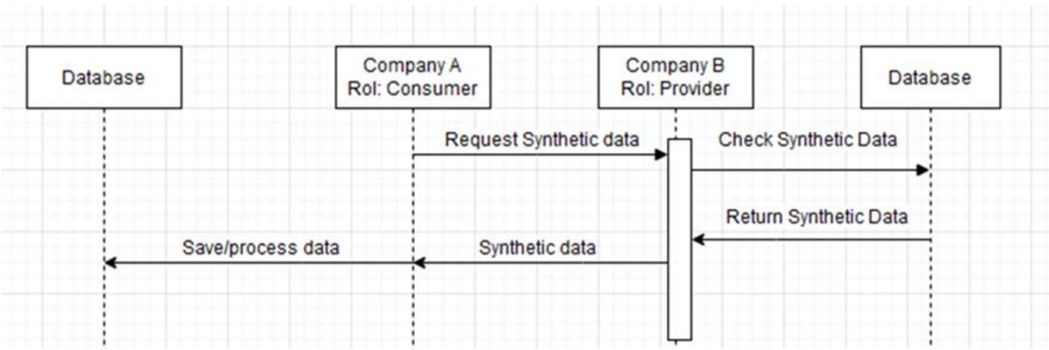

Figure 8. Message sequence for synchronous data exchange without input parameters.

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In some cases, input parameters need to be specified so that the service is able to retrieve the appropriate data. For example, the service that performs a benchmarking of wind turbines, needs as input the wind turbine models to be compared and their characteristics: power, generator technology (PM/DFIG), and pitch system manufacturer.

As the ArtifactRequestMessage does not have a payload, if the input data is just one value (such as an identifier), it could be included as part of the string provided in the requestedArtifact field. However, if the input parameters are more than one, we propose the following message sequence:

1. Company A (consumer role) sends a message of type ArtifactRequestMessage asking for a given artifact to Company B.
2. Company B (provider role) realises that input parameters are needed, so Company B rejects the request by sending a RejectionMessage.
3. Company B (now playing the role of a consumer) sends a message of type ArtifactRequestMessage asking for the value of the input parameters.
4. Company A (now playing the role of a provider) sends a message of type ArtifactResponseMessage with the value of the input parameters.
5. Company A (playing the role of a consumer) sends a message of type ArtifactRequestMessage asking again for the artifact.
6. Company B (playing the role of a provider) sends a message of type ArtifactResponseMessage with the requested data for the given artifact.

We suggest using the following 3 patterns for the strings to include in the requestedArtifact field:

- http://enershare.com/serviceName/UUID : First message used to request a given artifact
- http://enershare.com/serviceName/Input/UUID : Message used to request the values of the input parameters needed to execute the service
- http://enershare.com/serviceName/Output/UUID : Message used to request the output data once the input parameters have been sent.

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where:

- *serviceName* identifies each of the service functionalities, e.g., generateSyntheticData, or windTurbineBenchmarking.
- *UUID* represents a unique identifier that allows grouping the messages that correspond to the same request of data.

5.2.2 Message sequence for asynchronous data exchange

As in the previous case, the first message that needs to be sent by a consumer (Company A) when asking for a given artifact is of type ArtifactRequestMessage.

In this case, the provider (Company B) needs time to acquire the requested data so the Company B will need to reject the message. In the case where the artifact needs input parameters, Company B will need to request the input parameters.

Once the data is ready, Company B will send a message of type NotificationMessage informing that the data is available. Company A will request the data again using an ArtifactRequestMessage. Company B will send an ArtifactResponseMessage with a payload that contains the requested data.

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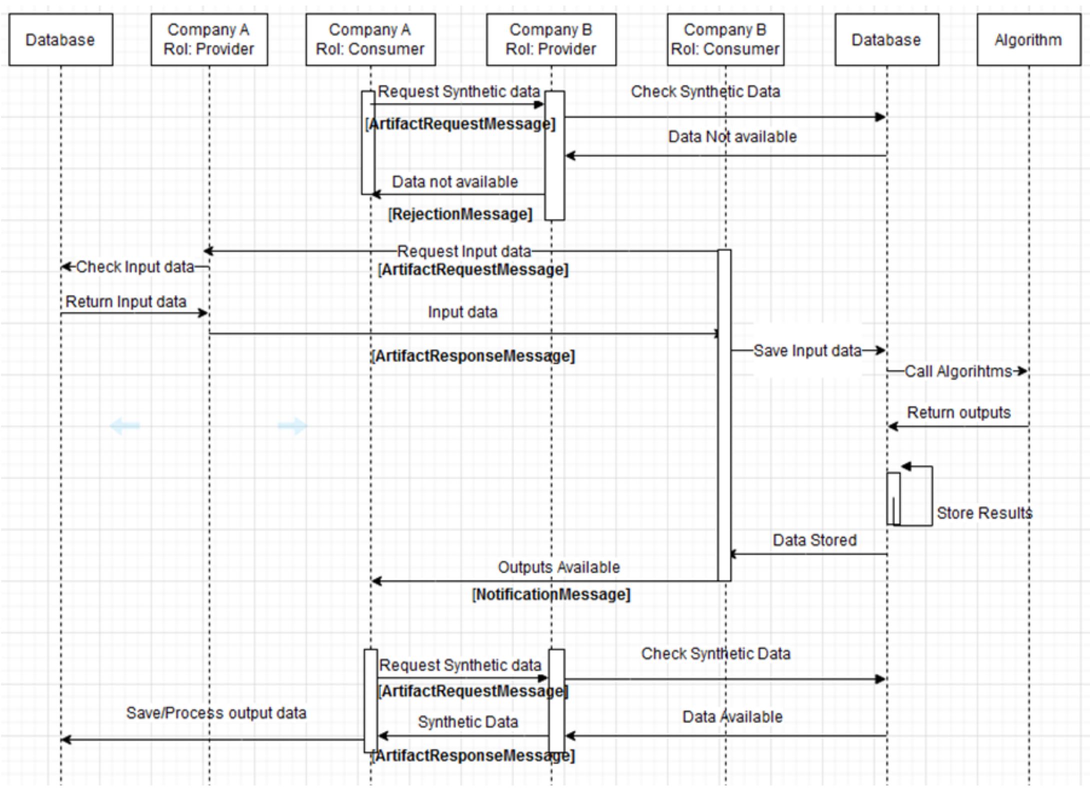

Figure 9. Message sequence for asynchronous data exchange with input parameters.

We suggest using the following 3 patterns for the strings to include in the requestedArtifact field:

- http://enershare.com/serviceName/UUID : First message used to request a given artifact
- http://enershare.com/serviceName/Input/UUID : Message used to request the values of the input parameters needed to execute the service
- http://enershare.com/serviceName/Output/UUID : Message used to request the output data once the service has been executed and a notification message has been received by the consumer.

where:

- *serviceName* identifies each of the service functionalities, e.g., generateSyntheticData, or windTurbineBenchmarking.

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- *UUID* represents a unique identifier that allows grouping the messages that correspond to the same request of data.

5.3 Context Broker

The following FIWARE Context Broker implementations, supporting the ETSI NGSI-LD 1.3.1. API specifications or higher are available:

- The Orion-LD Context Broker Generic Enabler [16] is a NGSI-LD Broker, which supports both NGSI-LD and the NGSI-v2 APIs.
- The Scorpio Broker Generic Enabler [17] is an alternative NGSI-LD Broker which can also be used in federated environments.
- The Stellio Context Broker Generic Enabler [18] is another alternative NGSI-LD Broker.

Besides, the NGSI.JS library provides a series of JavaScript functions allowing developers to connect and push context data to any NGSI compliant context broker.

5.3.1 Comparison between Orion-LD, Scorpio and Stellio

Different needs would lead to prioritizing different versions of the context brokers. Currently there are three main options provided by FIWARE (i.e., Orion-LD, Scorpio and Stellio) but in the near future others could be implemented as long as the specification is open, and anybody, potentially, could implement a new one. In this section we provide a comparison based on functional and performance evaluation.

In [19] the authors perform a functional evaluation of these three implementations as publish-subscribe systems. The three FIWARE implementations adopt the NGSI-LD information model for context data. As Scorpio and Stellio are based on Apache Kafka, an open-source distributed event streaming platform, they are error-tolerant which makes them useful in cases where messages should not be lost. For applications that process messages in real-time, Scorpio, and Stellio are the best solutions. Besides, both Scorpio and Stellio can connect to other external systems thanks to the Connector API of Kafka. The three implementations, namely Orion-LD, Scorpio, and Stellio, offer support for broker federation and broker clustering. They leverage Apache Kafka, where messages in Scorpio and Stellio are stored in multiple copies across partitions and queues. In terms of data persistence, messages in all

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three systems are stored on disk. Regarding security, all systems provide at least basic user identification and authorization mechanisms. Scorpio goes a step further by implementing OAuth2.0 for user identification. For a comprehensive overview of the main features, please refer to Table 5 in [19].

Feature	Orion-LD	Scorpio	Stellio
Open-Source	√	√	√
Language	C, C++	Java	Kotlin
Learning Difficulty	2/5	2/5	2/5
Message Format	NGSI-LD	NGSI-LD	NGSI-LD
Stream Processing	Stream API	Stream API	Stream API
Broker Clustering	High availability mode	√	√
Broker Federation	√	√	√
Fault Tolerance	High availability mode	√	√
Message Queries	√	√	√
Message Updates	√	√	√
Message Retention	√	√	√
Message Replication	√	√	√
Acknowledgement of Receipt	√	√	√
Message Delivery	Push, Pull	Push, Pull	Push, Pull
Message Storage	Mongo DB	PostgreSQL	Neo4j, TimescDB, PostGIS
Connection Encryption	SSL	No Info	No Info
Authentication, Authorization	CORS	LDAP, SASL, OAuth2.0	OAuth2.0
Protocol	HTTP	HTTP	HTTP

Table 5. Publish-Subscribe Systems comparison

In terms of performance comparison, to ensure a fair assessment, Orion-LD needs to be supplemented with Mintaka software [20] when comparing it with Scorpio and Stellio. Mintaka is an implementation of the NGSI-LD temporal retrieval API. In Appendix 8.1, you will find a performance comparison of the three FIWARE brokers.

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5.3.2 Current developments in ENERSHARE

The Digital Enabler [21] is an "Ecosystem" platform developed by Engineering, which provides a set of services and tools for data discovery, data collection, data integration, data harmonization and data visualization.

Since its birth, the Digital Enabler (DE) platform has been powered by FIWARE and by the Orion Context Broker, which has played an instrumental role in the architecture of the platform.

This powerful tool has facilitated the seamless integration and management of heterogeneous data sources, allowing several platform actors to access and analyze data in a flexible and efficient way.

In the context of the ENERSHARE project, it has become increasingly evident that the capacity to store and query Linked Data is a truly relevant aspect for achieving the project's overarching objectives. Recognizing this crucial need, a significant upgrade of the Context Broker in the Digital Enabler platform has been conducted, transitioning from the original version to the more advanced Orion-LD that supports Linked Data capabilities.

This upgrade represents a crucial milestone for the DE platform and for the ENERSHARE project as whole, empowering it to harness the full potential of Linked Data. With the integration of the Orion-LD Context Broker, the Digital Enabler is set to enhance its capabilities as a robust data management tool, capable of transforming numerous industries and applications, particularly in the energy sector. This advancement will empower users to gain novel insights, optimize current operations, and foster innovation across various domains.

5.4 Data Mashup Editor

5.4.1 Description

The Data Mashup Editor is a versatile tool that can be used in a variety of use cases, including data harmonization and data transformation. Data harmonization involves the process of bringing together data from various sources and making it consistent, accurate, and usable. Data transformation, on the other hand, involves the process

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of converting data from one format to another, or from one system to another. The Data Mashup Editor can be used at runtime e.g., by connectors, to create data transformation workflows that can convert data stored in the provider's systems into the NGSI-LD format defined according to the OpenAPIs (from T3.2) before sending the data to the consumer.

5.4.2 Existing implementation offered by the Digital Enabler

As mentioned before, the Digital Enabler [21] is an "Ecosystem" platform developed by Engineering, which provides a set of services and tools for data discovery, data collection, data integration, data harmonization and data visualization.

As part of these services, the Digital Enabler offers a Data Mashup Editor. Such a tool enables users to build correlations between different datasets and create Smart Data Models in a graphical way (no-code).

The tool offers a wide range of assets that can be combined to create highly sophisticated and customizable business logic.

The Data Mashup relies on the interoperation of 4 main assets: the first one is the Operator. It is a component that performs a specific data processing task and can be combined with other operators to create more complex business logic. The Mashup Editor includes a wide range of atomic operators that can perform common data processing tasks such as atomic data manipulation, filtering, and aggregating data. In addition to the atomic operations, the Mashup Editor also provides composite operators, which are a combination of multiple simple operators into a single, more complex one. This allows users to create highly sophisticated data processing workflows that can handle large volumes of data with ease. The Mashup Editor also includes custom operators that users can create themselves using JavaScript programming language. This feature enables users to extend the functionality of the Mashup Editor and create operators that are tailored to their specific needs.

Another critical asset in the Data Mashup Editor is the Datasource, providing users with access to external data sets and APIs that can be integrated into data processing workflows. A Datasource in the Data Mashup describes a set of OpenAPI v3 compliant HTTP endpoints that can be invoked during the Mashup execution. This flexibility enables users to integrate data from multiple sources into a single

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workflow, allowing them to gain valuable insights from diverse data sets. One of the key benefits of using Datasources in the Mashup Editor is that they enable users to work with live data, ensuring that the data used in the data processing workflows is always up to date.

The visual representation of a series of data processing steps that includes one or more Operators and one or more Datasources is called Mashup. It is one of the central concepts in the Data Mashup Editor and represents a complete data processing workflow from the input data to the final output. One of the key benefits of the Mashup is its ability to provide a clear and easy-to-understand overview of the entire data processing workflow. The visual representation of the workflow makes it easy for users to comprehend the data processing logic and identify any potential issues or inefficiencies. The Mashup Editor allows users to create highly customizable Mashups by combining a wide range of Operators and Datasources in various ways. Users can drag and drop Operators and Datasources onto the Mashup canvas, connect them in a specific order, and configure their properties as needed.

Additionally, the Mashup Editor enables users to create multiple versions of a Mashup and deploy them as Flows. Each Mashup version can have different inputs, outputs, Operators, and Datasources, allowing users to create highly tailored workflows for specific data processing tasks. Finally, the Mashup Editor also provides users with the ability to monitor and debug Mashup execution in real-time. This feature enables users to identify and address any issues that arise during data processing, ensuring that the workflow runs smoothly and efficiently. The Flow is an essential concept in the Data Mashup Editor that enables users to deploy and execute their Mashups in a production environment. Once a Mashup has been designed and tested, it can be saved as a Flow, which is a real-world deployment of the Mashup.

The Flow is a 1:1 relation with a specific Mashup version and defines the input and output data sources for the Mashup. Each Flow has only one trigger, which is an event that starts the execution of the Mashup. The event can be a time-based schedule, a message received via HTTP, MQTT, or Kafka, or any other custom event. Once the Flow is triggered, the Mashup executes and generates the desired output, which can then be published to one or more target systems. The Flow supports multiple targets, which are sink systems where the Mashup output is published.

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These targets can be databases, web services, messaging queues, or any other system that can consume data. The Flow also provides users with the ability to monitor and manage their Mashup execution in real-time. Users can monitor the status of their Flows, view execution logs, and receive notifications of any errors or issues that arise during execution.

5.4.3 Developments within ENERSHARE

In the ENERSHARE project, the Data Mashup Editor will be used as runtime for data transformation and harmonization. With the help of the Mashup Editor's functionalities, we can quickly and easily compose complex business logic that can handle large volumes of data. The graphical representation of the Mashup process allows us to easily understand and monitor our data processing in real-time, making it an ideal choice for the runtime aspect of our project.

In the data harmonization and transformation processes to be carried out in each of the pilots, the Data Mashup Editor will facilitate the task of bringing together data from various sources and transforming it into the common semantic data model defined in ENERSHARE. The Vocabulary Hub will act as a registry of data models for the Energy domain and its wizard will facilitate the creation, at design time, of the Open APIs specifications. In addition, the Data Mashup Editor uses those models and specifications enabling the creation of complex data processing workflows that can harmonize the data in runtime.

Data transformation, on the other hand, involves the process of converting data from one format to another, or from one system to another. The Data Mashup Editor can be used to create and trigger data transformation workflows that can convert data from the format used by the provider to the unified data format (NGSI-LD compliant) proposed in ENERSHARE.

Within the ENERSHARE project, significant progress is expected in the advancement of the Data Mashup Editor. The main results primarily revolve around integrating it with the Vocabulary Hub and developing dedicated operators that enable the tool to manipulate data and structures specific to the energy domain. This integration will enhance the capabilities of the Data Mashup Editor, empowering users to work seamlessly with energy-related data making it a valuable resource for stakeholders in the energy sector.

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Due to the variety of use cases in the energy domain and more specifically in the ENERSHARE project, the pilots require a robust and reliable data processing solution, and the Data Mashup Editor offers the flexibility and scalability that is needed. By using this tool, we can efficiently process large amounts of data and combine different data sources.

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6 Conclusions and future work for Beta version of the document

This deliverable presents the first results on the design and development of the intra-energy and cross-sector Data Space interoperability building blocks. As there are already plenty of generic technical solutions and standards available in the market for data spaces, the focus is set on data sharing across energy sectors and on cross-domain data space data sharing, exchange, and reuse.

A common semantic data model is a central element to ensure semantic interoperability between heterogeneous systems. The scope of this model has been defined according to the application domain of the seven pilots. Business and technical experts have been working together to identify concepts and relationships in the energy domain. The purpose is not to design another model from scratch but to reuse, whenever possible, concepts from existing ontologies and to extend the models to cover new concepts or attributes.

Tools like the Vocabulary Hub are very useful in a data space ecosystem allowing users to find relevant vocabularies, interact with them while checking available properties and metadata information.

Data exchanging between services can imply one-to-one or one-to-many communications. IDS connectors are the proposed solution for one-to-one data transfers, whereas a Context Broker based solution seems more appropriate for one-to-many data transfers. In both cases, Open APIs based on a common semantic data model are needed to ensure semantic interoperability.

The future work for the beta version will address the completion of the missing steps of the methodology to define the ENERSHARE ontology and the creation of the knowledge graphs (JSON-LD and NGSI-LD) for the data services Open APIs. Besides, the work will also focus on enhancing the functionalities of the building blocks for sematic interoperability, i.e., the Context Broker, the Vocabulary Hub and the Data Mashup Editor, as described in section 5.

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8 Appendix

8.1 Performance comparison between different context brokers

The results shown here are the results of a performance test done with a configuration based on a Kubernetes environment hosted on OVHCloud. These results were obtained in the project GreenMov [24]. It is worth to be noted that these benchmarks are only assessing performance in simple configuration and

1) Additional optimization in the configurations could make radical changes to the results
2) Performance is only one of the possible characteristics to be compared between different brokers, ability to be federated, persistence of the data, etc. are examples of others features to be assessed

The cluster characteristics were: 2 CPU, 8 GB of RAM and 50 GB of storage. The test tool that has been chosen is Hyperfoil. It is a web benchmark tool, licensed under Apache.

The first benchmark was about the number of updates a broker can support per second depending on the number of entities in the broker via POST "/ngsi-ld/v1/entities/<ENTITY_ID>/attrs".

The second benchmark was about the number of GET requests a broker can handle per second retrieving all entities in the broker via GET "/ngsi-ld/v1/entities?type=AirQualityObserved".

The third benchmark was about the number of GET requests a broker can handle per second when retrieving one single entity via GET "/ngsi-ld/v1/entities?type=AirQualityObserved&id=<ENTITY_ID>".

The fourth benchmark was about the number of GET requests, a broker can support per second for historic data depending on the number of updates via GET "/ngsi-ld/v1/temporal/entities/<ENTITY_ID>". For each entity update, 5 attributes of the entity were updated. There was only one entity into the broker.

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Finally, one last benchmark has been performed with a bigger Cluster Environment to test if horizontal scaling could improve the results. A Kubernetes environment hosted on OVHCloud has been used with 2 nodes with 4 CPU, 15GB of RAM and 100GB of storage. The choice has been made to make again the fourth benchmark describe above in order to compare the results.

Figure 10 shows the results describing the evolution of the number of updates per seconds according to the number of entities inside the broker.

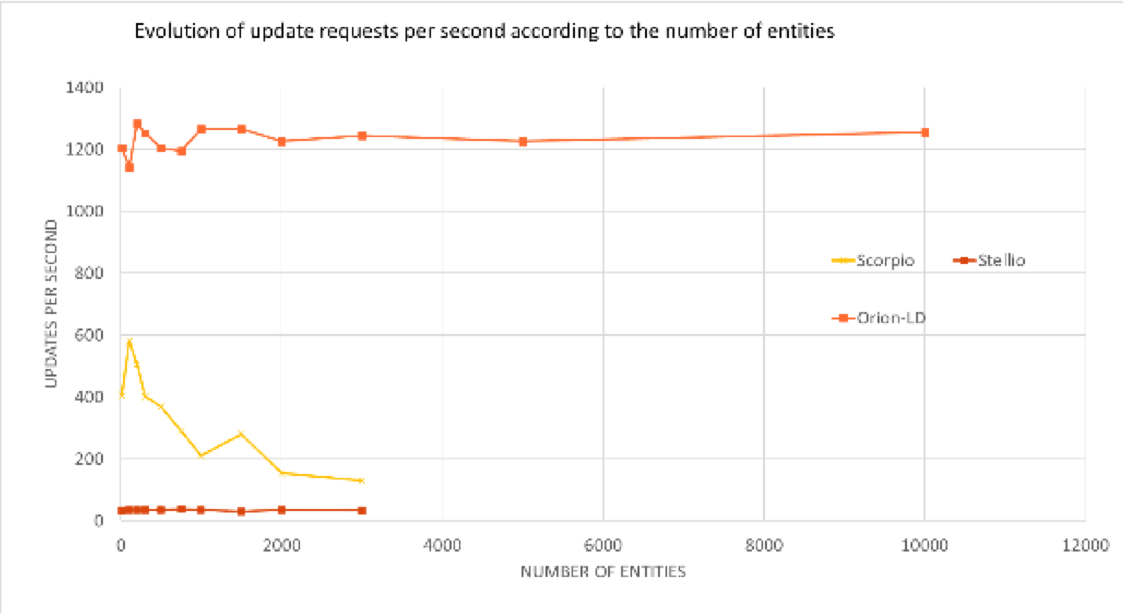

Figure 10. Evolution of update requests per second according to the number of entities.

Figure 11 shows the results for benchmark number 2, about the number of queries brokers can handle when retrieving all entities depending on the number of entities.

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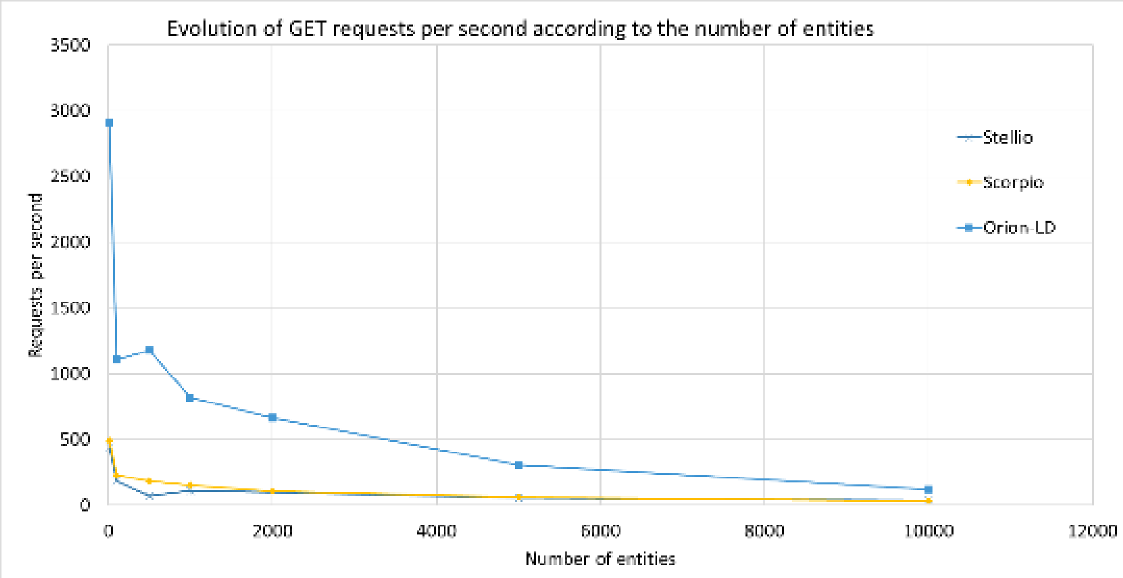

Figure 11. Evolution of query rate for all entities according to the number of entities.

Figure 12 provide the graph describing the number of queries each broker can support when retrieving one single entity depending on the number of entities.

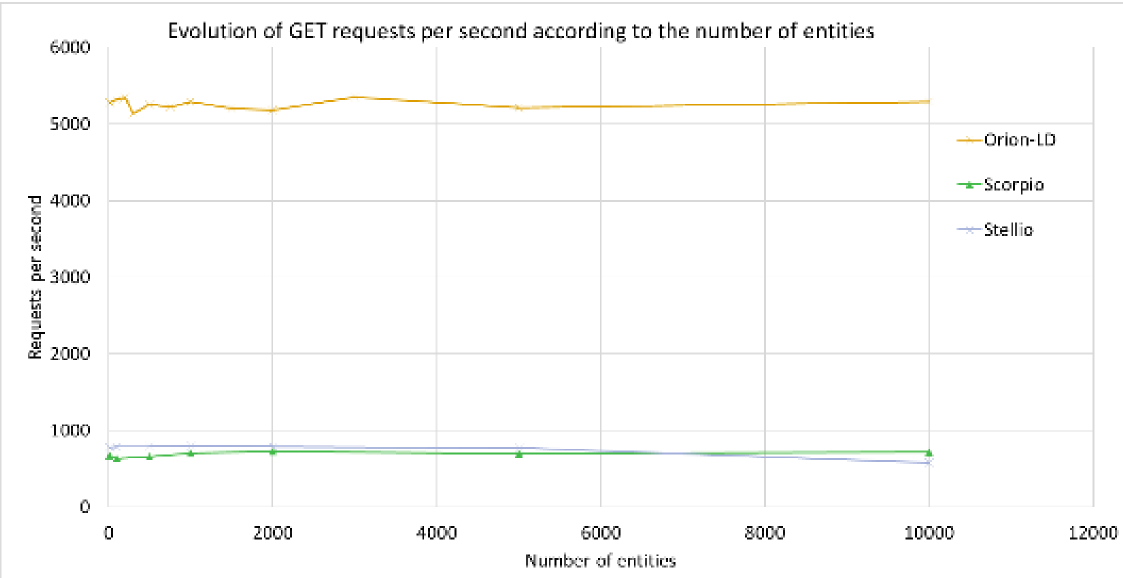

Figure 12. Evolution of queries rate for one entity according to the number of entities.

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Figure 13 depicts the results for benchmark number 4, describing the evolution of queries per seconds on temporal interface according to the number of updates.

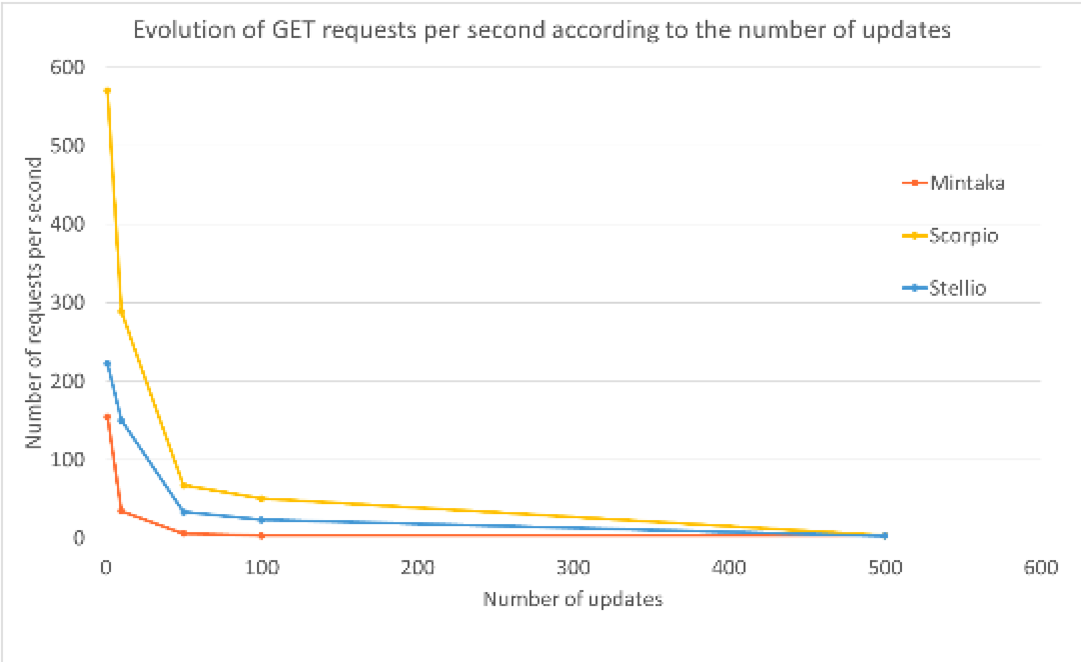

Figure 13. Evolution of queries rate according to the number of updates.

Figure 14 shows the graph that corresponds to the same benchmark than the one above but with a Kubernetes cluster with more resources.

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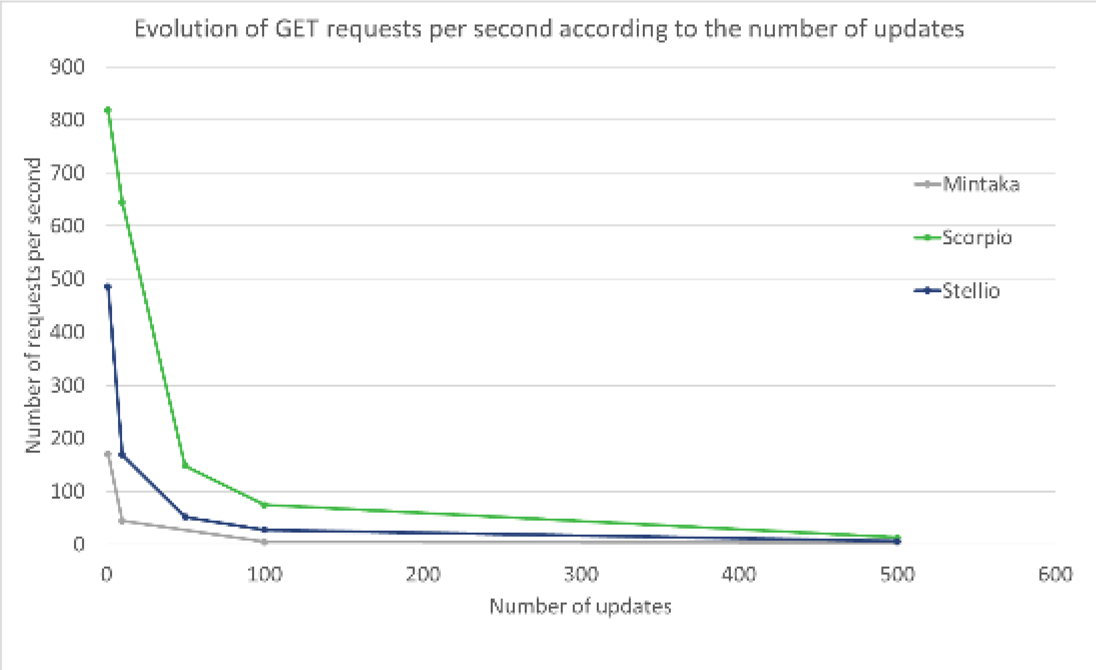

Figure 14. Evolution of query rate according to the number of updates with a bigger Kubernetes cluster.

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