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

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D3.2 ENERSHARE interoperability building blocks

Beta version

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Publication details

Grant Agreement Number	101069831
Acronym	ENERSHARE
Full Title	European Common Energy Data Space Framework Enabling Data Sharing-Driven Across — and Beyond — Energy Services
Topic	HORIZON-CL5-2021-D3-01-01 'Establish the grounds for a common European energy data space'
Funding scheme	HORIZON-IA: Innovation Action
Start Date	Jul 1, 2022
Duration	36 months
Project URL	enershare.eu
Project Coordinator	Engineering
Deliverable	D3.2. – ENERSHARE interoperability building blocks. Beta version
Work Package	WP3 – Extended intra-energy and cross-sector Data Space interoperability building blocks
Delivery Month (DoA)	M18
Version	1.0
Actual Delivery Date	December 19, 2023
Nature	Report

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Dissemination Level	PU
Lead Beneficiary	TECNALIA
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Quality Reviewer(s)	Eric Suignard (EDF) and Chiara Maria Capizzi (ENG)
Keywords	Semantic Interoperability, ontology, IDS connector, Open API, Vocabulary Hub, Context Broker, Data Mashup, Data Exchange Interoperability

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Document History

Ver.	Date	Description	Author	Partner
0.1	Oct 17, 2023	ToC & summary from alpha version	Sonia Bilbao, Ainhoa Pujana	TECNALIA
0.2.1	Nov 15, 2023	Vocabulary Hub	Wouter van den Berg	TNO
0.2.2	Nov 16, 2023	ENERSHARE data model	Lynda Temal	ENGIE
0.3.1	Nov 20, 2023	Data Mashup Editor	Chiara Capizzi	ENGINEERING
0.3.2	Nov 22, 2023	Update of section 2 and inclusion of Data Exchange Interoperability	Sonia Bilbao, Adelaida Lejarazu	TECNALIA
0.3.3	Nov 22, 2023	Section 1.5.1, 3.4 and appendix 8 with diagrams for step 3	Lynda Temal	ENGIE
0.4	Nov 28, 2023	Open APIs, data transformation and compliance services. Conclusions	Sonia Bilbao, Adelaida Lejarazu	TECNALIA
0.5	Nov 29, 2023	Context broker information update	Alberto Abella	FIWARE
	Nov 29, 2023	Vocabulary Hub information update	Wouter van den Berg	TNO
	Nov 30, 2023	Data mashup information update	Alessandro Lucani, Chiara Capizzi	ENGINEERING
	Nov 30, 2023	Consolidated	Sonia BILBAO	TECNALIA
0.6	Nov 30, 2023	Reviewed	Eric Suignard	EDF
	Dec 14, 2023	Reviewed	Chiara Capizzi	ENGINEERING

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0.7	Dec 15, 2023	Added information on compatibility with IEC 61850-7-2, IEC 61968-100 and usage control policies to address reviewers' comments	Eric Suignard, Ricardo Jover, Eric Lambert/ Adelaida Lejarazu, Sonia Bilbao	EDF / TECNALIA
1.0	Dec 19, 2023	Final Version	Sonia BILBAO, Ainhoa PUJANA	TECNALIA

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List of Acronyms

ACSI	Abstract Communication Service Interface
API	Application Programming Interface
BD4NRG	Big Data for Next-Generation Energy
CSV	Comma-Separated Values
DE	Digital Enabler
DME	Data Mashup Editor
DSBA	Data Spaces Business Alliance
DSO	Distribution System Operator
EC	European Commission
EO	Earth Observation
EV	Electric Vehicle
GUI	Graphical user Interface
HTTP	Hypertext Transfer Protocol
IDS	International Data Spaces
IDSA	International Data Spaces Association
IED	Intelligent Electronic Device
JSON	JavaScript Object Notation
JSON-LD	JavaScript Object Notation for Linked Data
NGSI	Next Generation Service Interfaces
OEO	Open Energy Ontology

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PV	Photovoltaic
RDF	Resource Description Framework
RML	RDF Mapping Language
SHACL	Shapes Constraint Language
SAREF	Smart Applications REFerence
TSG	TNO Security Gateway
TSO	Transmission System Operator
UC	Use Case
UTC	Universal Time Coordinated
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 second of a series of 3 (alpha, beta and final version), will present the intermediary 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 second of a series of 3 (alpha, beta and final version), presents the intermediary 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.

This document aims to be self-contained when presenting the intermediary results. For this reason, the deliverable contains updated information of sections in D3.1, plus extra sections with the new results of this beta version.

D3.1 also provided an analysis of how four EU projects and initiatives (i.e., PLATOON[1], BD4NRG[2], Interconnect[3] and OneNet[4]) have addressed the challenges of semantic interoperability in the energy domain, and how their results could be used and enhanced in the ENERSHARE project. Here, in D3.2, we present a summary of how some of the results from PLATOON (i.e., methodology and ontology) and BD4NRG (i.e., Vocabulary Hub) are being used in ENERSHARE's beta version.

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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. Although the first two steps were finalised for most use cases in the alpha version, the information is kept in this deliverable to ensure completeness and facilitate its comprehension to the user. In the final deliverable D3.3, we will only include the final version of the ontology and diagrams and we will refer to D3.2 for the methodology.

Additionally, the document outlines the architecture and scope of the building blocks designed to facilitate data exchange and 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 D2.5.

Finally, the deliverable describes the list of software components conforming the beta version.

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 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 6 chapters and 2 appendixes.

- Chapter 1 is this introduction and an overview of the updates from the alpha version to the beta version.
- Chapter 2 describes the architecture and the scope of the main functional components for data interoperability which have been identified in WP3.
- Chapter 3 explains the 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.

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- Chapter 4 addresses the list of software components that make up the Beta version.
- Chapter 5 presents some conclusions and the future work planned for the final version.
- Chapter 6 includes the list of references.
- Finally, appendices 7 and 8 provide examples of the diagrams developed from step 3 of the methodology and examples for the data transformation and compliance services.

1.5 Overview of the updates in beta version

In this chapter, an overview of the work progress performed in this beta version is presented.

1.5.1 Methodology and data model updates

As mentioned in the deliverable D3.1, to create the semantic data model for the ENERSHARE project, we followed the methodology proposed and applied in the PLATOON project. In the deliverable D3.1, we provided an overview of the methodology used in the PLATOON project and presented the progress of all ENERSHARE project pilots for the initial two steps of this methodology. In deliverable D3.2, we provide additional updates on the steps. Firstly, section 3.1 outlines the methodology based on the PLATOON background, providing some updates. Section 3.2 reminds the identified topics of the different pilots. Section 3.3 showcases the overall progress of all pilots, detailing adjustments made to the methodology and providing more information on the initial two steps from the previous deliverable. Section 3.4 outlines the upcoming steps. Finally, the appendix 7 includes diagrams for each pilot created during this second phase, offering a clear view of the progress.

1.5.2 Vocabulary Hub updates

The Vocabulary Hub and its accompanying wizard component were introduced in the ENERSHARE deliverable D3.1 alpha release. They have undergone further development and have two new features developed for the Beta release iteration.

This update enables data providers to leverage JSON Schema to accurately describe and structure their data sources. This improves interoperability because some

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common vocabularies such as Smart Data Models are published as JSON Schema. Additionally, the wizard now offers the capability to generate a data model directly from a data sample. This feature allows providers to use real data examples as a basis for defining a data model that includes terms and their definitions, thereby specifying the dataset's vocabulary use in a lightweight manner. Together, these improvements aim to enhance semantic interoperability and data reusability within the decentralized data spaces.

1.5.3 Data exchange updates (Open APIs, Data Transformation and Compliance)

This beta version includes a description of how the Open APIs are being defined for the pilot use cases. A new approach for data exchange interoperability, based on data transformations, is proposed. This approach is also suitable for low latency and big volumes of data exchange. Two new services have been implemented: the data transformation service and the compliance service. Examples of mapping rules and shapes files are also included.

Besides, a new section has been included explaining the compatibility of ENERSHARE with IEC standards to exchange information in the electricity domain, i.e., IEC 61850-7-2 and IEC 61968-100.

1.5.4 Context broker updates (FIWARE/ENG)

The NGSI-LD 1.7.1 specification [5], the specification basis for the context brokers, was released in June 2023, five months earlier than this document has been written, therefore software implementations are in the process of being created, tested, released, and integrated into solutions like the Data Mashup. Consequently, the context brokers implementations available (Orion-LD, Scorpio and Stellio) are based on NGSI-LD 1.6.1 specifications which their last updates are:

- Extended functionalities for the registration (registration refers to the process of allowing some or all data within an entity to be provided by an external context provider).
- New functionalities for the updating of information in existing entities stored in the context broker.

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- Improvements when inserting, updating, and deleting entities in batch mode (massive processing of entities).
- Improvements on the distributed operation when brokers' instances are working as a federation. Federation means that context brokers can retrieve information from other federated instances.

1.5.5 Data Mashup updates

In the latest developments, we have introduced the capability to define custom operators for encapsulating reusable JavaScript logic across diverse mashups. This functionality not only allows for the customization of operators to meet specific requirements but also presents extensive integration opportunities for logic pertaining to the energy domain. These custom operators could also be used to define operations on data to control data quality.

Furthermore, it has begun the incorporation of Custom Data Mappers that will introduce heightened flexibility by enabling the creation of bespoke mapping operators derived from the URL of a JSON schema. These operators yield outputs in varied formats, including NGSI-LD, NGSI v2, or standard JSON.

Additionally, the integration of a caching system stands out as a performance enhancement, facilitating expedited execution and preview processes. This technical refinement ensures a more streamlined and efficient workflow, contributing to an optimized development and testing environment.

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2 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.

2.1 Architecture

Figure 1 depicts the main functional components for data interoperability, which have been identified in WP3. In this beta version, a new service has been included, i.e., the Compliance Service, to check the compliance between semantic data models.

Figure 2 shows the internal and external relationships between the components in WP3 and with other components in ENERSHARE. The datasets published in the Metadata broker developed in WP5 are linked to the Vocabulary Hub through the DCAT-AP property "conforms to". The Vocabulary Hub stores the Open Energy Ontology and provides a wizard and editor to create Open APIs. These Open APIs define how to formalize the data to be exchanged in the payload of the messages transferred between data providers and consumers using IDS connectors of through the Context Broker. The Data Mashup editor allows defining the pipelines that need to be executed to transform the data according to the Open APIs. These pipelines

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are executed by the connector or by the client that published data to the Context Broker.

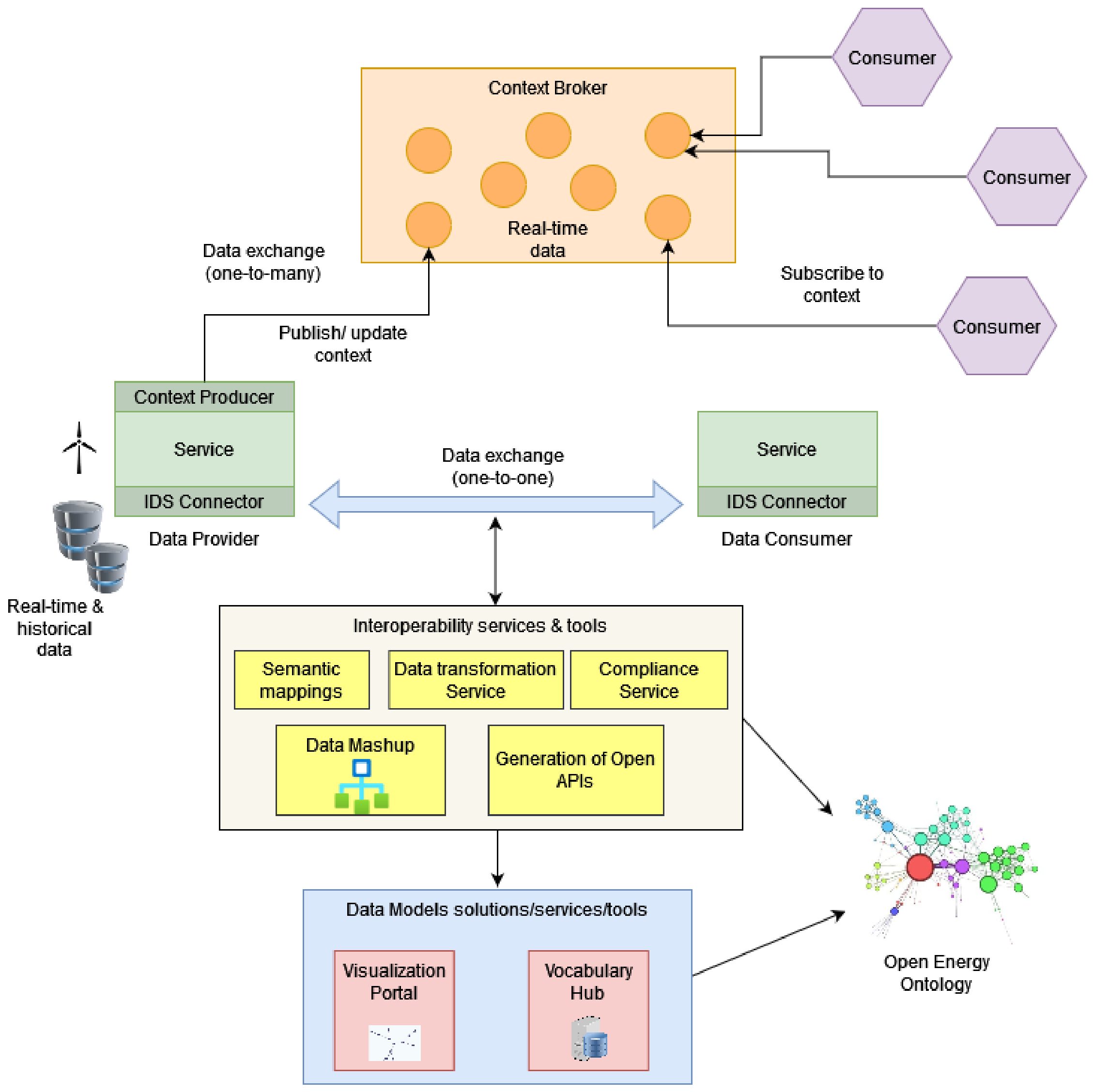

Figure 1: Functional components for data interoperability

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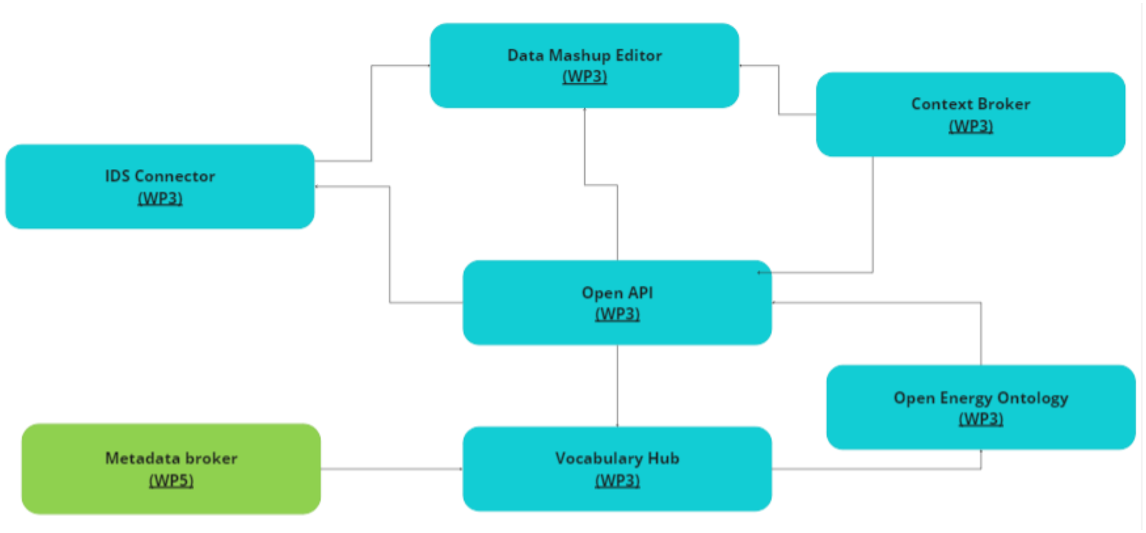

Figure 2: Internal and external relationships of WP3 components.

2.2 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.

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 3 explains the methodology that is being followed to define the OEO ontology and the 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).

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- 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.

2.3 Data Exchange APIs for the sharing and exchange of data

In an energy dataspace such as ENERSHARE, it is possible to exchange different types of data such as:

- Regulated data (e.g., power grid asset descriptions) that TSOs and DSOs can provide very cautiously,
- Personal data (e.g., customers' power consumption time series) whose exchanges need prior customers' consents or must be anonymized or aggregated,
- Commercially sensitive data (e.g., tariffs) which are strategic data for energy suppliers,
- Sensor measurements data or forecasted data which can only be used by one application or for a certain time period.

Some of these data, due to their nature, must receive special treatments to ensure their confidentiality and to cope with the restrictions, before being transferred.

“Usage control is about the specification and enforcement of restrictions regulating what must (not) happen to data. Thus, usage control is concerned with requirements that pertain to data processing (obligations), rather than data access (provisions)”.[13] IDS defines 21 policy classes. For example, data usage can be restricted to a specific Data Consumer, to a specific connector or to a specific application; to a specific location; to a specific “purpose” such as marketing purpose, research purpose, enershare-project; to a “time-interval” restricting the data usage to a specified time interval defined in the contract; the "data anonymization" policy demands to anonymize data before the data is used, applying Privacy Enhancing Technologies (PETs), etc.

These usage control policies are out of the scope of WP3 and are being addressed in WP4. WP3 deals with the data exchange APIs to use in the data transfer once these usage control policies have been met.

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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 [14], the TRUE Connector [15] and the TNO Security Gateway (TSG) [16] 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 (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 between data models, compliance of data models, the generation of Open APIs and a data mashup editor to combine data from different data sources. Section 4 contains a detailed description of these services and tools.

2.4 Data Exchange Interoperability

As stated in the DSSC Blueprint version 0.5 [17], the data exchange interoperability deals with the capabilities needed for smooth data sharing, interpretation, and integration between participants in a data space. These mechanisms should allow data space participant A to exchange data with data space participant B in any of the

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following scenarios: A gets access to data owned by B; B gets access to data owned by A; both get mutual access to their data.

Data exchange interoperability occurs at two levels: technical interoperability and semantic interoperability.

Technical interoperability defines a common protocol (i.e., syntax) to exchange the data. Common standardized protocols are e.g., HTTP(S), REST or NGSI-LD. In the case of data spaces, data exchange occurs by means of connectors. With the explosion of data spaces, the number of connectors started growing. However, these connectors were not interoperable and could not work together. For this reason, the Dataspace Protocol [18] has emerged as the common specification and future standard, at technical level, to guarantee interoperability among connectors in a data space. The protocol covers the principles of data sovereignty, trust and data governance.

In [19] it is also mentioned that "*there are two interoperability models: intra-data space, which is the interoperability of different connectors from different participants within the setting of one data space, and inter-data space, which is the interoperability between data spaces. The latter absolutely requires the connector protocol-based element of interoperability. If a participant needs interoperability between two data spaces, it means that the participant must actually participate in two data spaces. This would get extremely complicated if there were different protocols, connectors, and architectures in those data spaces*".

At implementation level, the Data Space Protocol distinguishes between a control plane and a data plane. The control plane is responsible for deciding how data is managed, routed, and processed, whereas the data plane is responsible for the actual moving and transmission of data. In this control plane any standard communication protocol can be used. This way, different performance of data exchanges can be supported depending on several criteria:

- Real time constraint (e.g., for power grid monitoring),
- Low latency for the exchanges of huge amounts of data (e.g., power grid descriptions or bunch of power consumption time series),
- Supported granularity of data exchanges (e.g., neighborhood-wide or continental-wide).

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Considering the aforementioned, the connectors to be used in the Energy Data Space should follow the Data Space Protocol specifications.

The second level of interoperability or semantic interoperability is about the correct and unambiguous interpretation and understanding of data. In this sense, a common vocabulary is needed. However, in practice, there is not a unique semantic model that covers all the concepts and relationships in a domain. In fact, a concept may be found in multiple ontologies and strategies like mappings between equivalent concepts is needed to ensure interoperability. This can be costly in terms of effort and time.

Another challenge to be addressed is the fact that two data spaces may be compliant with different semantic data models. So, how can the same connector be interoperable at the same time with connectors from the data space A and with connectors from the data space B? In ENERSHARE we propose an architecture based on a data transformation service.

Three use cases need to be covered:

1. The data exchanged is formalized according to the common semantic data model defined by the data space.
2. The data at origin needs to be transformed to a common semantic model before the data is provided by the connector.
3. The data at reception needs to be transformed by the data consumer in order to be understandable in the common semantic data model defined by the data space.

2.4.1 Data exchange without transformations (for services developed from scratch)

When developing two connectors from scratch that operate in just one data space, it is possible to agree on a common semantic data model to exchange information. In this case, there is no need for data transformations as both the provider and the consumer share the same vocabulary.

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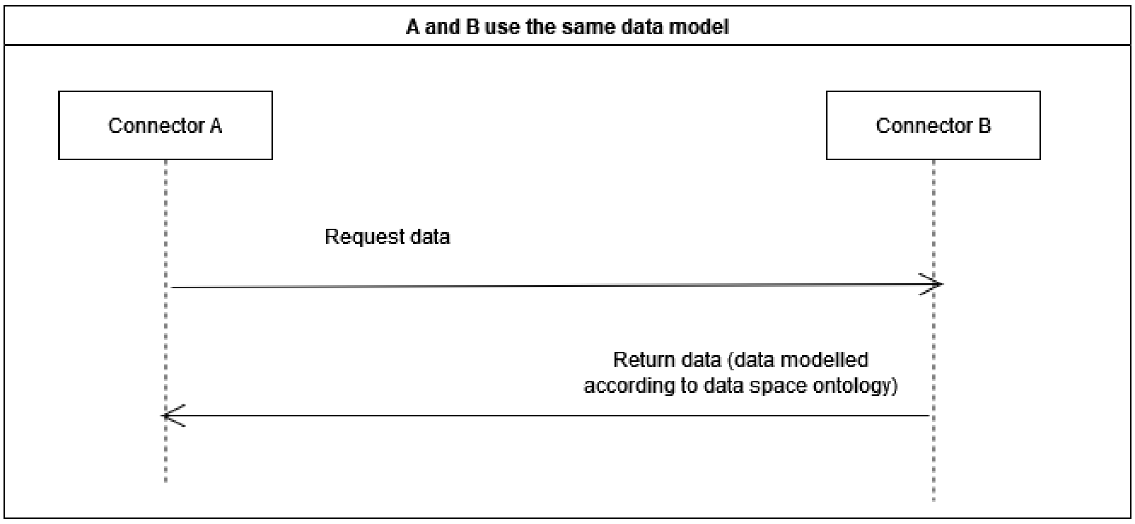
A and B use the same data model
Connector A
Connector B
Request data
Return data (data modelled according to data space ontology)

Figure 3: Data exchange between connectors without transformations

2.4.2 Data transformations at the provider (for services in production)

In real-life situations, connectors are not developed from scratch but on top of already existing and well tested services that are deployed in production. These services cannot be redesigned. In these situations, connectors need to transform the data coming from these services into the common data model understood in the data space, before providing the data to the consumer.

The data transformation service will take as input the data to be transformed plus a template in a standard language (such as RML or XSLT) that defines the transformations to be applied. The output of the data transformation service will be the same information but formatted according to the common data model understood by the data consumers in the data space.

This way the same connector could be interoperable with different data spaces, by just transforming the data according to the appropriate template, depending on the data space where the data is exchanged. Hence, the service in production will not need to be modified.

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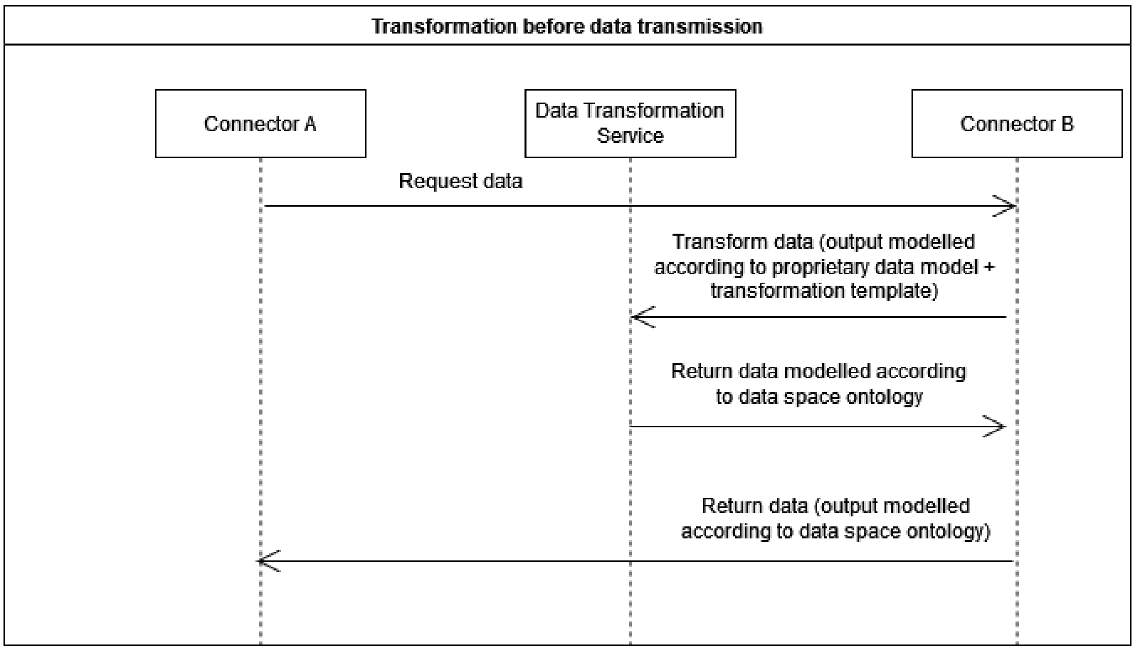
Transformation before data transmission
Connector A
Data Transformation Service
Connector B
Request data
Transform data (output modelled according to proprietary data model + transformation template)
Return data modelled according to data space ontology
Return data (output modelled according to data space ontology)

Figure 4: Data transformations at the provider before transmission.

2.4.3 Data transformations at the consumer (for low latency or big volume data exchange)

There are cases in which there is a need to exchange big volumes of data, e.g., when requesting datasets for machine learning algorithms or even cases when latency is critical as data is exchanged in periods of milliseconds or nanoseconds. In such situations, semantic data serializations such as JSON-LD or RDF can be too heavyweight. In these cases, it may be a better option to use a very lightweight data format and to transform the data at reception in the consumer side.

Once the consumer receives the data, it can check the provider's self-description at the metadata broker. This self-description will contain a link to the data model that is being used and/or a link to the transformation template to be used to transform the information into the common data model of the data space. This way, the consumer will be able to understand the data received independently of the data format used for its transmission.

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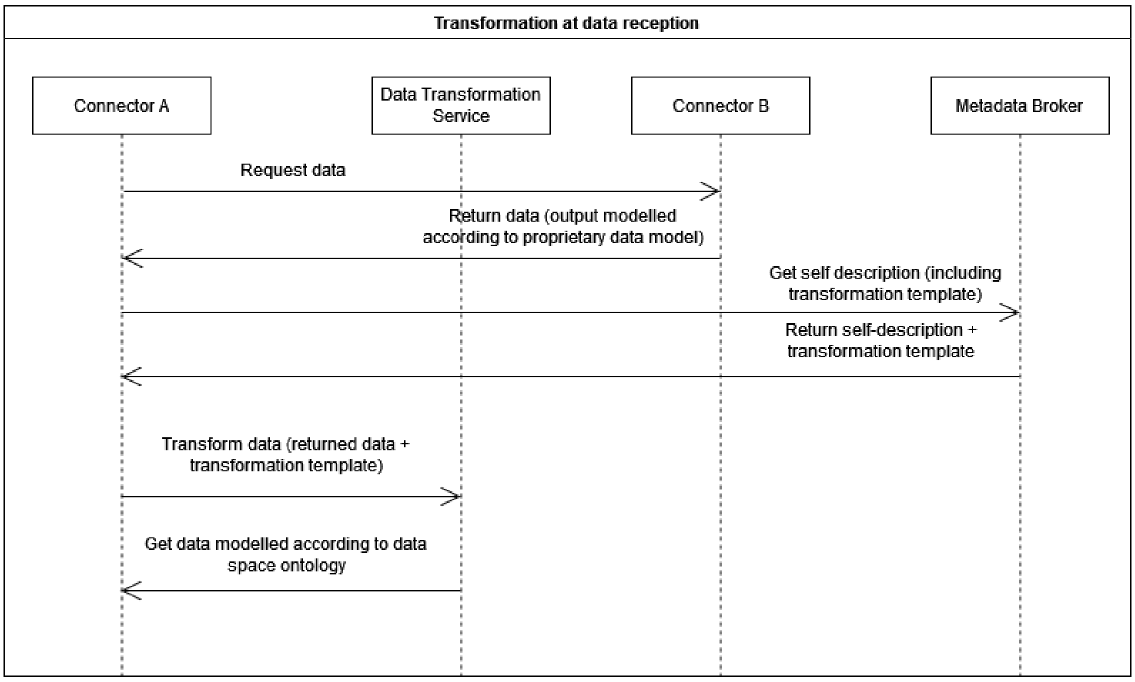
Transformation at data reception
Connector A
Data Transformation Service
Connector B
Metadata Broker
Request data
Return data (output modelled according to proprietary data model)
Get self description (including transformation template)
Return self-description + transformation template
Transform data (returned data + transformation template)
Get data modelled according to data space ontology

Figure 5: Data transformations at the consumer once the data is received.

2.5 Data Exchange message flow in one-to-one communications

As explained in section 2.3, 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.

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).

Considering 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

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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.

The previous deliverable D3.1 provided a detailed description of the IDS Messages to be used, the data to be provided in the body of the messages and their orchestration for both synchronous and asynchronous scenarios. However, these diagrams will need to be reviewed once the first version of the Data Space Protocol is released.

2.6 Data Exchange in the electricity domain

IEC standards to exchange information in the electricity domain are IEC 61850-7-2[6] and IEC 61968-100[7].

2.6.1 IEC 61850-7-2

IEC 61850-7-2:2010 applies to the ACSI (Abstract Communication Service Interface) communication for utility automation. The ACSI provides the following abstract communication service interfaces:

- abstract interface describing communications between a client and a remote server (normal operation, two-party-application-association (TPAA) class model);
- and abstract interface for fast and reliable system-wide event distribution between an application in one device and many remote applications in different devices (publisher/sub-scriber) and for transmission of sampled measured values (publisher/subscriber) (multicast-application-association (MCAA) class model).

The ACSI for use in the utility application domain requires real-time cooperation of intelligent electronic devices (IED). In this sense, time management is very important, and it must be ensured that all clocks are synchronized. IEC 61850-7-2 defines a time and time-synchronization model where timestamps are formatted in UTC Format (epoch 1970-01-01 Unix time).

The UTC Format contains a date and a time, separated by the letter "T". The format for the date contains a four-digit year, a 2-digit month, and a 2-digit day, separated

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by hyphens (yyyy-MM-dd). The format for the time contains 2-digits for the hour, based on a 24-hour clock, followed by two digits for minutes, and two digits for seconds, separated by colons (HH:mm:ss). The final character in the format designates the time zone, where Z is "zero-time", or Greenwich Mean Time. Times should be expressed with the UTC designator 'Z'. It should not be expressed using a timezone offset. An example of date/time will look like this: 2023-11-12T13:14:15Z.

IEC 61850-7-2 mainly deals with the data exchanges between IEDs and the systems that collect data from them or send orders to them, in the purpose of operating power grids. These data exchanges are at a lower level than those considered in the ENERSHARE project use cases and that involve different stakeholders (e.g., electricity DSOs, electricity TSOs, aggregators, EV fleet operators) in the context of energy data spaces. However, the ENERSHARE building blocks and the Data Space Protocol are compatible with the IEC 61850-7-2 principles, in particular the client-server patterns and the time synchronization. All timestamps exchanged in ENERSHARE will use the UTC Format (epoch 1970-01-01 Unix time).

2.6.2 IEC 61968-100

"IEC 61968-100:2022 defines how messages may be exchanged between cooperating systems in order to facilitate the transfer of application-specific data. Such application-specific data include but are not limited to the message payloads defined in IEC 61968 (Parts 3 to 9 and Part 13), IEC 61970 and IEC 62325"[7].

IEC 61968 (electricity distribution) is one the IEC standards defining the CIM (Common Information Model) along with IEC 61970 (electricity transmission) and IEC 62325 (electricity markets).

IEC 61968-100 mainly recommends the use of XML or JSON documents and services over SOAP, Java Message Service or REST protocols. It also recommends that these XML documents comply with XSD files and supports the use of XML RDF.

As a consequence, the ENERSHARE building blocks comply with IEC 61968-100 standard, as all the ENERSHARE data exchanges rely on XML RDF files (or equivalent serializations like JSON-LD) that comply with ontologies. Besides, the ENERSHARE data model complies with the IEC CIM semantics using the Smart Data Model defined

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at https://github.com/smart-data-models/dataModel.EnergyCIM. Other data formats could also be used thanks to the Data Transformation Service utility.

3 Methodology and advances for the ENERSHARE data model

3.1 Background based on PLATOON project

As explained in deliverable D3.1, the methodology and ontologies defined in the PLATOON EU project are being reused to design the semantic data model for the ENERSHARE project.

PLATOON Semantic Data Model covers 7 Pilots and 19 use cases in the Energy domain. Therefore, ENERSHARE Semantic Data Model is reusing, whenever possible, this model and extending it with new concepts and properties to cover extra needs of the ENERSHARE pilots. As an example, PLATOON and ENERSHARE use cases overlap in domains such as the wind turbine domain, the energy consumption and production, weather, meter, etc.

In addition, ENERSHARE is applying PLATOON's methodology (see Figure 6) to design and create the ENERSHARE semantic data models. However, for the ENERSHARE project, some adjustment in the two last steps of the methodology was brought to reflect the real process and clarify each step. The main steps of this methodology are (see Figure 7):

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.

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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) Design ontological Diagrams for each pilot: it targets a consolidation of all conceptual modules together and providing an example for each pilot. Interaction with stakeholders is maintained during all the designing process.

4) Harmonization & Formalization: the purpose of this step is to: (i) harmonize the diagrams of the different pilots, and (ii) formalize all ontological modules by using an ontology editor and a standard language and integrate all modules into an ontology system.

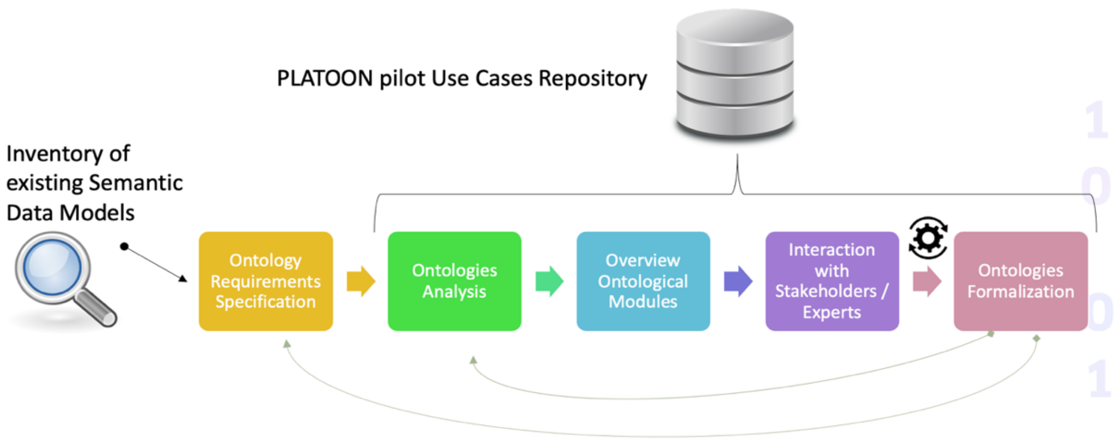
PLATOON pilot Use Cases Repository
Inventory of existing Semantic Data Models
Ontology Requirements Specification
Ontologies Analysis
Overview Ontological Modules
Interaction with Stakeholders / Experts
Ontologies Formalization

Figure 6: Overview of PLATOON Semantic Data Models methodology

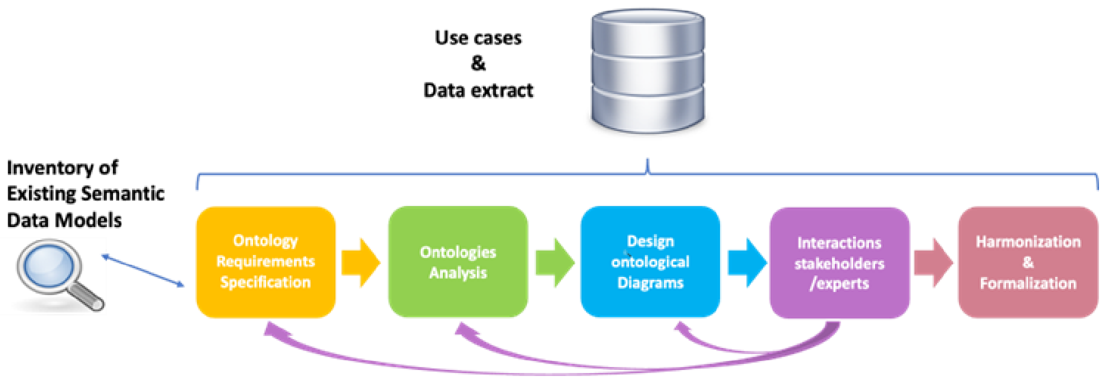
Use cases & Data extract
Inventory of Existing Semantic Data Models
Ontology Requirements Specification
Ontologies Analysis
Design ontological Diagrams
Interactions stakeholders /experts
Harmonization & Formalization

Figure 7: Overview of Semantic Data Models methodology in ENERSHARE

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3.2 Overview of main pilots' topics

In ENERSHARE project, seven pilots with twelve use cases 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 8):

- 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 (behaviour for flexibility, flexibility of EV, flexibility of end-users, etc.). We identified in this topic, the 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.

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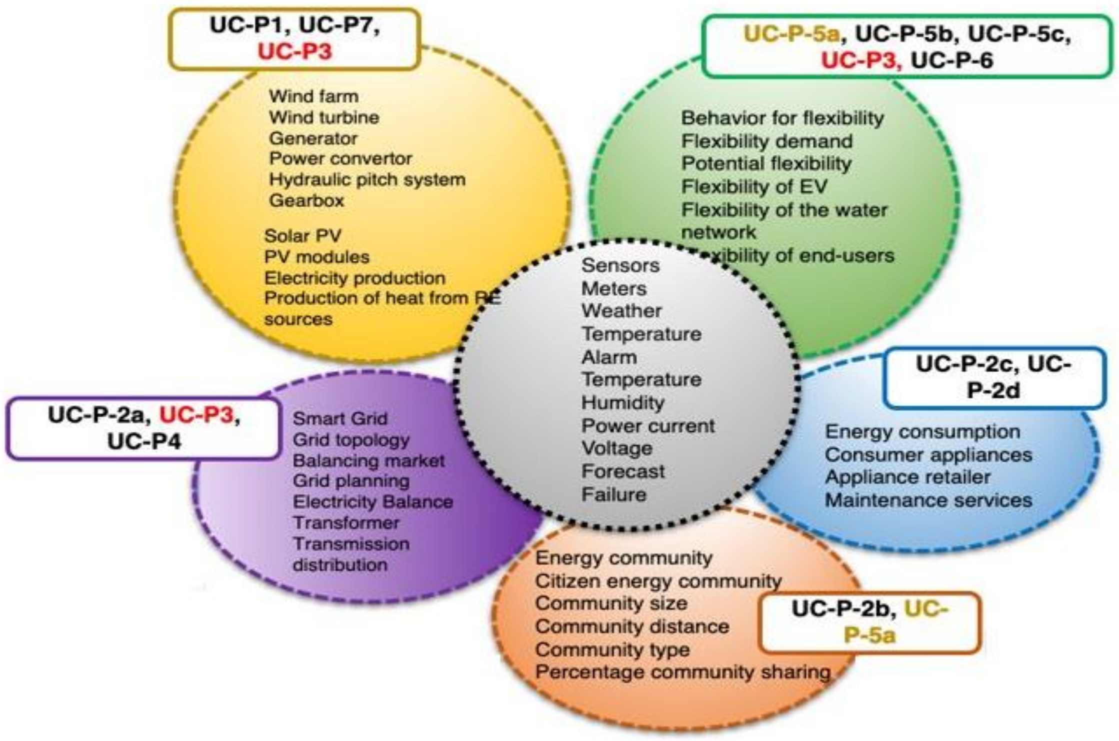

Figure 8: Overview of main topics

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.

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.

3.3 Proposed methodology application

The goal of this section is to describe the application of the proposed methodology for all the use cases of the presented pilots in the ENERSHARE project. We defined a common template document that was 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 were held to follow the steps of the methodology.

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

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	Pilots	Use cases	Number Of Meeting	List of Reused Ontologies	New Modules	Data Extract Provided ?	Status	Competency Questions	Main Contacts
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	**10**	plt/seas/sch/saref/brick/s4bldg/time/saref4City	ener-wind/ener-device/ener-prop/ener-fail	**YES/NO**	**95%**	**YES (80%)**	Ainoha, Sonia, adelaida, iarrizabalaga azubizarreta
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	**8**	plt/seas/sch/saref/brick/s4bldg//ic-flex/sch	ener-bldg/ener-mrkt/ener-flex/ener-play/ener-grid	**NO**	**60%**	**YES(50%)**	Fábio André Coelho
		Use Case B - Instantiation of energy communities and digital simulation of business models		plt/seas/saref	ener-btry/ener-play/ener-sys/ener-watr/	**NO**	**60%**	**YES(50%)**	Fábio André Coelho, Alexander Gouveia
		Use Case C - Detect irregularities in energy consumption in households with seniors living alone		plt/seas/foaf/saref	ener-bldg/ener-play	**NO**	**60%**	**YES(50%)**	Fábio André Coelho, Rui Martin, Maria adelaide Ambrosio
		Use Case D - Suggest maintenance of appliances based on NILM data		plt/seas/sch/	ener-sys/ener-play/ener-fail	**NO**	**60%**	**YES(50%)**	Fábio André Coelho
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	**10**	plt/seas/saref/cim/s4bldg/ecfo/qudt/time	ener-device/ener-pro/ener-sys/ener-flex/ener-bldg/	**YES**	**95%**	**YES(100%)**	Andrej Campa Tine Mlac
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	**7**	plt/seas/saref/saref4city/time/s4watr/pep/fso	ener-pro/ener-sys/ener-grid/ener-flex/ener-fc/ener-dt/ener-mrkt/ener-watr	**YES**	**60%**	**NO**	Sotiris pelekis Nikos Dimitropoulos Andriana Lazari
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	**9**	plt/seas/ic-flex/sch/ic-data/saref/time	ener-flex/ener-bldg/ener-sys/ener-grid/ener-play	**YES**	**90%**	**YES(80%)**	Prashanth PKP Kumar Francesco Bellesini
		Use Case B- Services for e-mobility CPOs, Evs drivers(or communities of EV drivers)		plt/seas/ic-flex/sch/ic-data/saref/time/vsso	ener-flex/ener-bldg/ener-sys/ener-grid/ener-play/ener-mrkt	**YES**	**90%**	**YES(80%)**	Prashanth PKP Kumar Francesco Bellesini
		Use Case C- Flexibility provision for electricity grid with water pumps and predictive maintenance pf the pumps		plt/seas/ic-flex/sch/ic-data/saref/time/pep/s4watr	ener-flex/ener-bldg/ener-sys/ener-grid/ener-play/ener-mrkt/ener-evnt/ene-watr/ener-pro/ener-device/ener-fail	**YES**	**90%**	**YES(80%)**	Prashanth PKP Kumar Francesco Bellesini
TeamWork 6	**Pilot 6**: Aggregation of available flexibility from the behind-the-meter consumers (**Sweden**) - **FORTUM**	Flexibility aggregation from behind-the-meter consumers	**8**	plt/seas/sch/saref/time/pep/cim/ic-flex	ener-play/ener-device/ener-flex/ener-sys/ener-schd	**NO**	**100%**	**YES(100%)**	Farzaneh Abbaspourtorbati
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	**10**	plt/seas/saref/time/s4bldg/sch/saref4city/qudt/ecfo	ener-sys/ener-bldg/ener-prop/ener-mrkt/ener-play	**YES**	**100%**	**YES(90%)**	Sotiris Pelekis Iveta Muceniece
Total	7 pilots	12 use cases	**62**	18	12	(YES)50%	**85%**		

Table 1. Progress Status of ENERSHARE use cases.

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To assess the progress made during the second period of the task 3.1, the status is evaluated against some metrics that give a global view of the progress of all use cases (see Table 1).

Obviously, the step 1 and the step 2 are achieved for all use case. The progress of the step 3 is represented in the Table 1. The step 4 is in their first phases.

Figure 9, represents the methodology followed to create the semantic data model of the ENERSHARE project. We can notice that, compared to PLATOON methodology, some adjustments are made in step 4 of the figure to reflect the real application of the methodology in the ENERSHARE Project.

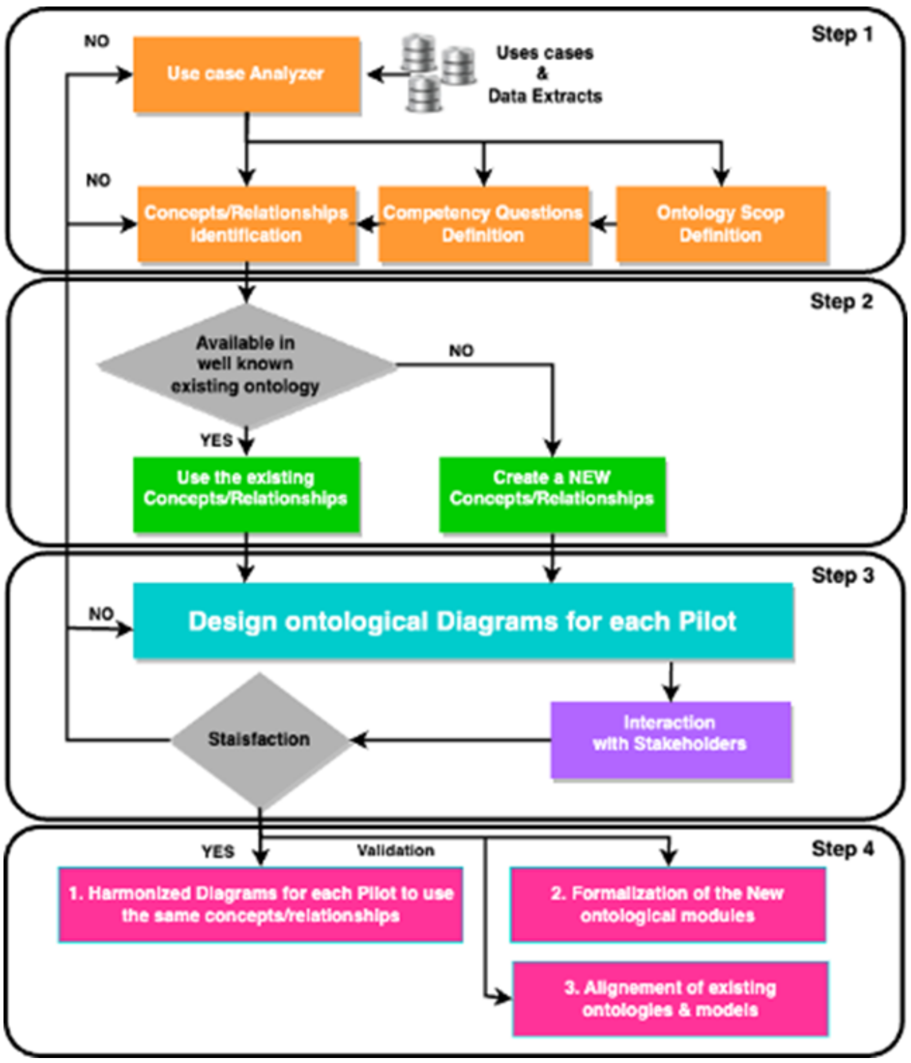
Step 1
NO
Use case Analyzer
Uses cases & Data Extracts
NO
Concepts/Relationships identification
Competency Questions Definition
Ontology Scop Definition
Step 2
Available in well known existing ontology
NO
YES
Use the existing Concepts/Relationships
Create a NEW Concepts/Relationships
Step 3
NO
Design ontological Diagrams for each Pilot
Interaction with Stakeholders
Staisfaction
Step 4
YES
Validation
1. Harmonized Diagrams for each Pilot to use the same concepts/relationships
2. Formalization of the New ontological modules
3. Alignement of existing ontologies & models

Figure 9: Steps of design methodology

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In the following section, we describe the application of the methodology for each step.

3.3.1 Application of Step 1 – Ontology Requirements Specification

Prior to starting the ontology design process, it is crucial to initiate an analysis of the requirements and specifications that are anticipated for the ontology or semantic data model. This initial step, denoted as "step 1," encompasses various significant tasks aimed at fulfilling the ontology's requisites. The specific details of these tasks are outlined below.

a) Use Case Analysis: begins with a comprehensive examination of the requirements, specifically the use case (UC). In ENERSHARE project, every use case was documented across IEC-62559 template that offered an extensive description of each Use Case associated with individual pilots. In a second time, some extract of data could be provided to complete this analysing phase.
b) Ontology scope definition: the scope of the ontology is a critical step in achieving a modular ontology design. Given that use cases frequently span multiple domains because we cannot define everything in the world, an ontology should have a limited scope which can facilitate its definition and sharing. Thus, delimiting the scope becomes essential. This task involves clearly outlining the ontology's scope aligned with the application domain. For instance, a limitation in scope might focus specifically on areas like Building Energy Efficiency and Heating/Cooling Systems. This focused scope aids in defining and sharing the ontology effectively.
c) Competency questions definition: Competency questions are natural language inquiries posed by domain experts, and they represent the information that experts seek from the ontology. To create a comprehensive list of competency questions, collaboration between the knowledge engineer and the group of domain experts is essential. These questions are formulated by asking domain experts to articulate the specific questions they anticipate the ontology system will be capable of addressing once it is fully implemented and operational. This compilation of competency questions serves not only as a guide for ontology development but also as a valuable tool for evaluating the final ontology's effectiveness.

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d) Term elicitation: the term elicitation process involves the knowledge experts carefully examining the IEC-62559 documents for each use case. During this analysis, they identify and extract all terms or concepts that hold significance within a particular domain. Additionally, they also scrutinize the list of competency questions to extract key terms that are pertinent for inclusion in the semantic model. Examples of such key terms may encompass entities like sensors, buildings, energy consumption, and specific details related to sensors such as their type and location. These key terms are pivotal for constructing a comprehensive semantic model that accurately represents the domain of interest.

To summarize, the output of this initial step (step 1) in ontology design comprises three essential components:

- A template document outlining the scope of the ontology, which defines its boundaries and purpose.
- A comprehensive list of competency questions, generated in collaboration with domain experts, which serve as a guide for the ontology's information retrieval capabilities.
- A tabulated list of extracted relevant terms, which are identified through an analysis of IEC-62559 documents and competency questions. These terms are then subjected to validation by domain business experts to ensure their relevance for inclusion in the semantic model. Domain experts also have the option to supplement this list with additional terms to cover any concepts that may have been omitted from the IEC-62559 documents.

The application of this step 1 is concretely illustrated in the Table 2 that, 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?

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- What is the typology of the turbine, in terms of speed?
- What are the sensors related to a wind turbine, where are they located and what do they measure?
- What is the abnormal behaviour of the wind turbine and what are the failure modes?
- Which kind of maintenance was done on the wind turbine, in which component, when it was done, by whom company?
- ….

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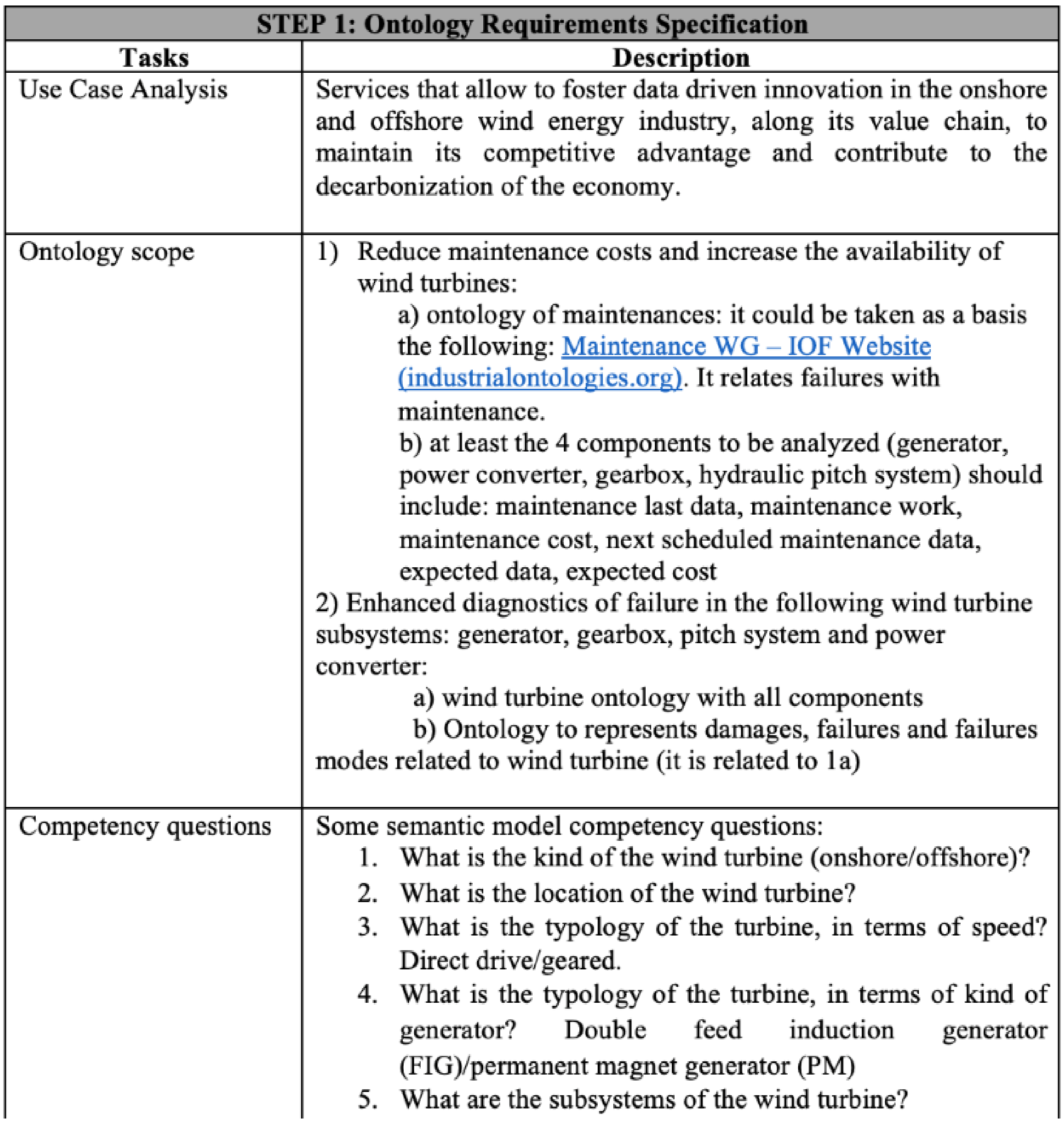

STEP 1: Ontology Requirements Specification	
Tasks	**Description**
Use Case Analysis	Services that allow to foster data driven innovation in the onshore and offshore wind energy industry, along its value chain, to maintain its competitive advantage and contribute to the decarbonization of the economy.
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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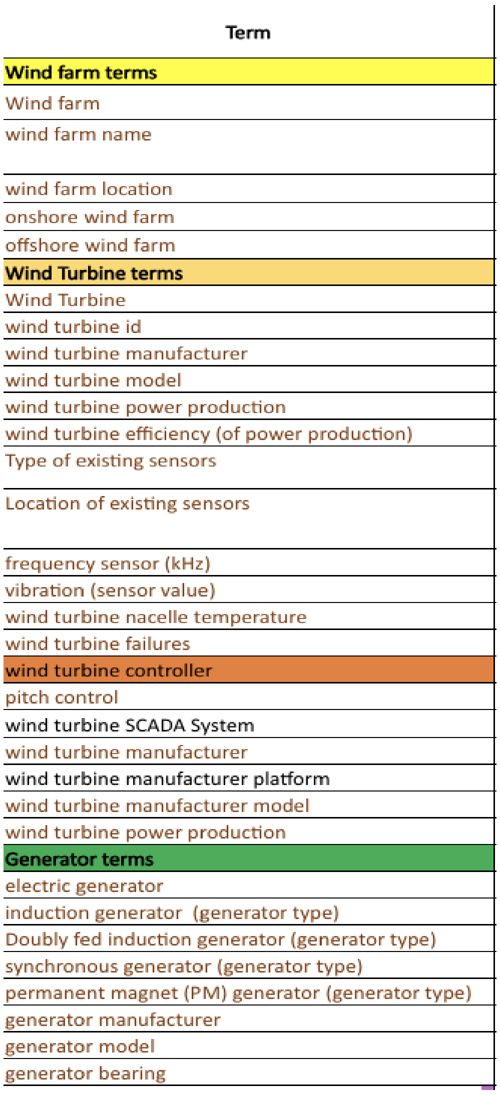
Table 3 shows an example of the relevant extracted terms from the IEC template of the pilot 1 use case. Different terms are detected such as wind turbine, wind farm, generator, sensors, etc.



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.

3.3.2 Application of Step 2 – Ontology Analysis

The step 2 is dedicated to establishing a foundation for the construction of the semantic data model. It adheres to the principle of ontology domain, which

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emphasizes the advantageous practice of reusing existing ontologies before starting on the creation of new ones. To achieve this, several tasks are defined, and they are elaborated upon in the following detailed description (Figure 9).

a) Identification of concepts and relations: The first task in step 2 involves the identification of concepts and relationships. This is done by associating each term or key notion from the list of extracted terms obtained during the elicitation task in step 1 with a concept name or relation name that will be used in the semantic data model. For instance, the term "sensor" might be associated with the concept "Sensor," and "humidity sensor" might be associated with the concept "HumiditySensor." This process aligns terms with their corresponding semantic representations in the model.
b) Reusing Ontology: The second aspect emphasizes the importance of reusing existing ontologies before introducing new concepts. For each concept identified in the previous task, an effort is made to search within existing ontologies to determine if the concept is already defined. When a concept is found in multiple ontologies, the strategy is to propose a mapping between these equivalent concepts to ensure interoperability. However, it is essential to analyse the hierarchy of the concept to ensure that the subsumption relation (is-a) is distinct from relationships like part-whole (part-of), composition, or location. This distinction is crucial to maintain semantic consistency and avoid confusion in the ontology.
c) Module Ontology Design: It is common that the ontological module in the domain exists and covers a part of the use case, but the concept doesn't exist in these modules. In this case we need to create a new module and extend the existing ontology with the new concept. Often, several concepts that we need to represent for the use cases are missing in the domain's module, then the new created module includes several concepts.

In practice, for each extracted term in the previous step, 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 see for the

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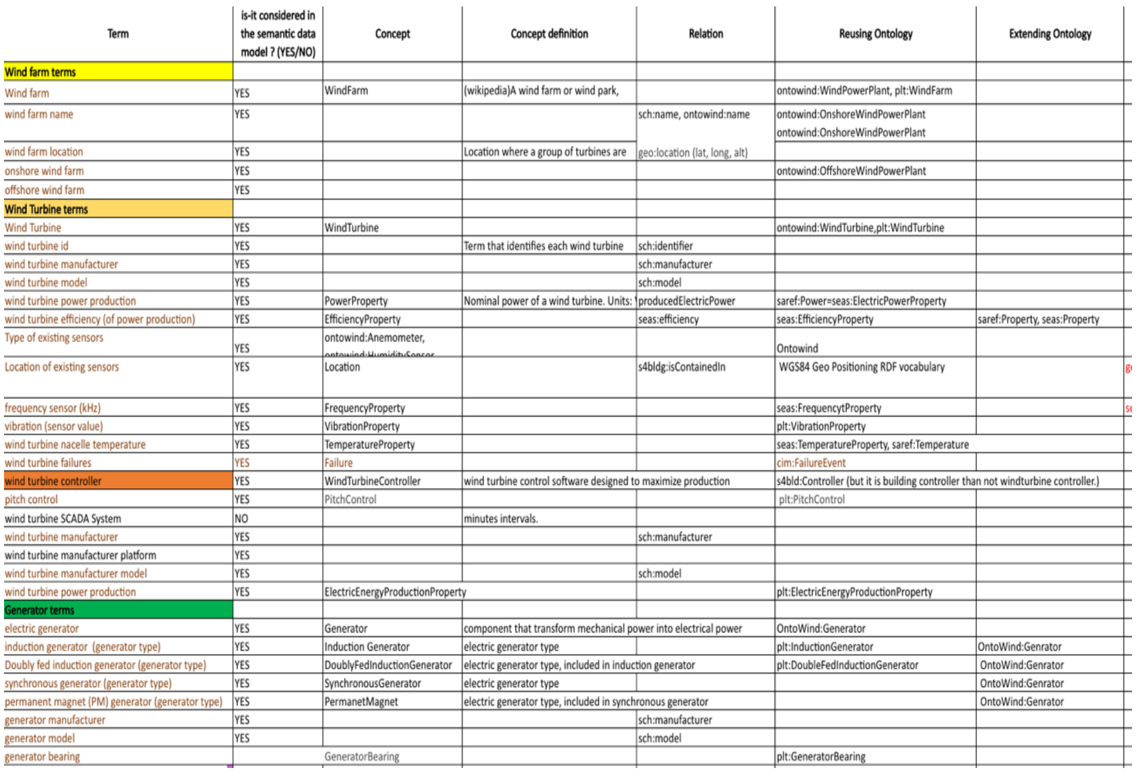
concept that could be extended with our new concept and put it in the "Extending ontology" column.

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 in PLATOON *(plt:WindTurbine)* ontologies. In this case, we can reuse existing ontologies for this concept. If we choose to reuse the concept of PLATOON *plt:WindTurbine*, in the mapping module, we add the equivalence relationship between the two concepts (*plt:WindTurbine owl:equivalent ontowind:WindTurbine)* to maximise the interoperability with systems that use the ontowind 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.

3.3.3 Application of Step 3 – Design ontological diagrams for each pilot

This step is initially based on the output files from the previous step (see Table 4). For each pilot, we have proposed a model represented by several diagrams showing concepts (reused/created) and how they are linked by semantic relationships. The aim of these diagrams is to represent the knowledge related to the pilot's uses

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cases. During all the process, ongoing interaction with stakeholders is maintained through meetings to validate and enrich the diagrams as the modelling was progressing.

We must notice that these diagrams are of crucial importance to the stakeholders, as they represent an imperative help to understanding the relations between the different concepts. Because without these diagrams, and only in the presence of an ontological formalization of the different modules, created and/or reused, a no-expert in the representation of knowledge through ontologies will be faced with a very difficult task of knowing how to use and combine all these concepts and relationships from different ontologies sources to represent their specific needs. Thus, these diagrams could be considered as a guide that shows someone the manner on how the concepts and relations could be used. For this purpose, we choose that each pilot gets at the end the diagrams that cover all the needs identified during the previous steps of the methodology application.

As noticed previously, Table 1, shows the assessment about the progress of the different pilots according to some metrics. If we take the pilot 1 as an example, we can get the following answers for the selected questions:

- Q1: Is data extract provided?
    - R1: Some data on maintenance were recently provided.
- Q2: How many meetings were held to work in the pilot?
    - R2: 11 meetings including all previous steps.
- Q3: Which existing ontologies are used in this pilot?
    - Platoon, SEAS, SAREF, s4BLDG, s4City, Schema, Brick, Time, qudt
- Q4: What are the new modules created to meet the need of the pilot?
    - Ener-wind, ener-device, ener-prop, ener-fail
- Q5: Has the model been checked against competency questions?
    - Almost all competency questions are checked and can have response from the model.
- Q6: What is the progress of the pilot 1?
    - The approximate progress is about 85%.
- Q7: Who were the stakeholders involved in defining the models?
    - Ainhoa, Sonia, Adelaida, Larrizabalaga, and Azubizarreta.

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In summary, and according to the Table 1, we held 65 follow up meetings; we reused around 19 existing ontologies; we created 16 modules, and the global progress is approximately estimated around 87%.

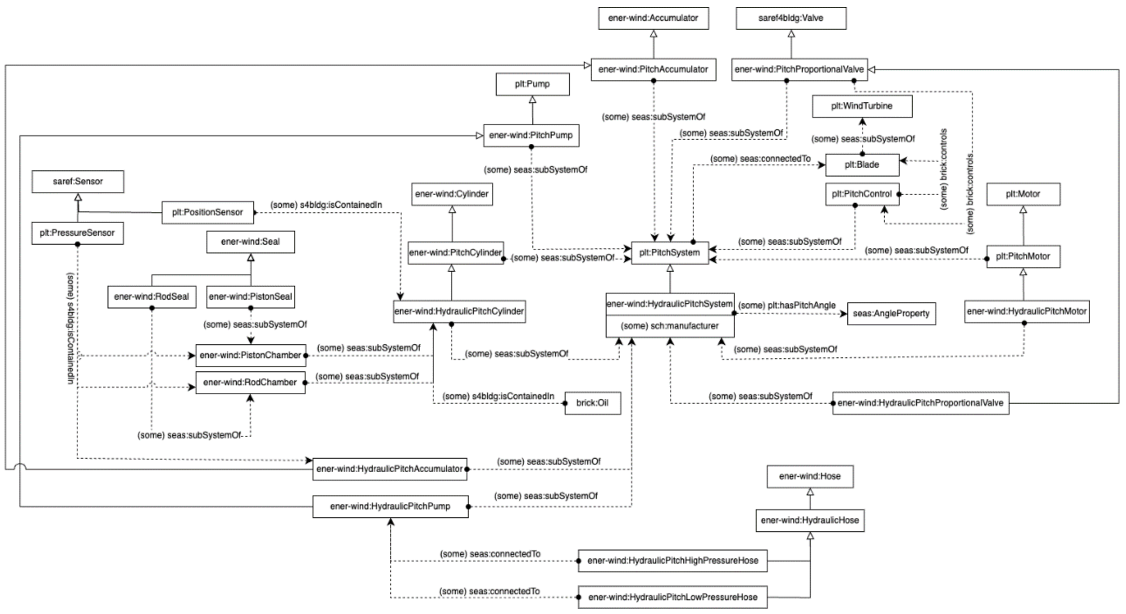

Figure 10: Extract of wind turbine ontology diagram - Hydraulic System.

The Figure 10 presents an extract of a diagram among fifteen other diagrams that were proposed to meet all the need of the use case of the pilot 1 (see Appendix 7). From this diagram, one can easily understand how a complex component like a hydraulic pitch system (`enr-wind:HydraulicPitchSystem`) which is kind of pitch system (`plt:PitchSystem`) is related to other components like hydraulic pitch motor (`ener-wind:Hydraulic PitchMotor`) with the relation sub system (`seas:subSystemOf`). The hydraulic pitch motor is a kind of pitch motor (`plt:PitchMotor`) which is a kind of motor (`plt:Motor`). The oil (`brick:Oil`) is contained in (`s4bldg:isContainedIn`) hydraulic pitch cylinder (`ener-wind:HydraulicPitchCylinder`) which is composed of (`seas:subSystemOf`) piston chamber (`ener-wind:PistonChamber`) and rod chamber (`ener-wind:RodChamber`). Piston seal (`ener-wind:PistonSeal`) and rod seal (`ener-wind:RodSeal`) which both are a kind of seal (`ener-wind:Seal`) are respectively a subsystem of (`seas:subSystemOf`) piston chamber (`ener-wind:PistonChamber`) and rod chamber (`ener-wind:Rod Chamber`).

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At the end, this kind of diagrams give a clear view of how the components are connected and serves as a guide for the representation of the knowledge related to domain in this case the hydraulic pitch system.

3.3.4 Application of Step 4 - Harmonization & Formalization

We have to notice that this step is in its beginning phases, so we don't have results to show and will be more detailed in the final deliverable.

The objective of the fourth step of the methodology is to harmonize the whole ontological modules and to formalize the created modules by using OWL, the standardized Ontological Web Language. This step consists of the following tasks (see Figure 9):

a) Diagrams Harmonization: the harmonization task consists of checking all the diagrams created for all the different pilots in order to verify that the concepts and relations are correctly used. For all reused concepts and relations, a verification of its effective existence and its spelling is correct. We also verify that for the same notion we use the same concept and relation. In this manner, we guarantee that all pilots will use the same concepts for the same meaning, and then increase the interoperability between them.
b) Ontology formalization: When the stakeholders express their satisfaction about the modelling, we proceed to the formalization process, which involves generating an OWL file for each new module. For instance, in the case of Pilot 1, four distinct modules were established: ener-wind, ener-device, ener-prop, and ener-fail. It is important to note that these modules do not encompass the entire domain; rather, they specifically address the novel concepts and relationships required for the ENERSHARE project that do not already exist. For instance, the "ener-device" module focuses on a subset of devices essential to the ENERSHARE project, excluding those already defined in the Platoon ontology. Consequently, if a device, such as an anemometer, is already present in the Platoon ontology, we opt to reuse this concept, thereby eliminating the need to redefine it within the ENERSHARE device module. In addition to the owl files corresponding to the created modules, we will provide also an alignment file that provide all the mapping if several concepts are represented in different ontologies.

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3.4 Next steps for final version

In next steps for final version, the step 4 of harmonization and formalization will be completed. We will provide an update of all the diagrams provided in the appendix 7, and provide also the owl files of the new designed modules. Additionally, the mapping file will be also provided.

4 List of components conforming the Beta version

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

4.1 Vocabulary Hub & Wizard for generation of Open APIs

The vocabulary hub building block and its wizard component have been introduced in ENERSHARE deliverable D3.1 (alpha release). This section consists of a brief summary of what the vocabulary hub is, followed by status updates of two new features developed and released as part of this Beta release iteration.

4.1.1 Brief description of the ENERSHARE Vocabulary Hub building block

The work on semantic interoperability in the BD4NRG project has been influenced by data space design principles from initiatives like GAIA-X[8], DSBA[9], Open DEI[10] and IDS[11]. 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. This requires the use of common vocabularies. The vocabulary hub building block acts as a repository of vocabularies, making them findable and

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accessible. This is its basic function. In addition, the vocabulary hub building block can provide services to facilitate adoption of these vocabularies by data owners, further fostering interoperability.

ENERSHARE is further developing the Energy Vocabulary Hub, initiated by the BD4NRG project. It is deployed by TNO and available at https://energy.vocabulary-hub.eu/. This implementation of the vocabulary hub building block uses open-source software called *Semantic Treehouse,* development which is led by TNO.

The purpose of a single Energy Vocabulary Hub is to broaden the scope and combine the shared need for such a vocabulary hub functionality in European energy data space projects, by providing a single registry for both standardized data models and pilot specific data models, and ways to integrate these. 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.

4.1.2 Development goals

One of the key ways the Energy Vocabulary Hub drives adoption of existing standards is by facilitating model-driven development of data models, schemas, and Open API specifications. This is achieved with the wizard component of the vocabulary hub. More information on the wizard component can be found in section 5.1 of ENERSHARE deliverable 3.1.

Of the three possible functional extensions of the Energy Vocabulary Hub identified in deliverable 3.1, two have been included in the scope of ENERSHARE WP3 activities. The first involves extending the wizard to support standardized JSON vocabularies such as the Smart Data Models. The second concerns implementing support for the five-star framework for vocabulary use [12]. The framework defines five milestones on the journey towards better semantic interoperability (i.e., vocabulary use). Each milestone is defined by a specific 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 allows comparing the vocabulary use of two datasets.

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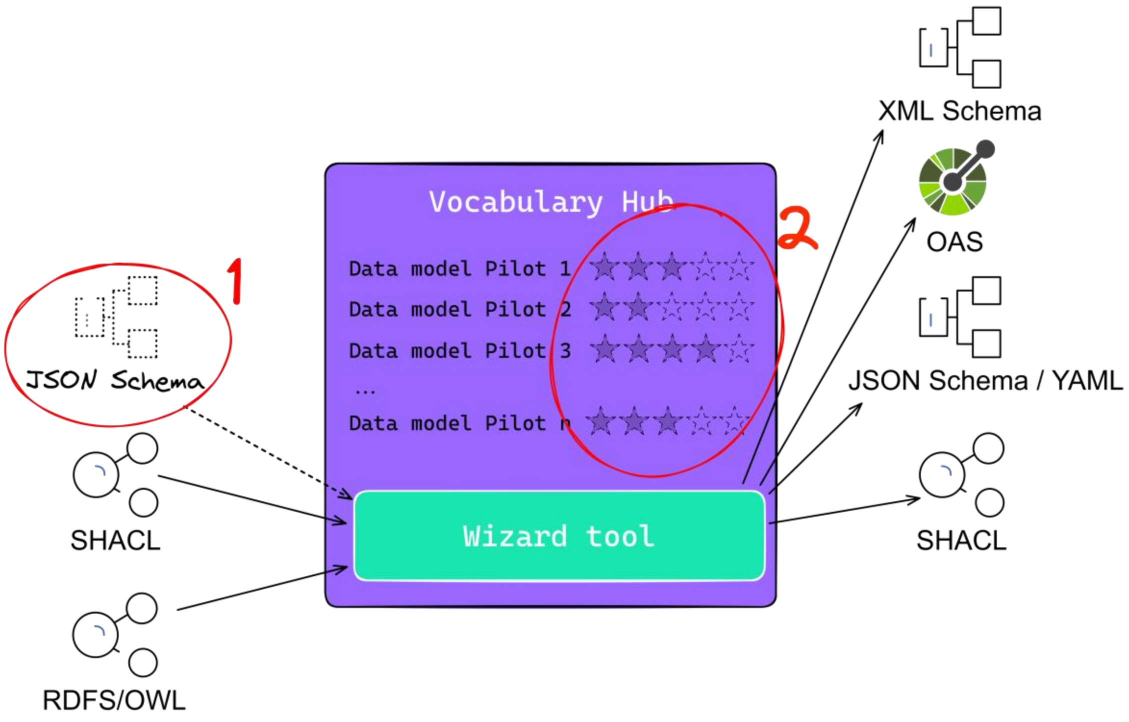

Figure 11: Illustration of the two functional extensions of the Vocabulary Hub in scope for WP3

4.1.3 Development goal 1: support for JSON Schema-based data models

As of the v2.19.0 release of Semantic Treehouse[1], implementation of this extension has been completed.

Domain-specific vocabularies are crucial for accurate and consistent data interpretation by different individuals and systems. These vocabularies provide a shared conceptualization of knowledge within a particular domain. We observe the emergence of these vocabularies in diverse formats such as Smart Data Models, HR Open and Open Trip Model, which express their vocabularies in JSON or XML schemas, not in RDF/SHACL.

The wizard component of the Semantic Treehouse used to support only ontologies, but now also supports JSON schema as starting point. This means that models like Smart Data Models, HR Open and the Open Trip Model can now be used for to start

[1] https://www.semantic-treehouse.nl/releases/#v2190--v300-alpha3-30-june-2023

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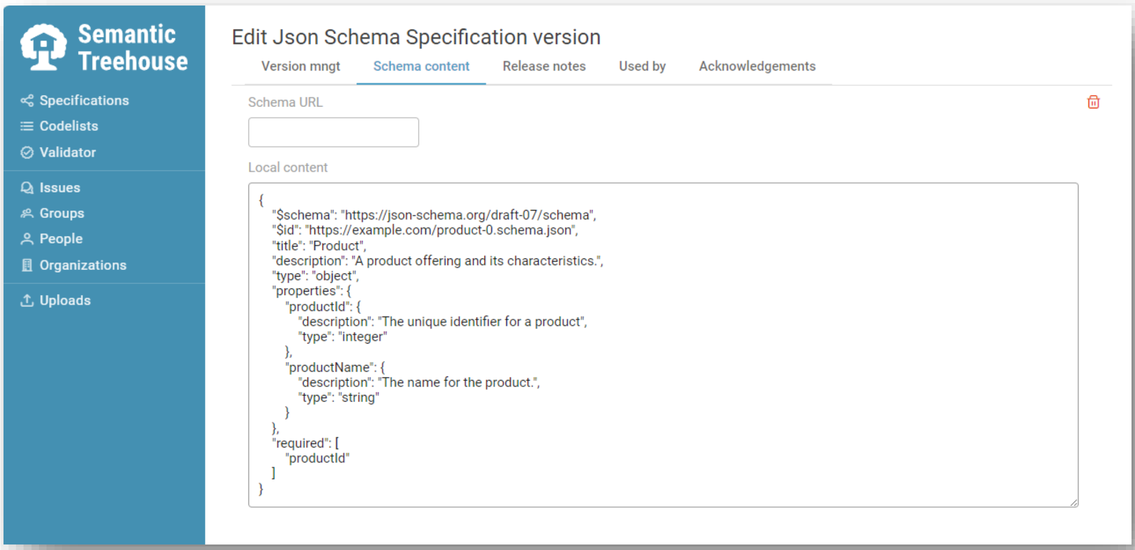
the model-driven development of data models, schemas, and Open API specifications.

4.1.3.1 How it works

The main addition to the existing wizard here is the import option of existing JSON schemas. This can be done in two ways: via a JSON Schema pasted as JSON text in the *Local content* text field. Alternatively, a URL import option is available (the *Schema URL* field). If a JSON Schema is provided by URL, the vocabulary hub does preprocessing of external references and then fills *Local content* field with the result. From there it is included in the wizard.



```
{
  "$schema": "https://json-schema.org/draft-07/schema",
  "$id": "https://example.com/product-0.schema.json",
  "title": "Product",
  "description": "A product offering and its characteristics.",
  "type": "object",
  "properties": {
    "productId": {
      "description": "The unique identifier for a product",
      "type": "integer"
    },
    "productName": {
      "description": "The name for the product.",
      "type": "string"
    }
  },
  "required": [
    "productId"
  ]
}
```

Figure 12: Entering a local JSON Schema

4.1.3.2 Simple example

After selecting this JSON Schema, the wizard allows us to build the message model. For example, below is a basic JSON schema that Semantic Treehouse can import. It considers the cardinality and data type constraints specified in the schema.

```
{
  "$schema": "https://json-schema.org/draft-07/schema",
  "$id": "https://example.com/product-0.schema.json",
  "title": "Product",
  "description": "A product offering and its characteristics.",
```

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```
  "type": "object",
  "properties": {
    "productId": {
      "description": "The unique identifier for a product",
      "type": "integer"
    },
    "productName": {
      "description": "The name for the product.",
      "type": "string"
    }
  },
  "required": ["productId"]
}
```

After loading the JSON Schema in the wizard, users can take the next step: specify the root concept of the message. This means that the wizard will start finding sub-properties from this root concept down the tree. The default is to find the root object of the JSON schema, in our example the object with title Product. After doing that, the wizard will present the following message tree view displaying two potential sub-properties (see top left in Figure 13).

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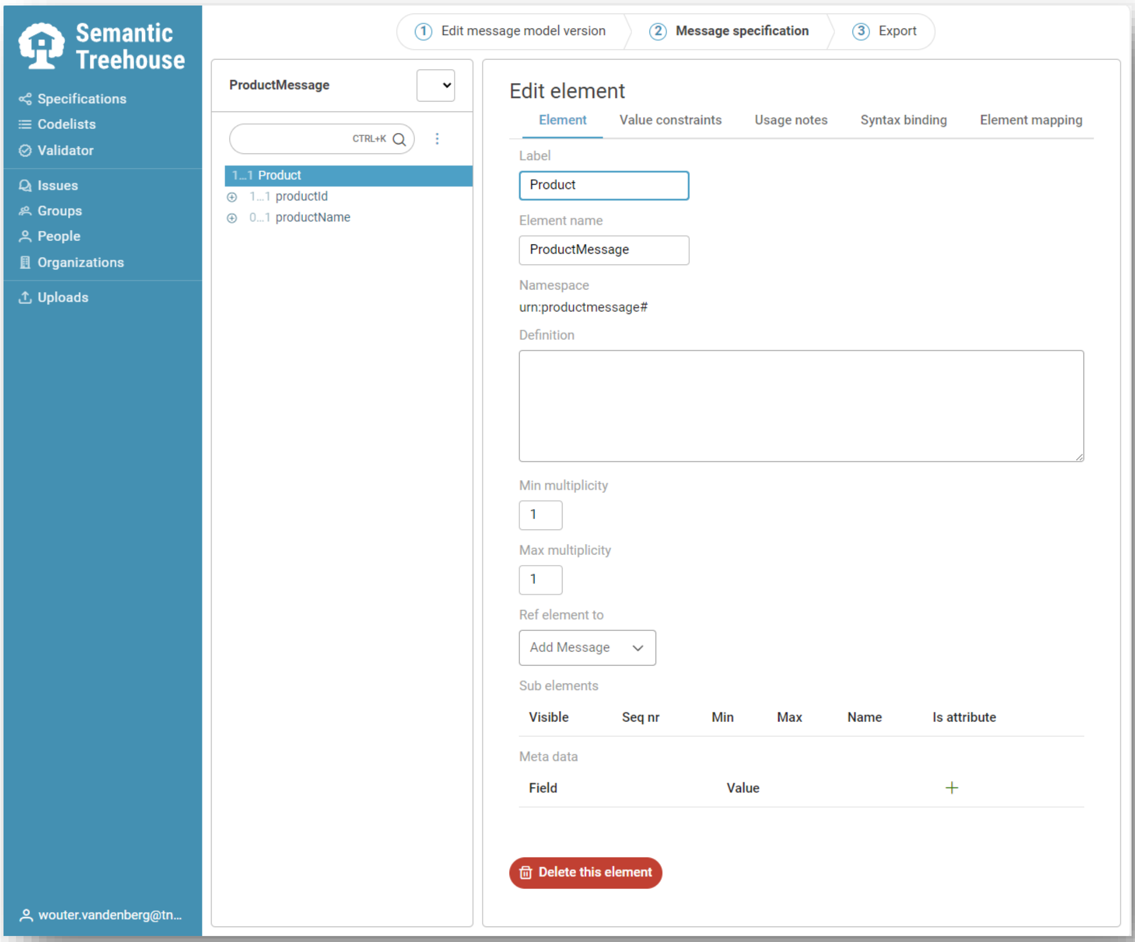

Label: Product
Element name: ProductMessage
Namespace: urn:productmessage#
Definition:
Min multiplicity: 1
Max multiplicity: 1
Ref element to: Add Message
Sub elements

Visible	Seq nr	Min	Max	Name	Is attribute

Meta data

Field	Value

Figure 13: The application presents the list of elements from the JSON Schema to the user.

Users can now create a custom data model that is essentially a profile of the JSON schema we started with. The profile can have numerous constraints on the original model. Users can choose if they need to select both properties and customize their characteristics, such as definition, cardinality, and element name.

4.1.3.3 Main limitations

The limitations of the current implementation of JSON schema in the Vocabulary Hub can be grouped into three categories:

1. JSON Schema version support;

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2. applicator keywords, and
3. reverse properties

Apart from these limitations, most simple and advanced JSON schema constructs are picked up by the wizard.

4.1.3.3.1 Version support

This release supports JSON schemas with versions until `Draft-07`[2], so not 2019-09 nor 2020-12.

4.1.3.3.2 Applicator keywords

This release of the Vocabulary Hub supports as far as we know all datatypes. We provide basic support for advanced constructs, called Applicator Keywords. These are `OneOf`, `AnyOf` and `AllOf`. For `OneOf` lists, we don't offer all of the options but only an arbitrary first schema of a possibly nested `OneOf` list. `AllOf` schema lists will all be added as possible sub-properties and offered in the Wizard.

4.1.3.3.3 Reverse properties

JSON Schemas have an innate direction or tree-form: there is always a root object that can hold child objects, and so on. Even though conceptually, it can be argued for any property that the reverse property is also valid and relevant to knowledge modelers. As an example, consider a `Person` schema that holds property `drives` with the target schema of an object `Car`. It can be equally validly modeled as a `Car` schema that holds a property `drivenBy` with target schema `Person`. Ideally, our wizard would offer the "reverse" property of `drivenBy` to a modeler who makes a message model of a `Car`. The current implementation does not offer support for showing this reverse property, though it has to be noted that JSON Schemas don't hold reverse text for properties (like in this example the name `drivenBy`). Currently the wizard only offers properties in the direction of 'down the tree'.

4.1.3.4 Next steps for final version

From an iterative development perspective, this extension is now ready for further validation with ENERSHARE pilot partners. The resulting feedback process can be

[2] https://json-schema.org/draft-07/json-schema-release-notes

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used to improve this feature, which in turn is included in the next and final ENERSHARE technology release.

4.1.4 Development goal 2: implementing the five-star model of vocabulary use

Implementation of this extension is ongoing. Progress has been made in further defining the next increment towards this goal, which is described below. Delivery of this increment is expected before the last technology release and will be followed by further validation together with the help of pilot partners.

4.1.4.1 The five-stars model of vocabulary use

The five stars of vocabulary use[3], as inspired by Tim Berners-Lee's framework for Linked Open Data[4], is intended to encourage the use of vocabularies and enhance the (re)usability and interoperability of data on the web. The framework rates vocabulary usage of datasets along five levels (six, if we count the baseline of zero stars):

- Zero stars: Refers to Linked Data without any vocabulary. Data at this level do not refer to any web-accessible descriptions of the vocabulary used, making interpretation and integration difficult.
- One star: Linked Data provides dereferenceable human-readable information about the vocabulary. This may include documentation, examples, or contact information, and serves to help users better understand the dataset's context.
- Two stars: The vocabulary includes machine-readable explicit axiomatization, ideally using semantic web standards like RDFS and OWL. However according to our interpretation this can be any machine-readable vocabulary definition.
- Three stars: The vocabulary is linked to other vocabularies through explicit alignments or reuse, denoted by relations like `subClassOf` or `equivalentClass`. These links should be at the vocabulary level, not between individual entities.

[3] https://www.semantic-web-journal.net/content/five-stars-linked-data-vocabulary-use
[4] https://5stardata.info/en/

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- Four stars: There is dereferenceable and machine-readable metadata available about the vocabulary, which might include licensing, contact details, modification dates, the ontology language used, and the methodology behind the vocabulary's development.
- Five stars: The vocabulary is linked to by other vocabularies, reflecting its external usage and perceived usefulness. This star level indicates that the vocabulary is recognized and integrated within the broader Linked Data ecosystem, although the creators have limited influence on achieving this star.

The aim of this framework is not to judge the quality of the vocabularies themselves but to promote their accessibility on the web, thereby fostering semantic interoperability.

4.1.4.2 Next increment of the Energy Vocabulary Hub

Taking inspiration of the five-star framework, the new feature extends the functionality of the Vocabulary Hub by enabling a more accessible entry point for data providers to align with semantic interoperability standards. Recognizing the varying levels of expertise and resources among data providers, this feature aims to lower the barrier to participation by offering an alternative to the model-driven route currently provided by the wizard.

Utilizing a bottom-up methodology, the extended wizard allows users to upload a sample of their existing dataset. Through a parsing and analysis process, the Vocabulary Hub constructs a machine-readable data model that represents the structure and semantics of the provided data.

Adding such a feature for data model generation serves a dual purpose:

- Facilitating easy adoption: By automating the initial steps of modeling, the feature enhances the ease of adoption for data providers new to semantic technologies and linked data principles. It provides a supportive steppingstone towards full utilization of common vocabularies and ontologies.
- Achieving Two-Star vocabulary use: In accordance with the "Five Stars Model of Vocabulary Use", generating a machine-readable data model corresponds to achieving a two-star level of interoperability. This distinguishes the

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dataset from others with less stars (either no information on vocabulary use, or only providing human-readable information). At the same time, it communicates that more can be done. Perhaps the dataset owner can take the next step towards three or four stars.

4.1.4.3 Preliminary UX design

1. Data Upload: The user begins by uploading a sample dataset in a common file format, restricted to CSV for this increment. The sample should be representative of the full dataset to ensure the generated schema is applicable across the entire data collection.

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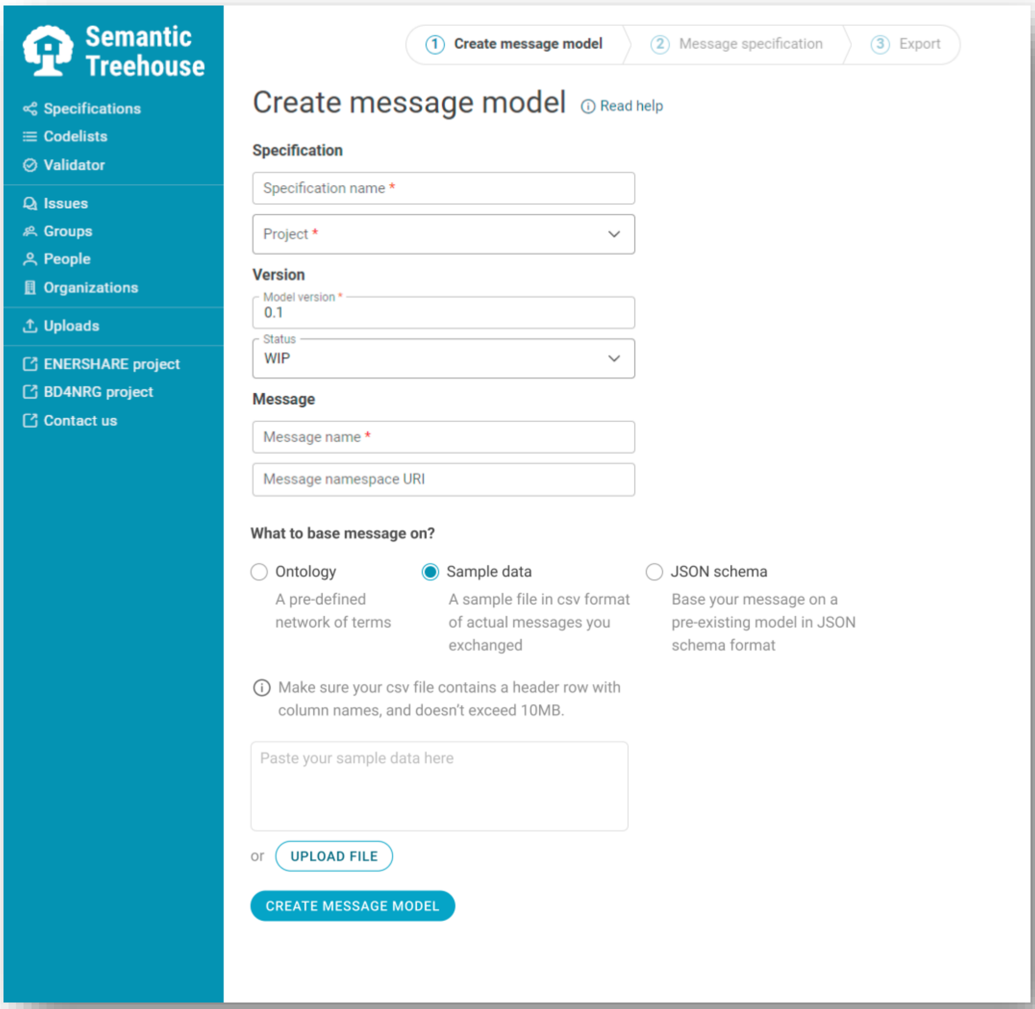

Create message model

Specification

Specification name *

Project *

Version

Model version * 0.1

Status WIP

Message

Message name *

Message namespace URI

What to base message on?

Ontology — A pre-defined network of terms [✓ Sample data] — A sample file in csv format of actual messages you exchanged JSON schema — Base your message on a pre-existing model in JSON schema format

Make sure your csv file contains a header row with column names, and doesn't exceed 10MB.

Paste your sample data here

or

Figure 14: Uploading a CSV sample (mock-up)

2. Data Analysis: Upon upload, the Vocabulary Hub performs a thorough analysis of the sample. It detects patterns, infers types, and identifies potential concepts and relationships inherent in the data. This step leverages machine learning algorithms and heuristic rules to interpret the dataset's structure.
3. Model Suggestion: Based on the analysis, the wizard proposes a preliminary data model that describes the CSV sample.

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4. User Review and Refinement: The user is then invited to review the suggested data model (interface as shown in Figure 13). They may accept, modify, or extend the model to better fit their particular context and requirements. Out of scope for this increment, but promising future research: the vocabulary hub provides guidance on how to align the customized model with shared ontologies and vocabularies, promoting semantic integrity and interoperability.
5. Schema Generation: Once the user finalizes their adjustments, the wizard generates the final data schema in a standard format or even open API specification.

By providing this alternative route next to the model-driven flow in the wizard component, the Vocabulary Hub opens the door to semantic interoperability for data providers of all sizes and expertise—laying the foundation for a more connected and semantically-rich data space.

4.1.4.4 Next steps

The next steps are 1) completing the developing of this increment of the Vocabulary Hub, and 2) further validation of the added value of this functionality, and 3) further implementing the five-star framework for promoting vocabulary use.

Validation will consist of testing it with data from the ENERSHARE pilot partners. Pilot partners represent users (data providers) and their feedback is essential to discover new requirements and prioritize features. In addition to refined requirements, the validation step will result in the creation of a set of new data models in the Vocabulary Hub that reflect the structure of (CSV) data available in a particular pilot.

4.1.4.5 Future research

Future increments of the Vocabulary Hub will focus on the interaction between the Vocabulary Hub and Metadata Broker components to further implement the five-star framework for vocabulary use. The Metadata Broker will be extended so that each dataset entry in its catalogue contains a vocabulary use score. That way it will be clear to every data space participant what the current vocabulary use score is for each dataset. Potential data consumers can use this information to estimate the degree of semantic interoperability of datasets. Data providers, in turn, can change the value of this score for their own datasets by taking actions in the Vocabulary Hub,

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for example creating a data model from data sample as described in the previous sections.

4.2 Open APIs

As stated in section 2.4, Open APIs based on a common semantic data model are needed to ensure semantic interoperability.

An Open API will be created for each of the types of data services developed in the ENERSHARE use cases that need to exchange information between the Dataspace participants.

These Open APIs define how to formalize the data to be exchanged in the payload of the messages transferred between data providers and data consumers. Data providers must be able to describe and publish their data sources in such a way that these become easily findable and usable for data consumers.

The first step for the creation of the Open API for the different services, has been to analyse the input and output data of each of them. Next, each concept and attribute in the input and output has been mapped to a concrete class or property in the ENERSHARE semantic model described in section 3. For example, in the case of the data-driven failure detection algorithm for wind turbines, the service needs as input the following parameters described in Table 5: the identifiers of the wind farm and wind turbine, the timestamp when the measurements were taken and the values of the nacelle temperature, the pitch angle of the blade, the wind speed, and the active power, current and torque of the generator. These parameters are mapped to the concepts and properties of the ontology as described in the column "ontology mapping". These mappings are represented graphically in diagrams which are a subset of the diagrams in the appendix 7. See Figure 15 and Figure 16 for examples of the subsystems of a wind turbine and the properties of a generator.

Table 5: Input parameters of a data-driven failure detection algorithm for wind turbines

Input param		
name	**ontology mapping**	**example**
timestamp	time:Instant xsd:inXSDDateTime	2019-08-24T00:00:00Z

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windfarm id	plt:WindFarm rdfs:label	FRBRT
windturbine id	plt:OnshoreWindTurbine rdfs:label	91840
nacelle temperature	plt:Nacelle plt:hasAverageTemperature seas:TemperatureProperty seas:TemperatureEvaluation	"@type" : "cdt:temperature", "@value" : "27.54 Cel"
blade pitch angle	plt:Blade plt: hasAveragePitchAngle seas:PitchAngleProperty seas:AverageEvaluation	"@type": "cdt:angle", "@value": "450 deg"
windspeed	plt:OnshoreWindTurbine plt:hasAverageWindSpeed seas:WindSpeedProperty seas:WindSpeedEvaluation	"@value": "9.32 m/s", "@type": "cdt:speed"
generator active power	plt:Generator plt:hasAverageActivePower seas:ElectricPowerProperty seas:ElectricPowerEvaluation	"@type": "cdt:power", "@value": "495.7 kW"
generator current	plt:Generator plt:hasAverageCurrent seas:CurrentProperty seas:CurrentEvaluation	"@type": "cdt:electricCurrent", "@value": "417.18 A"
generator torque	plt:Generator plt:hasAverageTorque plt:TorqueProperty plt:TorqueEvaluation	"@type": "cdt:energy", "@value": "3370.42 N.m"

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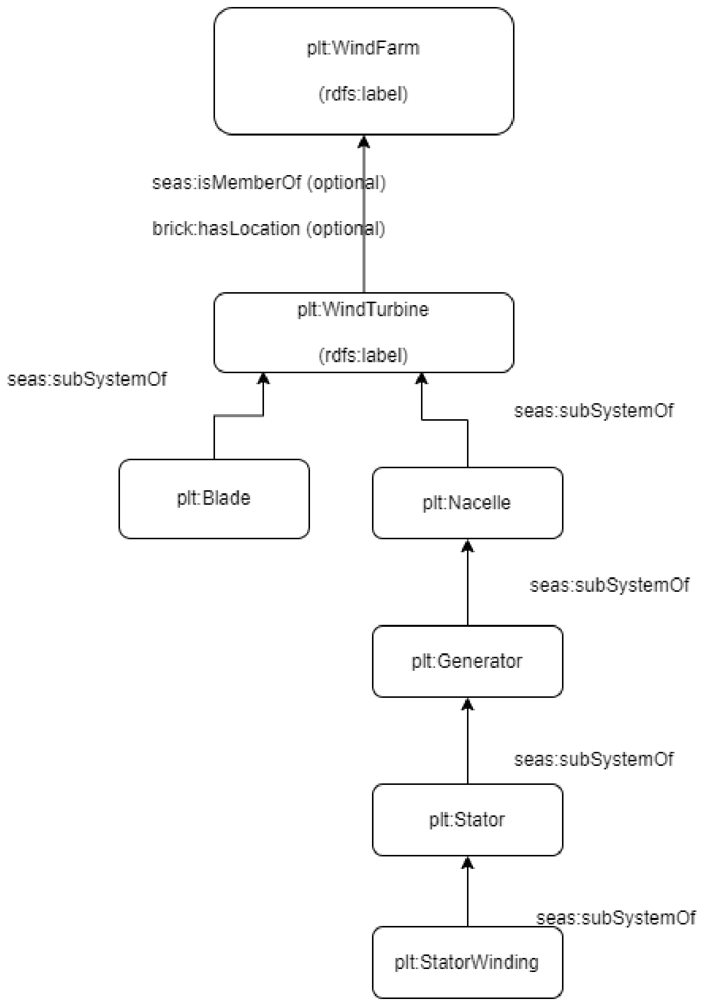

Figure 15: Diagram of the subsystems of a wind turbine.

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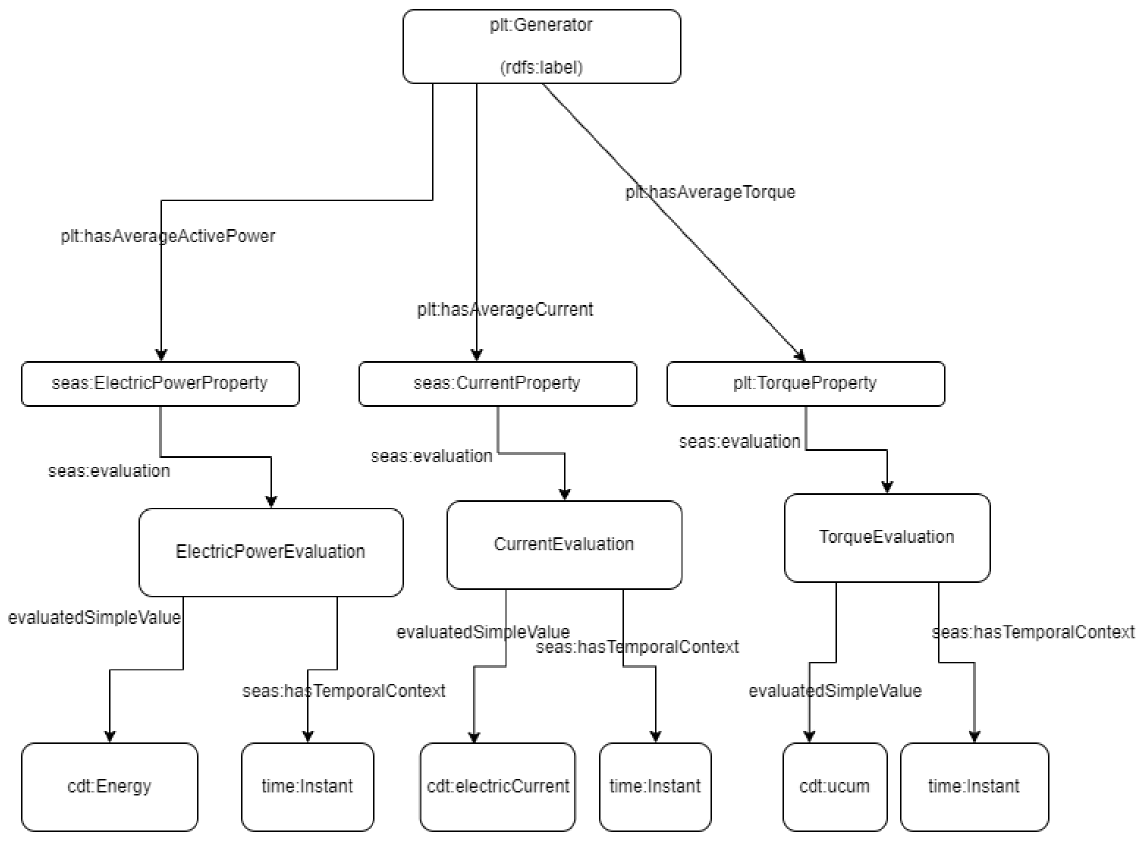

Figure 16: Diagram of the properties of a generator.

Once the mappings are clear, the inputs and outputs can be serialized according to ENERSHARE semantic data format, e.g., in Turtle or in JSON-LD (see Table 14 and Table 15).

For each Open API, different alternative data schemas will be provided. For example, a lightweight representation in JSON of Table 14 could be.

```
{
        "windturbine": {
                "timestamp": "2019-08-24T00:00:00Z",
                "windfarm_id": "FRBRT",
                "windturbine_id": "91840",
                "nacelle_temperature": "27.54 Cel",
                "blade_pitch_angle": "450 deg",
                "windspeed": "9.32 m/s",
                "generator_active_power": "495.7 kW",
                "generator_current": "417.18 A",
                "generator_torque": "3370.42 N.m",
```

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```
                    "stator_winding_temperature": "27.54 Cel"
          }
}
```

For each alternative data schema, we will also define the set of mapping rules in RML to transform the data into the ENERSHARE data model, as explained in section 2.4 using the Data Transformation Service.

The wizard of the Vocabulary Hub can be used in design time to generate the mapping rules in RML and to generate the skeleton of the data format in the Open APIs.

The specification of the Open APIs will be provided in yaml/json files. This specification can be used by the pilots to develop their REST APIs as well as to describe the service in the data space for possible consumers.

4.2.1 Next steps

For the final version we will finalise the specification of the Open APIs for all the services exchanging data in the pilot use cases. We will also define shape files to validate the compliance of the data models. We will provide alternative schemas in JSON with the corresponding RML mapping rules. Finally, we will also provide schemas compliant with Smart Data Models in NGSI-LD using the Data Models Contribution API[5].

4.3 Data Transformation Service

In the beta version, the data transformation service is defined as a REST service (implemented in Python language) which, given any data in a structured source format and a mapping file with rules written in RDF Mapping Language (RML), transforms the data to RDF and provides the output in the requested serialization format including n3, json-ld, hext, nquads, pretty-xml, trig, trix, turtle, longturtle and xml.

[5] https://smartdatamodels.org/index.php/data-models-contribution-api/

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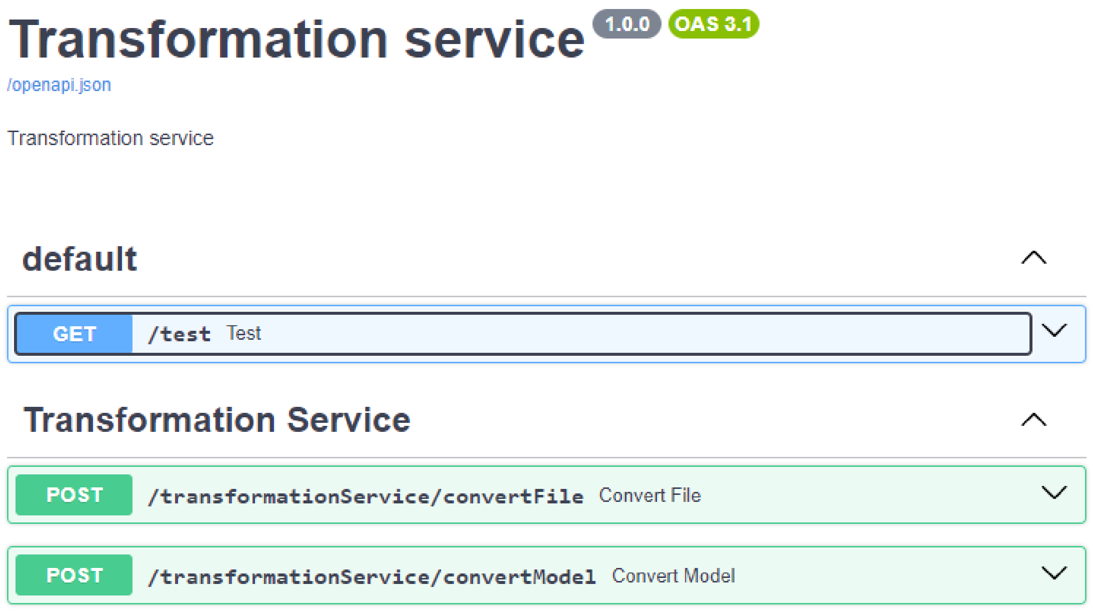
The service offers three methods:

- /test: to test the connection with the service endpoint.
- /transformationService/convertFile: converts the data into RDF, where both the URLs of the data source and the mapping files are provided as input
- /transformationService/convertModel: converts the data into RDF, where both the content of the data source and the mapping files are provided as input strings

Transformation service - Swagger UI endpoint: https://transformation.enershare.urban.tecnalia.dev/docs


Transformation service 1.0.0 OAS 3.1
/openapi.json
Transformation service

default

GET /test Test

Transformation Service

POST /transformationService/convertFile Convert File

POST /transformationService/convertModel Convert Model

Figure 17: Swagger file of the Data Transformation rest service

Table 6: Method to test the connection with the service endpoint

Title	Test connection
URL	
/test	
Method	
GET	

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Data Params	
No parameters	
Success response	
200	"OK"
Error response	
404	Not found
Sample call	

```
curl -X 'GET' \
  'http://XXX.XX.XX.XX:XXXX/test' \
  -H 'accept: application/json'
```

Table 7: Method to convert data given the URLs of the data source and mapping files

Title	convert data given the URLs of the data source and the mapping files
URL	
/transformationService/convertFile	
Method	
POST	
Data Params	
Required:	
json_file_url	the URL of the data source
mapping_file_url	the URL of the mapping file with rules written in RML
Optional:	
serialize_format	the serialization format for the data model provided as output. Default value: turtle. Possible values: n3, json-ld, hext, nquads, pretty-xml, trig, trix, turtle, longturtle, xml.
Success response	
200	Semantic data model in the requested serialization format. Examples are available in Table 14 (Turtle) and in Table 15 (JSON-LD).
Error response	
422	Transformation error
Sample call	

```
curl -X 'POST' \
'http://XXX.XX.XX.XX:XXXX/transformationService/convertFile?json_file_url=https%3A%2F%2Fgit.
code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fmappings%2Fpilot1_windturbine_simplejson.json&mapping_file_url=https%3A%2F%2
Fgit.code.tecnalia.com%2Fopen%2Fenershare%2F-%2Fraw%2Fmain%2Fmappings%2Fpilot1-windturbine-
mapping-json.ttl&serialize_format=turtle' \
  -H 'accept: application/json' \
  -d ''
```

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Table 8: Method to convert data given the content of the data source and mapping files

Title	convert data given the content of the data source and the mapping files
URL	
/transformationService/convertModel	
Method	
POST	
Data Params	
Required:	
json_file_data	the content of the data source file
mapping_file_data	the content of the mapping file with rules written in RML
Optional:	
serialize_format	the serialization format for the data model provided as output. Default value: turtle. Possible values: n3, json-ld, hext, nquads, pretty-xml, trig, trix, turtle, longturtle, xml.
Success response	
200	Semantic data model in the requested serialization format. Examples are available in Table 14 (Turtle) and in Table 15 (JSON-LD).
Error response	
422	Transformation error

4.4 Compliance Service

In the beta version, the compliance service is defined as a REST service which, given a semantic model and a SHACL file, validates the RDF graph against the set of conditions specified in the shapes graph. The service is implemented in Python language.

This service allows connectors to validate their APIs against the shapes (SHACL files) provided for each Open API, so that interoperability in the data space is guaranteed.

The service offers three methods:

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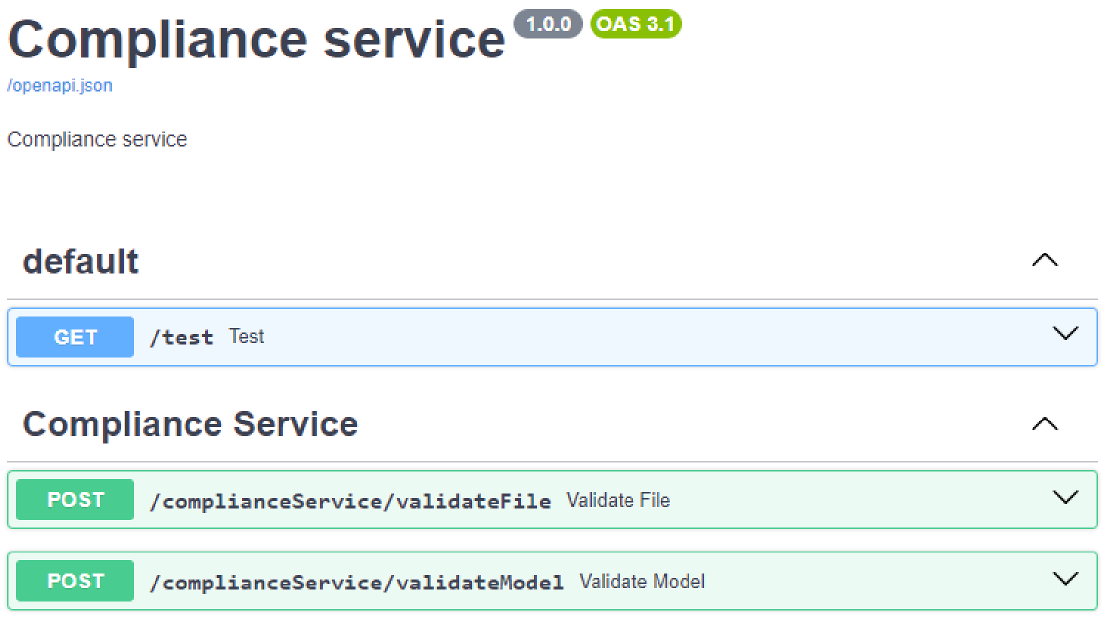
- /test: to test the connection with the service endpoint.
- /complianceService/validateFile: validates the RDF graph, where both the URLs of the data model and the shapes files are provided as input
- /complianceService/validateModel: validates the RDF graph, where both the content of the data model and the shapes files are provided as input strings

Compliance service - Swagger UI endpoint: https://compliance.enershare.urban.tecnalia.dev/docs



Compliance service 1.0.0 OAS 3.1

/openapi.json

Compliance service

default

GET /test Test

Compliance Service

POST /complianceService/validateFile Validate File

POST /complianceService/validateModel Validate Model

Figure 18: Swagger file of the Compliance rest service

Table 9: Method to test the connection with the service endpoint

Title	Test connection
URL	
/test	
Method	
GET	
Data Params	
No parameters	
Success response	

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200	"OK"
Error response	
404	Not found
Sample call	

```
curl -X 'GET' \
  'http://XXX.XX.XX.XX:XXXX/test' \
  -H 'accept: application/json'
```

Table 10: Method to validate the data given the URLs of the data model and shapes files

Title	Validate the RDF graph given the URLs of the data model and the shapes files
URL	
/complianceService/validateFile	
Method	
POST	
Data Params	
Required:	
json_file_url	the URL of the data model
shacl_file_url	the URL of the shapes file written in SHACL (see example in Table 16)
Success response	
200	Json object: - conforms: Boolean indicating if the graph is correct. - report: content of the validation report Example 1 (correct model):

```
{
  "conforms": true,
  "report": "Validation Report\nConforms: True\n"
}
```

Example 2 (incorrect model):

```
{
  "conforms": false,
  "report": "Validation Report\nConforms: False\nResults (1):\nConstraint Violation in MinCountConstraintComponent (http://www.w3.org/ns/shacl#MinCountConstraintComponent):\n\tSeverity: sh:Violation\n\tSource Shape: [ sh:minCount Literal(\"1\", datatype=xsd:integer) ; sh:path [ sh:inversePath rdf:type ] ]\n\tFocus Node: seas:PitchAngleProperty\n\tResult Path: [ sh:inversePath rdf:type ]\n\tMessage: Less than 1 values on seas:PitchAngleProperty->[ sh:inversePath rdf:type ]\n"
}
```

Error response	

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422	Validation error
Sample call	

```
curl -X 'POST' \
'http://XXX.XX.XX.XX:XXXX/complianceService/validateFile?jsonld_file_url=https%3A%2F%2Fgit.c
ode.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fmappings%2Fpilot1_windturbine_generated.jsonld&shacl_file_url=https%3A%2F%2F
git.code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fshacl%2Fpilot1_anomaly_detection_input.shacl.ttl' \
  -H 'accept: application/json' \
  -d ''
```

Table 11: Method to validate data given the content of the data model and shapes files

Title	Validate the RDF graph given the content of the data model and the shapes files
URL	
/complianceService/validateModel	
Method	
POST	
Data Params	
Required:	
graph_file_data	the content of the data model
shacl_file_data	the content of the shapes file written in SHACL
Optional:	
data_file_format	the serialization format of the data model Default value: json-ld.
shapes_file_format	the serialization format of the shapes model Default value: turtle.
Success response	
200	Json object: - conforms: Boolean indicating if the graph is correct. - report: content of the validation report Examples (same as above for validateFile)
Error response	
422	Validation error

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4.5 Context Broker

An NGSI-LD context broker is a key component in the NGSI-LD (Next Generation Service Interface with Linked Data) architecture, which is used for managing context information. It acts as the primary access point to context information for context consumers (sensors, legacy applications, microservices, etc), allowing them to store, retrieve, and subscribe to context information. NGSI-LD allows the storing of information but also the storing of relations between different entities stored. The context broker can store NGSI-LD entity information (a subset of JSON LD) provided by context producers or request it from context sources. It also uses the context source discovery functionality to find relevant NGSI-LD entities. The NGSI-LD specification is regularly updated and published by ETSI in its Context Information Management group[6], with the latest version being 1.7.1 as of June 2023.

The following FIWARE Context Broker implementations, supporting the ETSI NGSI-LD 1.6.1. API specifications or higher are available:

- The Orion-LD Context Broker Generic Enabler [20] is an alternative NGSI-LD Context Broker written in C/C++, which supports both NGSI-LD and the NGSI-v2 APIs. It is a standalone executable and therefore small, fast, lightweight, and easy to handle.
- The Scorpio Broker Generic Enabler [21] is an alternative NGSI-LD Broker which can also be used in federated environments. Two interaction styles are supported, a synchronous query-response, and an asynchronous subscribe/notify, where notifications can be based on a change in property or relationship, or on a fixed time interval. In addition to the regular context interface that provides the most current properties and relationships for each entity, Scorpio implements NGSI-LD's optional temporal interface for requesting historic information, e.g., the property values measured within a specified time interval.
- The Stellio Context Broker Generic Enabler [22] is another alternative NGSI-LD Broker. It is built around a Kafka message broker for improved extensibility, scalability, and decoupling of services. These services embed a graph database (Neo4J) for context management as well as a timeseries

[6]https://www.etsi.org/committee/cim

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(TimescaleDB) and geospatial (PostGIS) database to manage temporal and geospatial properties.

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.

A detailed comparison, based on functional and performance evaluation, between Orion-LD, Scorpio and Stellio can be found in deliverable D3.1 and in FIWARE Catalogue GitHub README[7]. In this spreadsheet there are several sections to show how the different brokers implement the API, the entity operations, the subscriptions, the temporal API, the registry API, and the JSON-LD context. It is also included in what version of the NGSI-LD specification every feature is defined.

In the context of the ENERSHARE project, the Context Broker in the Digital Enabler [23], which is an "Ecosystem" platform developed by Engineering, has been upgraded to Orion-LD that supports Linked Data capabilities.

4.6 Data Mashup Editor

4.6.1 Description

The Data Mashup Editor (DME) 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 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.

Please refer to deliverable D3.1 for a more detailed description of the existing implementation offered by the Digital Enabler.

[7] https://bit.ly/context_broker_comparison

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4.6.2 Developments within ENERSHARE

In the ENERSHARE project, the Data Mashup Editor has been provided in version 2.3 as runtime for data transformation and harmonization. Thanks to the provided functionalities it is possible to connect data from heterogeneous sources and compose complex business logics in a graphical way simply connecting existing atomic operators. 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.

An important aspect of the Data Mashup Editor features is the support to the common semantic data model defined in ENERSHARE. In the ICT architecture, the Vocabulary Hub acts as a registry of data models for the Energy domain and its wizard facilitates the creation, at design time, of the Open APIs specifications.

The Data Mashup Editor is also used to trigger the created flow through the IDS Connector. In particular, the DME has been already integrated with the True Connector. According to ENERSHARE project requirements, the Data Mashup Editor is evolving with the possibility to add custom operators (defined by the user through a JSON Schema) to integrate data models coming from the Vocabulary Hub and make them available to the pilots.

4.6.3 Next steps for final version

Our upcoming focus includes finalizing the Custom Data Mapper for seamless integration with the NGSI-LD standard. Additionally, we're working on a redesigned drawing area to enhance user interaction and improve the overall usability of the tool.

The Data Mashup Editor will be validated in at least one pilot developing data-driven cross-sector services. These services are:

- Multi-energy flexibility potential assessment
- Cross-operators' portal (COP)
- Emissions and ecological footprint
- EV charging monitoring and remote management
- ML-based models for assessing renovation actions in residential buildings
- Health insurance alarms for senior living alone

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- Appliances maintenance or retrofit.

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5 Conclusions and future work for the final version of the document

Data exchange interoperability occurs at two levels: technical interoperability and semantic interoperability. At technical level, interoperability among connectors will be guaranteed by the Dataspace Protocol Specification. At semantic level, a common data model is needed. However, in practice, it is not realistic to assume that there will be a unique semantic model that will cover all the concepts and relationships in a domain. For this reason, we support the idea of a data transformation service, that given a data schema and some mapping rules allows transforming any data model into the data model expected by the data space to ensure interoperability between data providers and consumers. This approach is also suitable for cross-domain interoperability, for services deployed in production and for low latency or big volume data exchange.

Besides, tools like the Vocabulary Hub facilitate the work needed to define, at design time, the data transformation rules and the definition of the Open APIs taking as input already existing data models, whereas tools like the Data Mashup Editor facilitate the work needed at run-time to transform the data before being published.

In addition, compliance services allow to easily validate that connectors inputs and outputs are compliant with the Open APIs specification.

The next version of this document will provide the final version of the ENERSHARE ontology, the Open APIs specification in a variety of data schemas (JSON, JSON-LD and NGSI-LD), the mapping rules for the transformations and the shapes files for the validation of the data models.

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6 References

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[2] BD4NRG Project. https://www.bd4nrg.eu/

[3] Interconnect Project. https://interconnectproject.eu/

[4] OneNet Project. https://onenet-project.eu/

[5] NGSI-LD Specifications: https://fiware-datamodels.readthedocs.io/en/stable/ngsi-ld_howto/

[6] IEC 61850-7-2 standard. https://webstore.iec.ch/publication/6015

[7] IEC 61968-100 standard. https://webstore.iec.ch/publication/67766

[8] Gaia-X: A Federated Secure Data Infrastructure. https://gaia-x.eu/

[9] The Data Spaces Business Alliance (DSBA). https://data-spaces-business-alliance.eu/

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[13] Usage Control in the International Data Spaces. Position Paper Version 3.0 March 2021. https://internationaldataspaces.org/wp-content/uploads/dlm_uploads/IDSA-Position-Paper-Usage-Control-in-the-IDS-V3..pdf

[14] Data Connector Report. https://internationaldataspaces.org/data-connector-report/

[15] TRUE Connector. https://github.com/Engineering-Research-and-Development/true-connector

[16] TNO Security Gateway. https://tno-tsg.gitlab.io/

[17] DSSC Blueprint version 0.5, September 2023: https://dssc.eu/space/BPE/179175433/Data+Spaces+Blueprint+%7C+Version+0.5+%7C+September+2023

[18] Dataspace Protocol Specification: https://github.com/International-Data-Spaces-Association/ids-specification

[19] IDSA. Dataspace Protocol – ensuring data space interoperability, May 4, 2023: https://internationaldataspaces.org/dataspace-protocol-ensuring-data-space-interoperability/

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[20] FIWARE Orion-LD, Orion Context Broker (with Linked Data Extensions): https://github.com/FIWARE/context.Orion-LD
[21] FIWARE Scorpio Broker: https://scorpio.readthedocs.io/en/latest/
[22] FIWARE Stellio Context Broker: https://stellio.readthedocs.io/en/latest/
[23] Digital Enabler. https://www.eng.it/en/our-platforms-solutions/digital-enabler

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7 Appendix: Diagrams from step 3

This annex presents the result of the work realised for each pilot during the step 3 of the methodology for the ENERSHARE data model.

7.1 Pilot 1: Wind farm integrated predictive maintenance and supply chain optimization [Spain] - TECN, ENGIE, ACE, HINE

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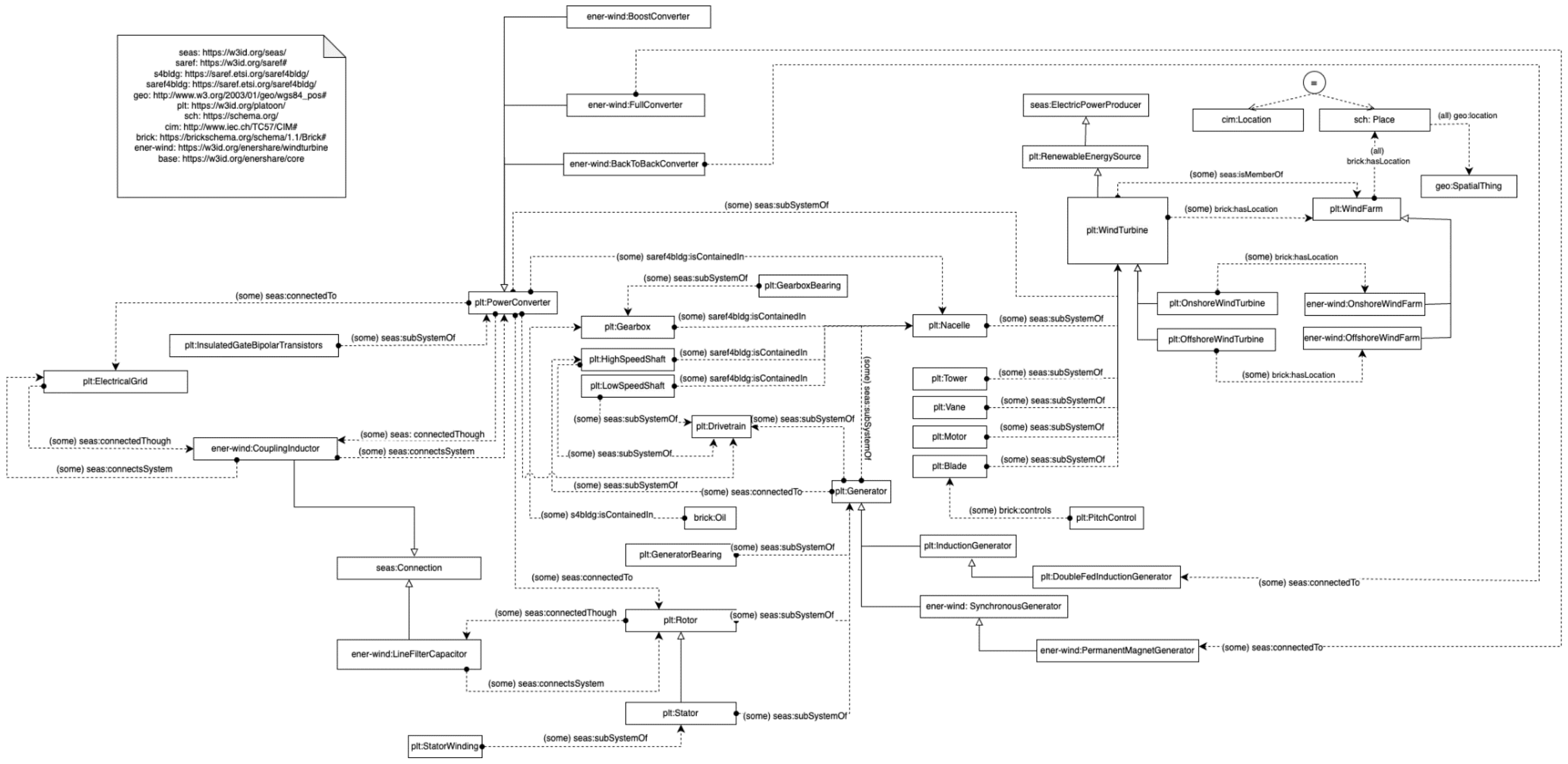

Figure 19: Pilot 1 - Wind Turbine Components

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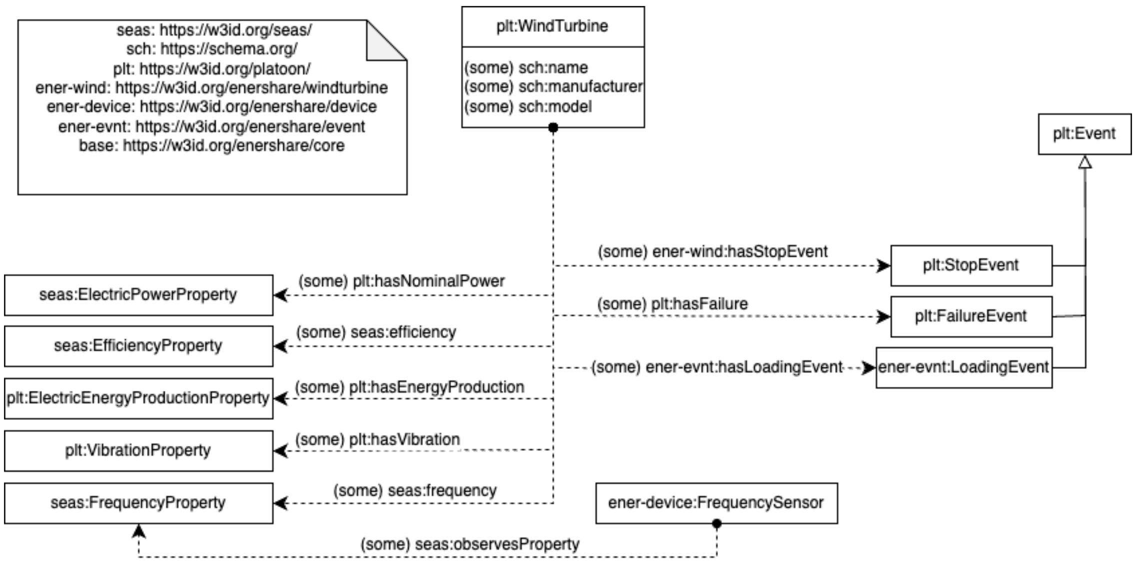
seas: https://w3id.org/seas/
sch: https://schema.org/
plt: https://w3id.org/platoon/
ener-wind: https://w3id.org/enershare/windturbine
ener-device: https://w3id.org/enershare/device
ener-evnt: https://w3id.org/enershare/event
base: https://w3id.org/enershare/core
plt:WindTurbine
(some) sch:name
(some) sch:manufacturer
(some) sch:model
plt:Event
(some) ener-wind:hasStopEvent
plt:StopEvent
(some) plt:hasFailure
plt:FailureEvent
(some) ener-evnt:hasLoadingEvent
ener-evnt:LoadingEvent
seas:ElectricPowerProperty
(some) plt:hasNominalPower
seas:EfficiencyProperty
(some) seas:efficiency
plt:ElectricEnergyProductionProperty
(some) plt:hasEnergyProduction
plt:VibrationProperty
(some) plt:hasVibration
seas:FrequencyProperty
(some) seas:frequency
ener-device:FrequencySensor
(some) seas:observesProperty

Figure 20 : Pilot 1 – Wind Turbine Properties

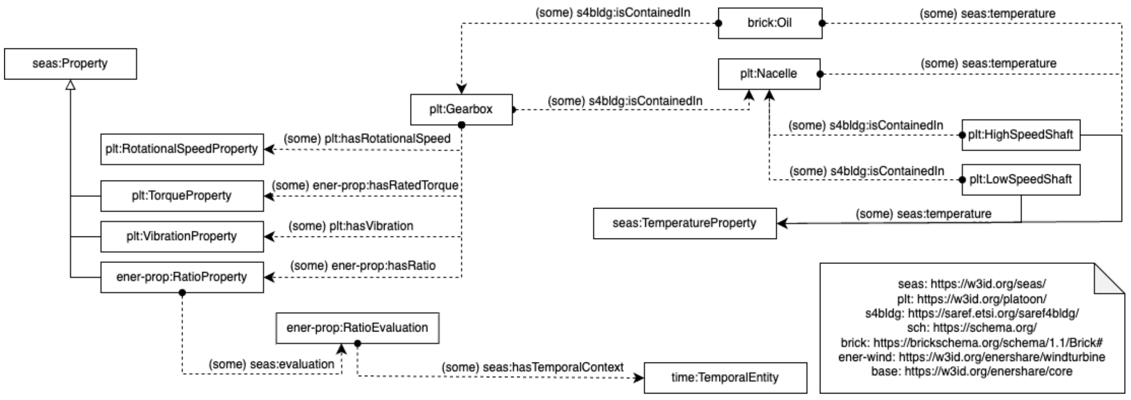
(some) s4bldg:isContainedIn
brick:Oil
(some) seas:temperature
seas:Property
plt:Nacelle
(some) seas:temperature
plt:Gearbox
(some) s4bldg:isContainedIn
plt:RotationalSpeedProperty
(some) plt:hasRotationalSpeed
(some) s4bldg:isContainedIn
plt:HighSpeedShaft
(some) s4bldg:isContainedIn
plt:LowSpeedShaft
plt:TorqueProperty
(some) ener-prop:hasRatedTorque
seas:TemperatureProperty
(some) seas:temperature
plt:VibrationProperty
(some) plt:hasVibration
ener-prop:RatioProperty
(some) ener-prop:hasRatio
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
s4bldg: https://saref.etsi.org/saref4bldg/
sch: https://schema.org/
brick: https://brickschema.org/schema/1.1/Brick#
ener-wind: https://w3id.org/enershare/windturbine
base: https://w3id.org/enershare/core
ener-prop:RatioEvaluation
(some) seas:evaluation
(some) seas:hasTemporalContext
time:TemporalEntity

Figure 21: Pilot 1 - Nacelle Properties

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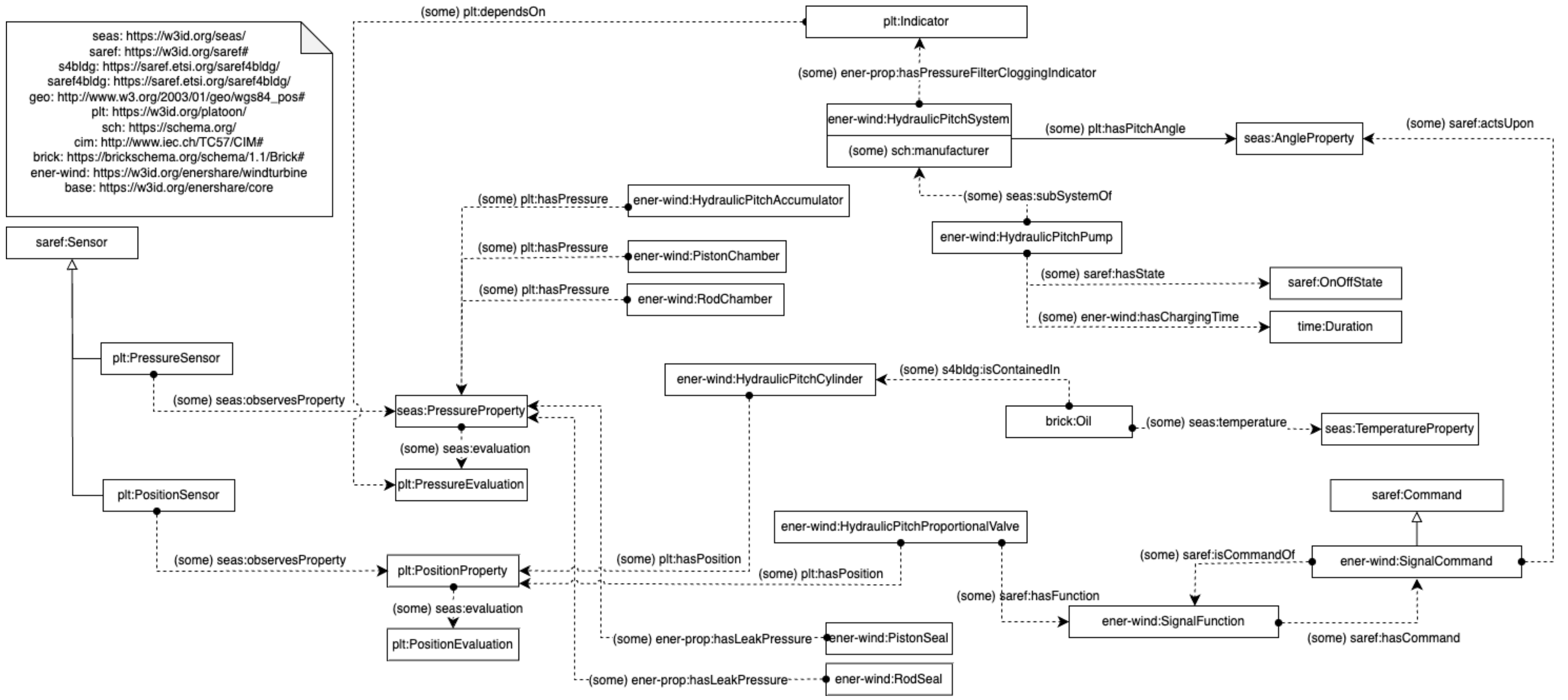
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
saref4bldg: https://saref.etsi.org/saref4bldg/
geo: http://www.w3.org/2003/01/geo/wgs84_pos#
plt: https://w3id.org/platoon/
sch: https://schema.org/
cim: http://www.iec.ch/TC57/CIM#
brick: https://brickschema.org/schema/1.1/Brick#
ener-wind: https://w3id.org/enershare/windturbine
base: https://w3id.org/enershare/core
(some) plt:dependsOn
plt:Indicator
(some) ener-prop:hasPressureFilterCloggingIndicator
ener-wind:HydraulicPitchSystem
(some) sch:manufacturer
(some) plt:hasPitchAngle
seas:AngleProperty
(some) saref:actsUpon
saref:Sensor
(some) plt:hasPressure
ener-wind:HydraulicPitchAccumulator
(some) seas:subSystemOf
ener-wind:HydraulicPitchPump
(some) plt:hasPressure
ener-wind:PistonChamber
(some) saref:hasState
saref:OnOffState
(some) plt:hasPressure
ener-wind:RodChamber
(some) ener-wind:hasChargingTime
time:Duration
plt:PressureSensor
ener-wind:HydraulicPitchCylinder
(some) s4bldg:isContainedIn
(some) seas:observesProperty
seas:PressureProperty
brick:Oil
(some) seas:temperature
seas:TemperatureProperty
(some) seas:evaluation
plt:PressureEvaluation
plt:PositionSensor
saref:Command
ener-wind:HydraulicPitchProportionalValve
(some) saref:isCommandOf
ener-wind:SignalCommand
(some) seas:observesProperty
plt:PositionProperty
(some) plt:hasPosition
(some) plt:hasPosition
(some) saref:hasFunction
(some) seas:evaluation
ener-wind:SignalFunction
plt:PositionEvaluation
(some) ener-prop:hasLeakPressure
ener-wind:PistonSeal
(some) saref:hasCommand
(some) ener-prop:hasLeakPressure
ener-wind:RodSeal

Figure 22: Pilot 1 - Hydraulic System Properties

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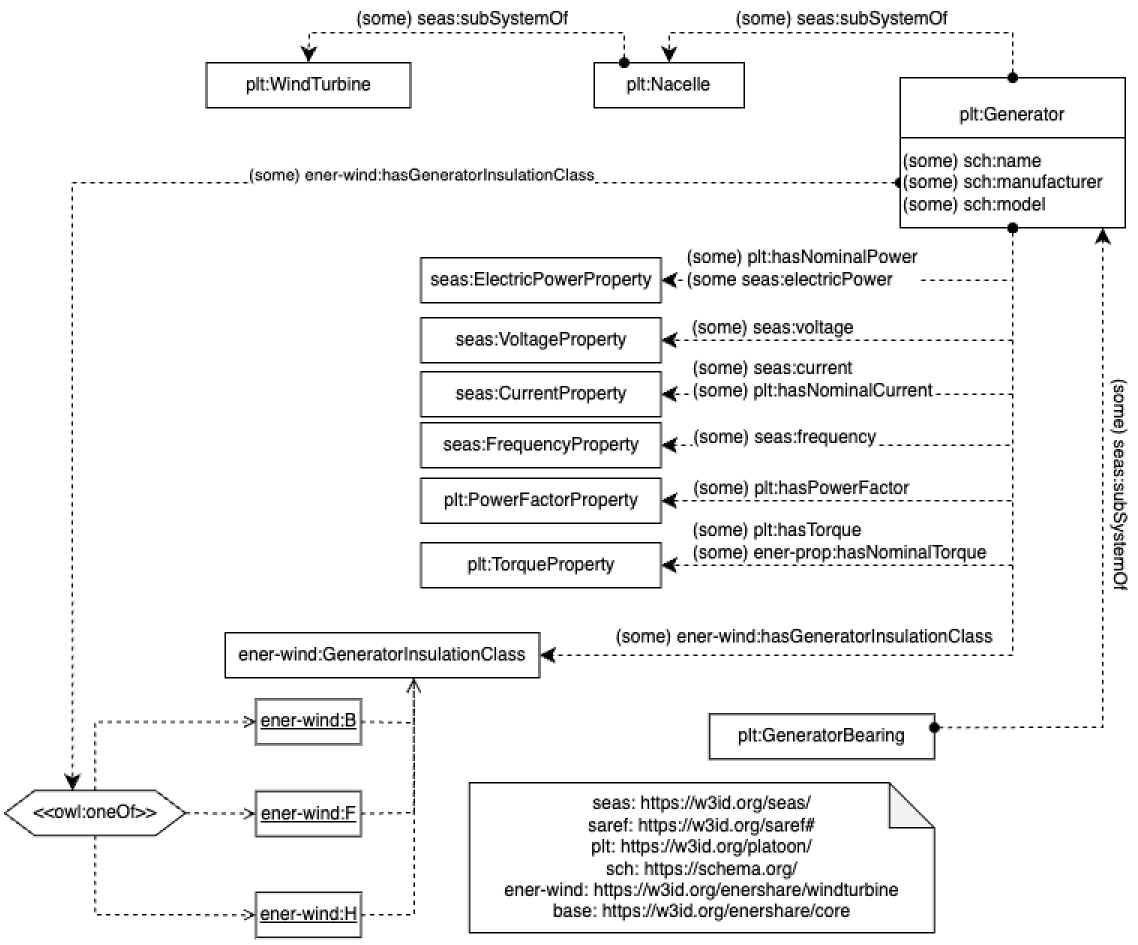

Figure 23: Pilot 1 - Generator Properties

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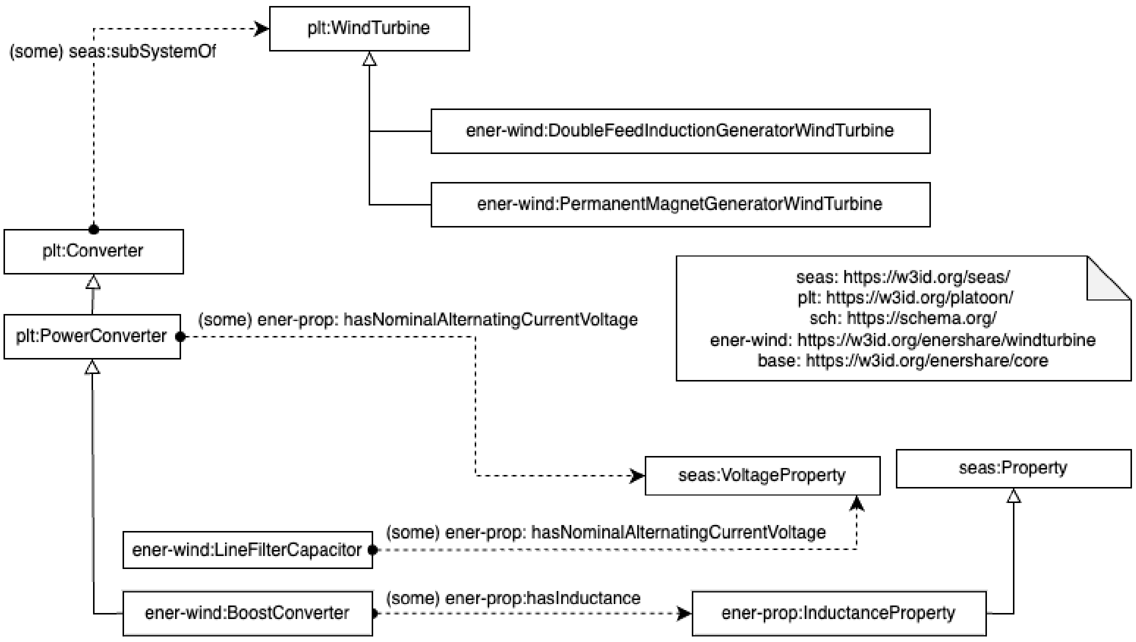
plt:WindTurbine
(some) seas:subSystemOf
ener-wind:DoubleFeedInductionGeneratorWindTurbine
ener-wind:PermanentMagnetGeneratorWindTurbine
plt:Converter
plt:PowerConverter
(some) ener-prop: hasNominalAlternatingCurrentVoltage
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-wind: https://w3id.org/enershare/windturbine
base: https://w3id.org/enershare/core
seas:VoltageProperty
seas:Property
ener-wind:LineFilterCapacitor
(some) ener-prop: hasNominalAlternatingCurrentVoltage
ener-wind:BoostConverter
(some) ener-prop:hasInductance
ener-prop:InductanceProperty

Figure 24: Pilot 1 - Converter Properties

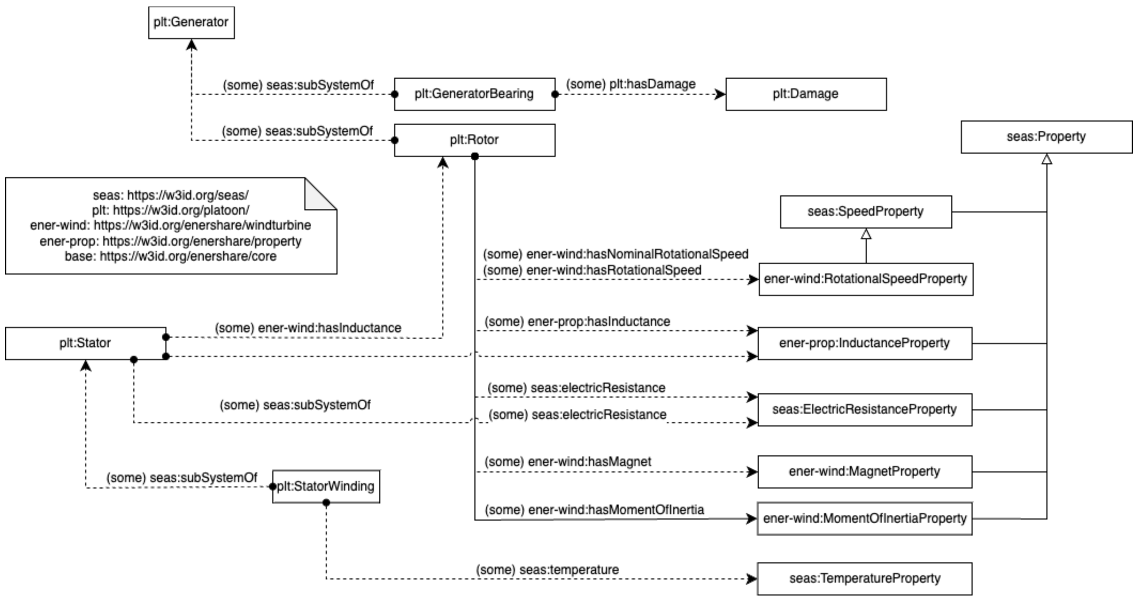
plt:Generator
(some) seas:subSystemOf
plt:GeneratorBearing
(some) plt:hasDamage
plt:Damage
(some) seas:subSystemOf
plt:Rotor
seas:Property
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
ener-wind: https://w3id.org/enershare/windturbine
ener-prop: https://w3id.org/enershare/property
base: https://w3id.org/enershare/core
seas:SpeedProperty
(some) ener-wind:hasNominalRotationalSpeed
(some) ener-wind:hasRotationalSpeed
ener-wind:RotationalSpeedProperty
plt:Stator
(some) ener-wind:hasInductance
(some) ener-prop:hasInductance
ener-prop:InductanceProperty
(some) seas:subSystemOf
(some) seas:electricResistance
(some) seas:electricResistance
seas:ElectricResistanceProperty
(some) ener-wind:hasMagnet
ener-wind:MagnetProperty
(some) seas:subSystemOf
plt:StatorWinding
(some) ener-wind:hasMomentOfInertia
ener-wind:MomentOfInertiaProperty
(some) seas:temperature
seas:TemperatureProperty

Figure 25: Pilot 1 - Rotor Properties

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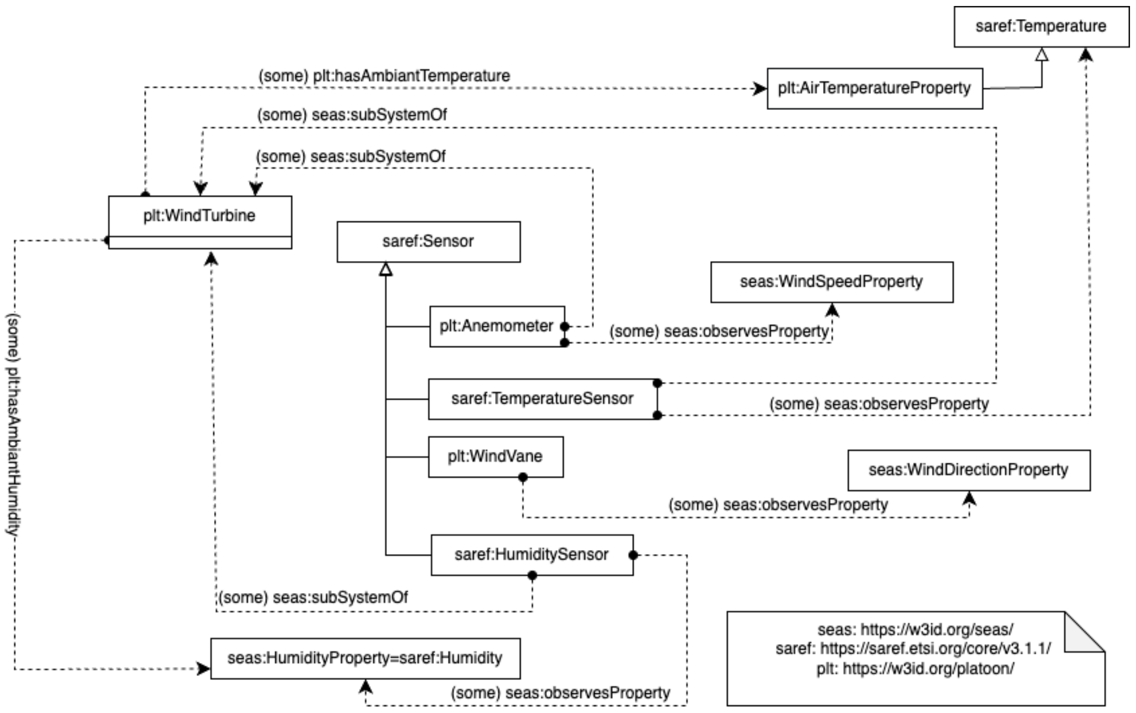

saref:Temperature
plt:AirTemperatureProperty
(some) plt:hasAmbiantTemperature
(some) seas:subSystemOf
(some) seas:subSystemOf
plt:WindTurbine
saref:Sensor
seas:WindSpeedProperty
plt:Anemometer
(some) seas:observesProperty
saref:TemperatureSensor
(some) seas:observesProperty
plt:WindVane
seas:WindDirectionProperty
(some) seas:observesProperty
saref:HumiditySensor
(some) seas:subSystemOf
(some) plt:hasAmbiantHumidity
seas:HumidityProperty=saref:Humidity
(some) seas:observesProperty
seas: https://w3id.org/seas/
saref: https://saref.etsi.org/core/v3.1.1/
plt: https://w3id.org/platoon/

Figure 26: Pilot 1 - Weather – sensor

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

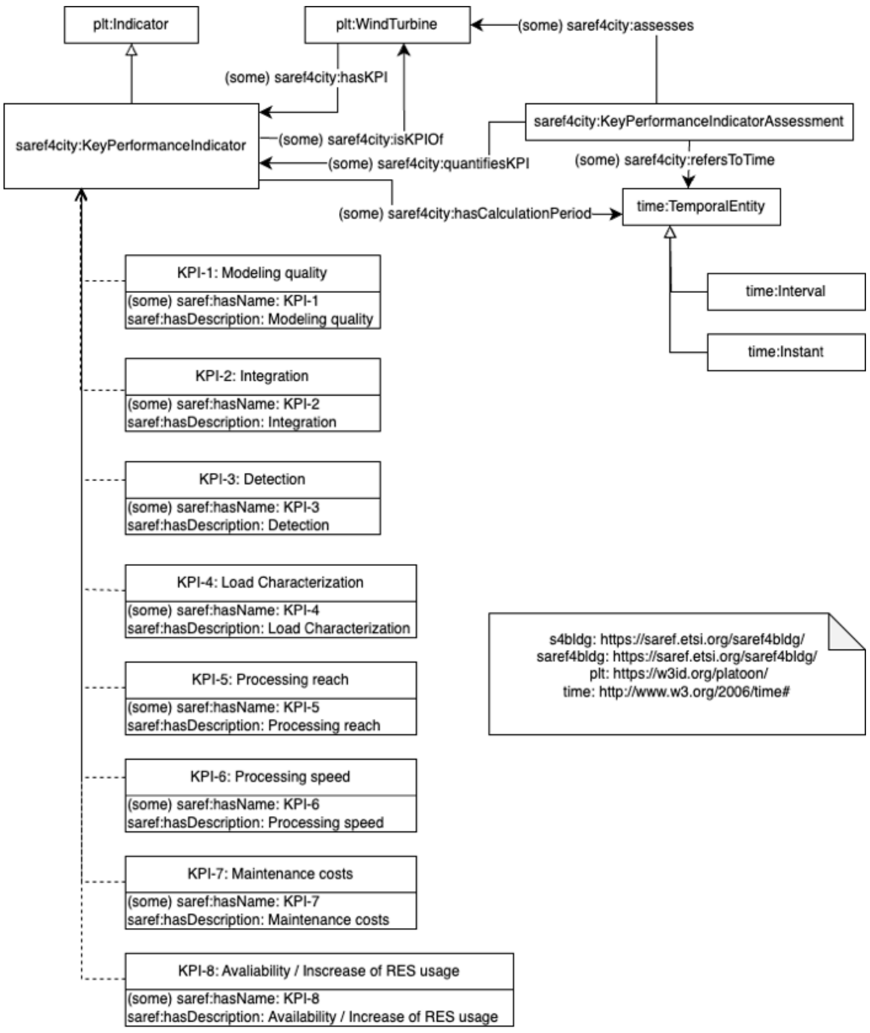

plt:Indicator
plt:WindTurbine
(some) saref4city:assesses
(some) saref4city:hasKPI
saref4city:KeyPerformanceIndicator
saref4city:KeyPerformanceIndicatorAssessment
(some) saref4city:isKPIOf
(some) saref4city:quantifiesKPI
(some) saref4city:refersToTime
(some) saref4city:hasCalculationPeriod
time:TemporalEntity
time:Interval
time:Instant
KPI-1: Modeling quality
(some) saref:hasName: KPI-1
saref:hasDescription: Modeling quality
KPI-2: Integration
(some) saref:hasName: KPI-2
saref:hasDescription: Integration
KPI-3: Detection
(some) saref:hasName: KPI-3
saref:hasDescription: Detection
KPI-4: Load Characterization
(some) saref:hasName: KPI-4
saref:hasDescription: Load Characterization
KPI-5: Processing reach
(some) saref:hasName: KPI-5
saref:hasDescription: Processing reach
KPI-6: Processing speed
(some) saref:hasName: KPI-6
saref:hasDescription: Processing speed
KPI-7: Maintenance costs
(some) saref:hasName: KPI-7
saref:hasDescription: Maintenance costs
KPI-8: Avaliability / Inscrease of RES usage
(some) saref:hasName: KPI-8
saref:hasDescription: Availability / Increase of RES usage
s4bldg: https://saref.etsi.org/saref4bldg/
saref4bldg: https://saref.etsi.org/saref4bldg/
plt: https://w3id.org/platoon/
time: http://www.w3.org/2006/time#

Figure 27: Pilot 1 – KPI

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

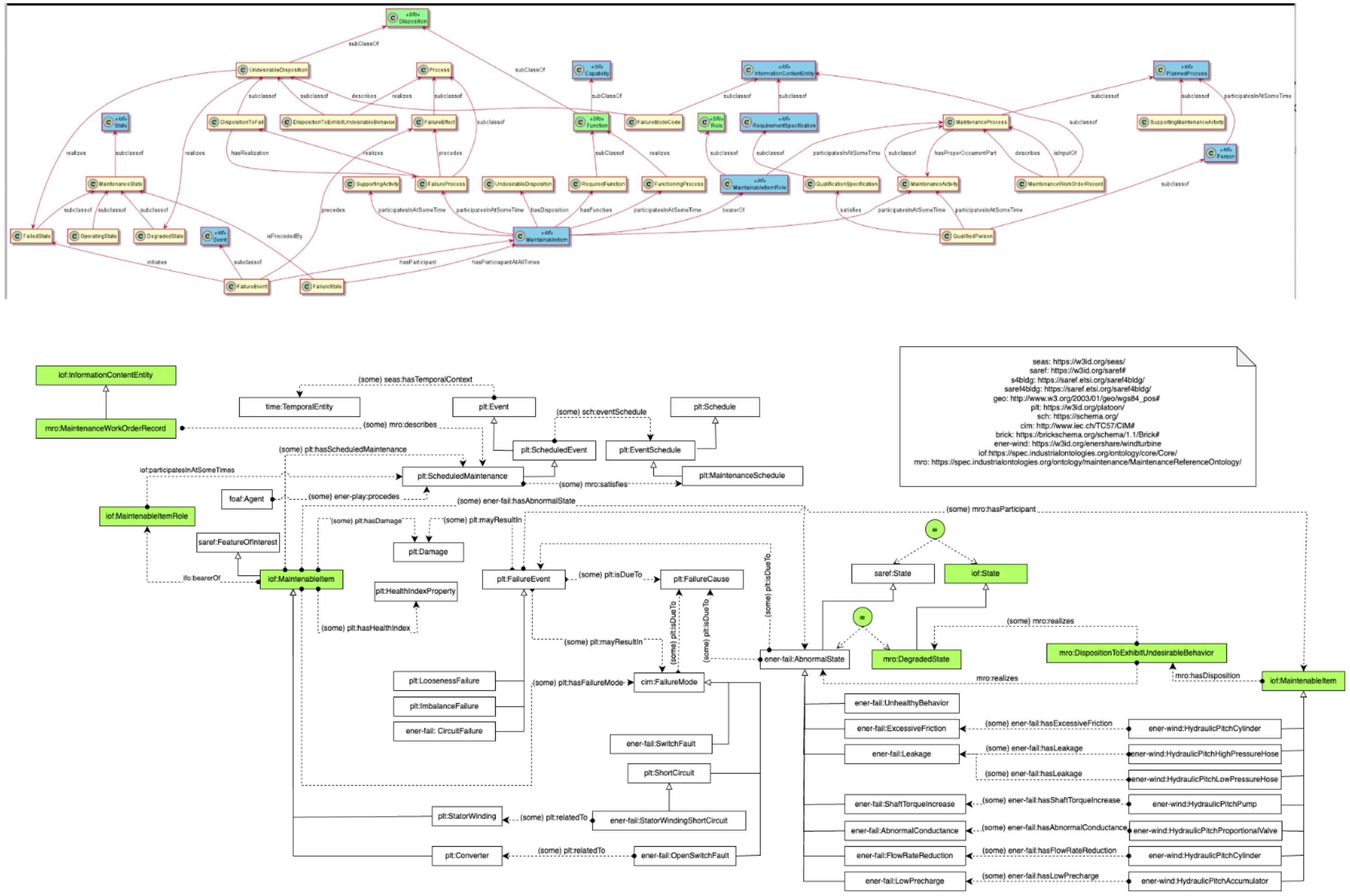

Disposition
UndesirableDisposition
Process
Capability
InformationContentEntity
PlannedProcess
State
DispositionToFail
DispositionToExhibitUndesirableBehavior
FailureEffect
Function
FailureModeCode
Role
RequirementSpecification
MaintenanceProcess
SupportingMaintenanceActivity
Person
MaintenanceState
SupportingActivity
FailureProcess
UndesirableDisposition
RequiredFunction
FunctioningProcess
MaintainableItemRole
QualificationSpecification
MaintenanceActivity
MaintenanceWorkOrderRecord
FailedState
OperatingState
DegradedState
Event
MaintainableItem
QualifiedPerson
FailureEvent
FailureState
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
saref4bldg: https://saref.etsi.org/saref4bldg/
geo: http://www.w3.org/2003/01/geo/wgs84_pos#
plt: https://w3id.org/platoon/
sch: https://schema.org/
cim: http://www.iec.ch/TC57/CIM#
brick: https://brickschema.org/schema/1.1/Brick#
ener-wind: https://w3id.org/enershare/windturbine
iof:https://spec.industrialontologies.org/ontology/core/Core/
mro: https://spec.industrialontologies.org/ontology/maintenance/MaintenanceReferenceOntology/
iof:InformationContentEntity
mro:MaintenanceWorkOrderRecord
time:TemporalEntity
plt:Event
plt:Schedule
plt:ScheduledEvent
plt:EventSchedule
plt:ScheduledMaintenance
plt:MaintenanceSchedule
foaf:Agent
iof:MaintenableItemRole
saref:FeatureOfInterest
iof:MaintenableItem
plt:Damage
plt:HealthIndexProperty
plt:FailureEvent
plt:FailureCause
saref:State
iof:State
ener-fail:AbnormalState
mro:DegradedState
mro:DispositionToExhibitUndesirableBehavior
plt:LoosenessFailure
plt:ImbalanceFailure
ener-fail: CircuitFailure
cim:FailureMode
ener-fail:SwitchFault
plt:ShortCircuit
plt:StatorWinding
ener-fail:StatorWindingShortCircuit
plt:Converter
ener-fail:OpenSwitchFault
ener-fail:UnhealthyBehavior
ener-fail:ExcessiveFriction
ener-fail:Leakage
ener-fail:ShaftTorqueIncrease
ener-fail:AbnormalConductance
ener-fail:FlowRateReduction
ener-fail:LowPrecharge
ener-wind:HydraulicPitchCylinder
ener-wind:HydraulicPitchHighPressureHose
ener-wind:HydraulicPitchLowPressureHose
ener-wind:HydraulicPitchPump
ener-wind:HydraulicPitchProportionalValve
ener-wind:HydraulicPitchCylinder
ener-wind:HydraulicPitchAccumulator

Figure 28: Pilot 1 - Failure & Maintenance

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

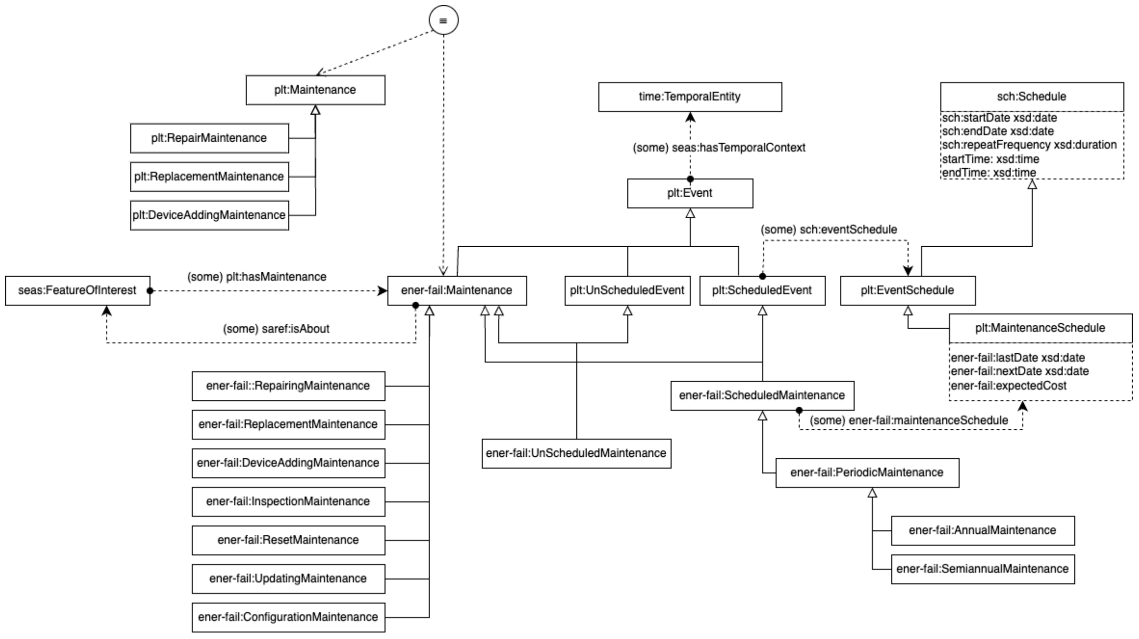
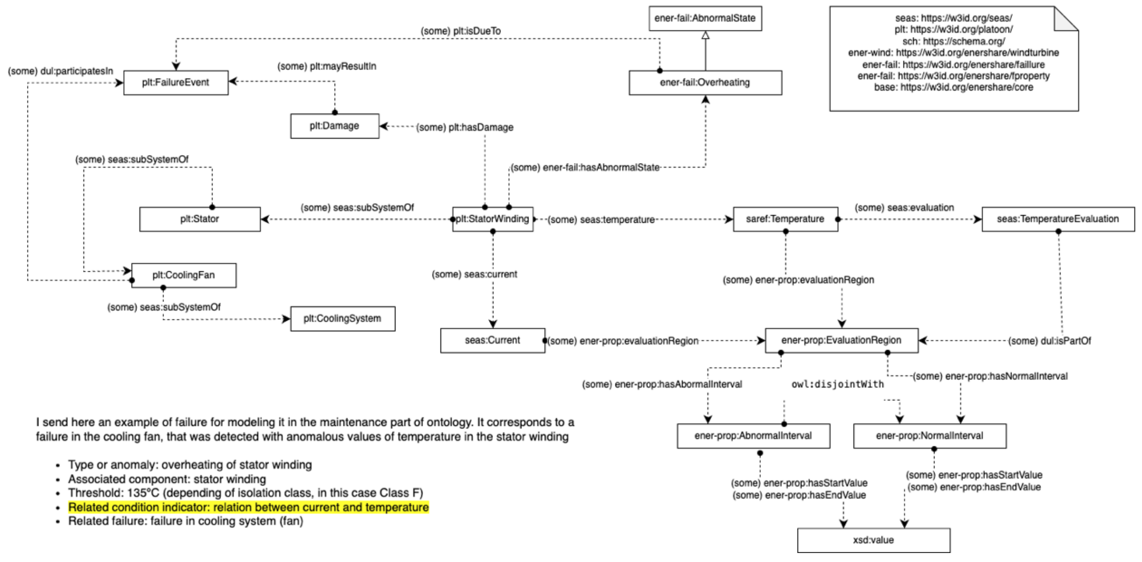

≡
plt:Maintenance
plt:RepairMaintenance
plt:ReplacementMaintenance
plt:DeviceAddingMaintenance
time:TemporalEntity
(some) seas:hasTemporalContext
plt:Event
sch:Schedule
sch:startDate xsd:date
sch:endDate xsd:date
sch:repeatFrequency xsd:duration
startTime: xsd:time
endTime: xsd:time
(some) sch:eventSchedule
seas:FeatureOfInterest
(some) plt:hasMaintenance
ener-fail:Maintenance
plt:UnScheduledEvent
plt:ScheduledEvent
plt:EventSchedule
(some) saref:isAbout
plt:MaintenanceSchedule
ener-fail:lastDate xsd:date
ener-fail:nextDate xsd:date
ener-fail:expectedCost
ener-fail::RepairingMaintenance
ener-fail:ReplacementMaintenance
ener-fail:DeviceAddingMaintenance
ener-fail:InspectionMaintenance
ener-fail:ResetMaintenance
ener-fail:UpdatingMaintenance
ener-fail:ConfigurationMaintenance
ener-fail:ScheduledMaintenance
(some) ener-fail:maintenanceSchedule
ener-fail:UnScheduledMaintenance
ener-fail:PeriodicMaintenance
ener-fail:AnnualMaintenance
ener-fail:SemiannualMaintenance

Figure 29: Pilot 1 - Maintenance and Schedule


ener-fail:AbnormalState
(some) plt:isDueTo
(some) dul:participatesIn
plt:FailureEvent
(some) plt:mayResultIn
ener-fail:Overheating
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-wind: https://w3id.org/enershare/windturbine
ener-fail: https://w3id.org/enershare/faillure
ener-fail: https://w3id.org/enershare/fproperty
base: https://w3id.org/enershare/core
plt:Damage
(some) plt:hasDamage
(some) seas:subSystemOf
(some) ener-fail:hasAbnormalState
plt:Stator
(some) seas:subSystemOf
plt:StatorWinding
(some) seas:temperature
saref:Temperature
(some) seas:evaluation
seas:TemperatureEvaluation
plt:CoolingFan
(some) seas:current
(some) ener-prop:evaluationRegion
(some) seas:subSystemOf
plt:CoolingSystem
seas:Current
(some) ener-prop:evaluationRegion
ener-prop:EvaluationRegion
(some) dul:isPartOf
(some) ener-prop:hasNormalInterval
(some) ener-prop:hasAbormalInterval
owl:disjointWith
ener-prop:AbnormalInterval
ener-prop:NormalInterval
(some) ener-prop:hasStartValue
(some) ener-prop:hasEndValue
(some) ener-prop:hasStartValue
(some) ener-prop:hasEndValue
xsd:value

I send here an example of failure for modeling it in the maintenance part of ontology. It corresponds to a failure in the cooling fan, that was detected with anomalous values of temperature in the stator winding

- Type or anomaly: overheating of stator winding
- Associated component: stator winding
- Threshold: 135°C (depending of isolation class, in this case Class F)
- Related condition indicator: relation between current and temperature
- Related failure: failure in cooling system (fan)

Figure 30: Pilot 1 : Modeling of Overheating example

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

7.2 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

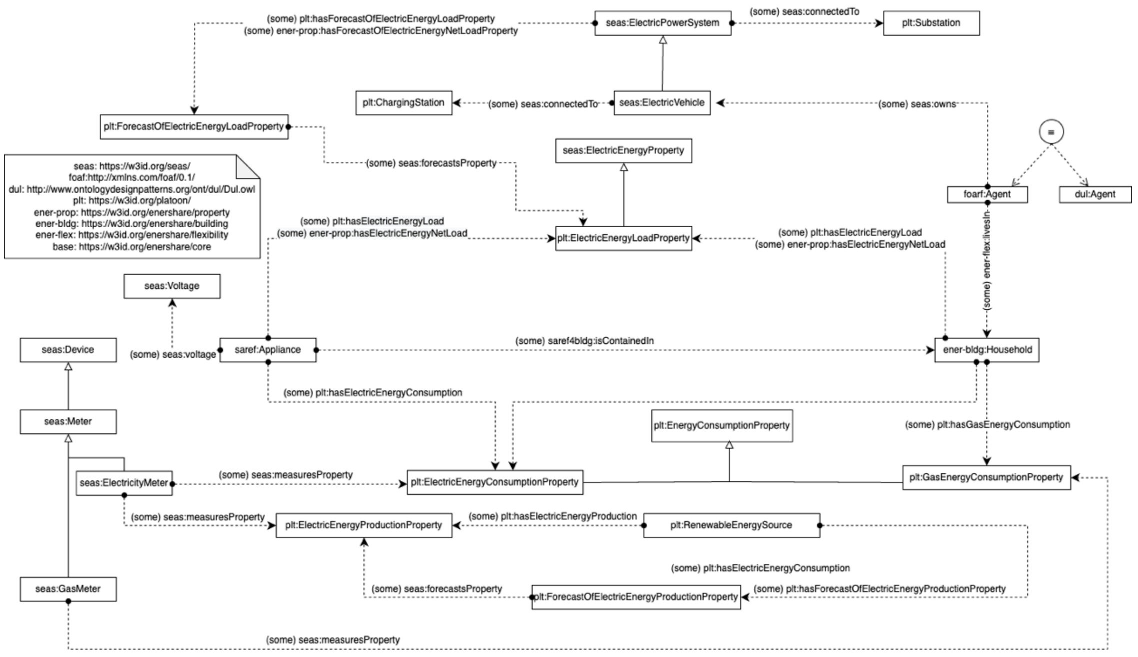

(some) plt:hasForecastOfElectricEnergyLoadProperty
(some) ener-prop:hasForecastOfElectricEnergyNetLoadProperty
seas:ElectricPowerSystem
(some) seas:connectedTo
plt:Substation
plt:ChargingStation
(some) seas:connectedTo
seas:ElectricVehicle
(some) seas:owns
plt:ForecastOfElectricEnergyLoadProperty
(some) seas:forecastsProperty
seas:ElectricEnergyProperty
≡
foarf:Agent
dul:Agent
seas: https://w3id.org/seas/
foaf:http://xmlns.com/foaf/0.1/
dul: http://www.ontologydesignpatterns.org/ont/dul/Dul.owl
plt: https://w3id.org/platoon/
ener-prop: https://w3id.org/enershare/property
ener-bldg: https://w3id.org/enershare/building
ener-flex: https://w3id.org/enershare/flexibility
base: https://w3id.org/enershare/core
(some) plt:hasElectricEnergyLoad
(some) ener-prop:hasElectricEnergyNetLoad
plt:ElectricEnergyLoadProperty
(some) plt:hasElectricEnergyLoad
(some) ener-prop:hasElectricEnergyNetLoad
(some) ener-flex:livesIn
seas:Voltage
seas:Device
(some) seas:voltage
saref:Appliance
(some) saref4bldg:isContainedIn
ener-bldg:Household
(some) plt:hasElectricEnergyConsumption
seas:Meter
plt:EnergyConsumptionProperty
(some) plt:hasGasEnergyConsumption
seas:ElectricityMeter
(some) seas:measuresProperty
plt:ElectricEnergyConsumptionProperty
plt:GasEnergyConsumptionProperty
(some) seas:measuresProperty
plt:ElectricEnergyProductionProperty
(some) plt:hasElectricEnergyProduction
plt:RenewableEnergySource
(some) plt:hasElectricEnergyConsumption
seas:GasMeter
(some) seas:forecastsProperty
plt:ForecastOfElectricEnergyProductionProperty
(some) plt:hasForecastOfElectricEnergyProductionProperty
(some) seas:measuresProperty

Figure 31: Pilot 2 - building consumption & mobility

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

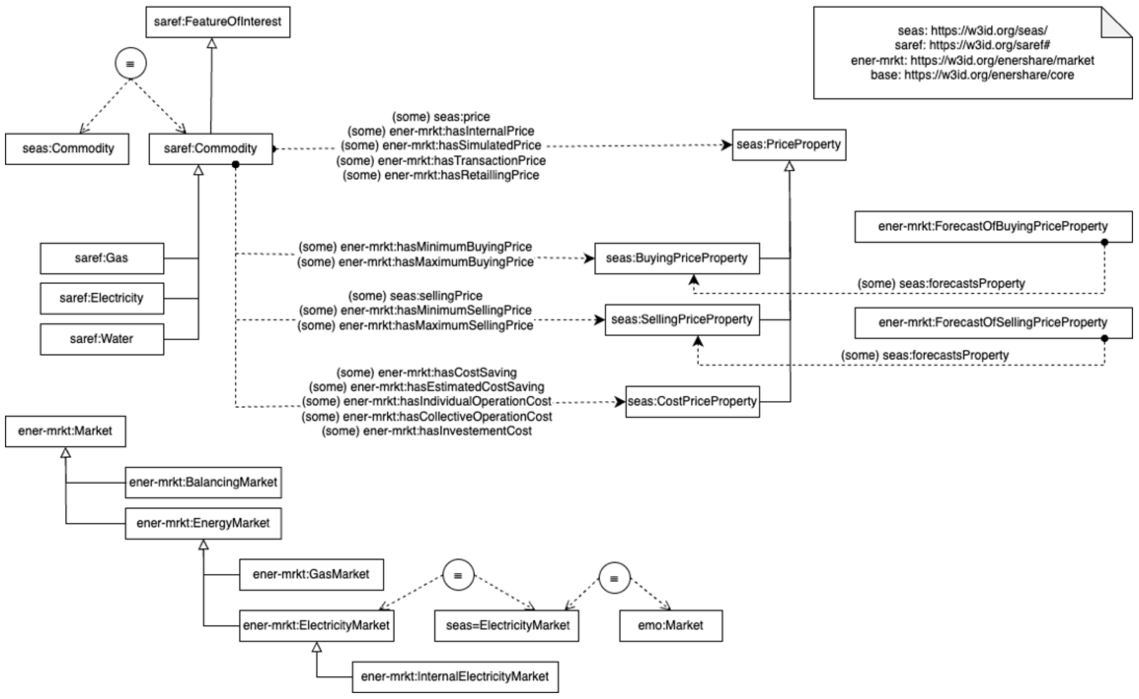

saref:FeatureOfInterest
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
ener-mrkt: https://w3id.org/enershare/market
base: https://w3id.org/enershare/core
≡
seas:Commodity
saref:Commodity
(some) seas:price
(some) ener-mrkt:hasInternalPrice
(some) ener-mrkt:hasSimulatedPrice
(some) ener-mrkt:hasTransactionPrice
(some) ener-mrkt:hasRetaillingPrice
seas:PriceProperty
ener-mrkt:ForecastOfBuyingPriceProperty
saref:Gas
(some) ener-mrkt:hasMinimumBuyingPrice
(some) ener-mrkt:hasMaximumBuyingPrice
seas:BuyingPriceProperty
(some) seas:forecastsProperty
saref:Electricity
(some) seas:sellingPrice
(some) ener-mrkt:hasMinimumSellingPrice
(some) ener-mrkt:hasMaximumSellingPrice
seas:SellingPriceProperty
ener-mrkt:ForecastOfSellingPriceProperty
saref:Water
(some) seas:forecastsProperty
(some) ener-mrkt:hasCostSaving
(some) ener-mrkt:hasEstimatedCostSaving
(some) ener-mrkt:hasIndividualOperationCost
(some) ener-mrkt:hasCollectiveOperationCost
(some) ener-mrkt:hasInvestementCost
seas:CostPriceProperty
ener-mrkt:Market
ener-mrkt:BalancingMarket
ener-mrkt:EnergyMarket
ener-mrkt:GasMarket
≡
≡
ener-mrkt:ElectricityMarket
seas=ElectricityMarket
emo:Market
ener-mrkt:InternalElectricityMarket

Figure 32: Pilot 2 - Price & Market

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

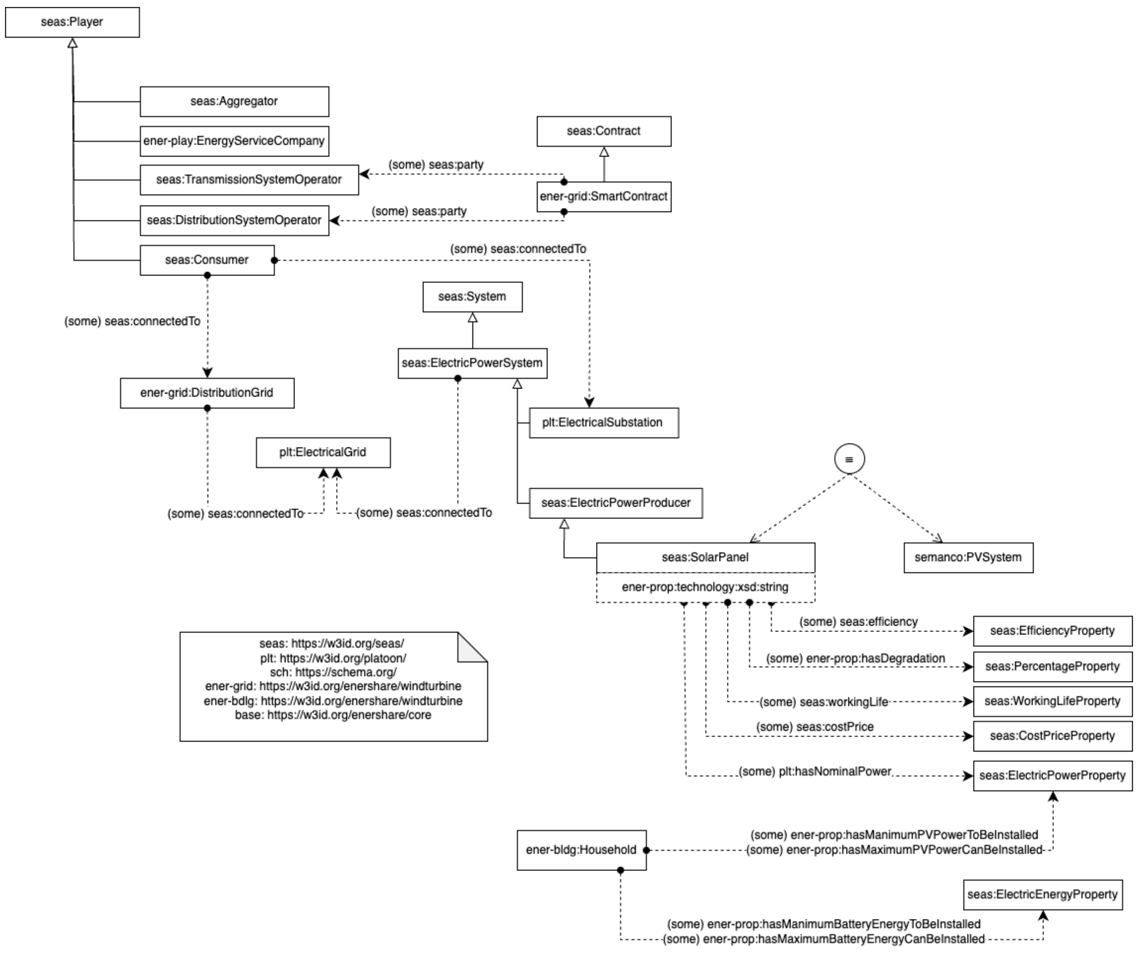

seas:Player
seas:Aggregator
ener-play:EnergyServiceCompany
seas:TransmissionSystemOperator
seas:DistributionSystemOperator
seas:Consumer
seas:Contract
ener-grid:SmartContract
(some) seas:party
(some) seas:party
(some) seas:connectedTo
seas:System
seas:ElectricPowerSystem
(some) seas:connectedTo
ener-grid:DistributionGrid
plt:ElectricalSubstation
plt:ElectricalGrid
(some) seas:connectedTo
(some) seas:connectedTo
seas:ElectricPowerProducer
≡
seas:SolarPanel
ener-prop:technology:xsd:string
semanco:PVSystem
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-grid: https://w3id.org/enershare/windturbine
ener-bdlg: https://w3id.org/enershare/windturbine
base: https://w3id.org/enershare/core
(some) seas:efficiency
seas:EfficiencyProperty
(some) ener-prop:hasDegradation
seas:PercentageProperty
(some) seas:workingLife
seas:WorkingLifeProperty
(some) seas:costPrice
seas:CostPriceProperty
(some) plt:hasNominalPower
seas:ElectricPowerProperty
ener-bldg:Household
(some) ener-prop:hasManimumPVPowerToBeInstalled
(some) ener-prop:hasMaximumPVPowerCanBeInstalled
seas:ElectricEnergyProperty
(some) ener-prop:hasManimumBatteryEnergyToBeInstalled
(some) ener-prop:hasMaximumBatteryEnergyCanBeInstalled

Figure 33: Pilot 2 - Grid & Solar Panel Properties

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

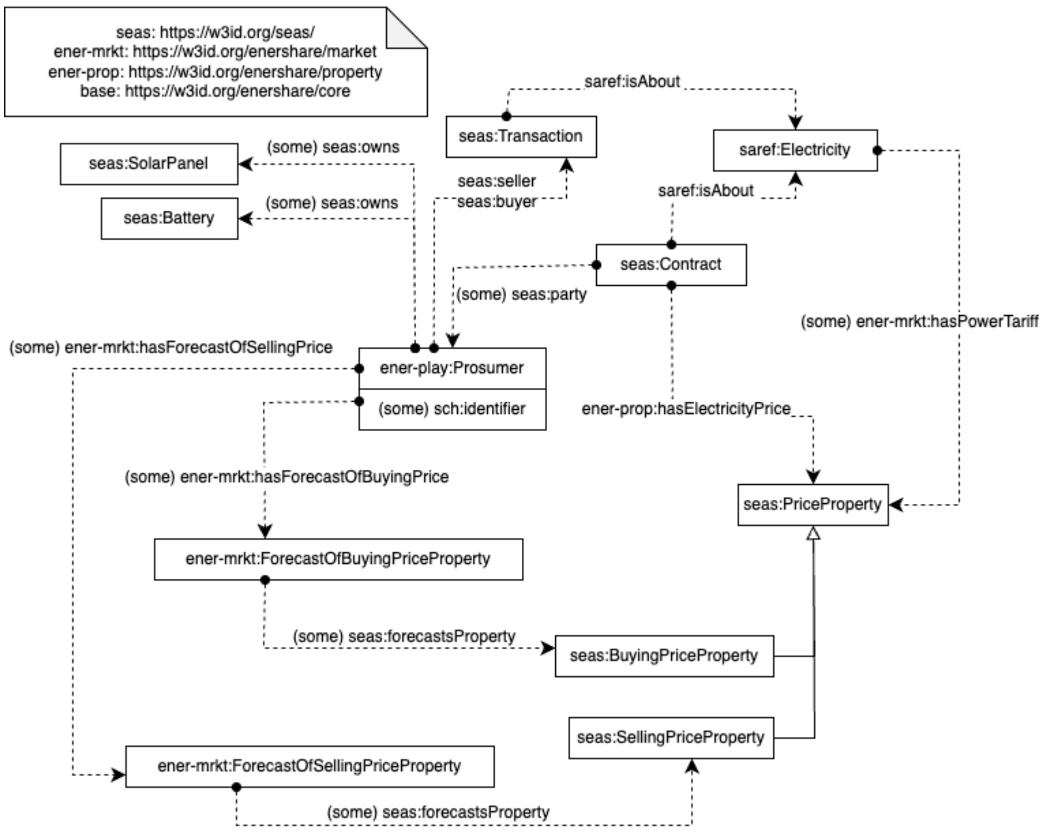

seas: https://w3id.org/seas/
ener-mrkt: https://w3id.org/enershare/market
ener-prop: https://w3id.org/enershare/property
base: https://w3id.org/enershare/core
saref:isAbout
seas:Transaction
saref:Electricity
seas:SolarPanel
(some) seas:owns
seas:Battery
(some) seas:owns
seas:seller
seas:buyer
saref:isAbout
seas:Contract
(some) seas:party
(some) ener-mrkt:hasPowerTariff
(some) ener-mrkt:hasForecastOfSellingPrice
ener-play:Prosumer
(some) sch:identifier
ener-prop:hasElectricityPrice
(some) ener-mrkt:hasForecastOfBuyingPrice
seas:PriceProperty
ener-mrkt:ForecastOfBuyingPriceProperty
(some) seas:forecastsProperty
seas:BuyingPriceProperty
seas:SellingPriceProperty
ener-mrkt:ForecastOfSellingPriceProperty
(some) seas:forecastsProperty

Figure 34: Pilot 2 – Prosumer Context

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

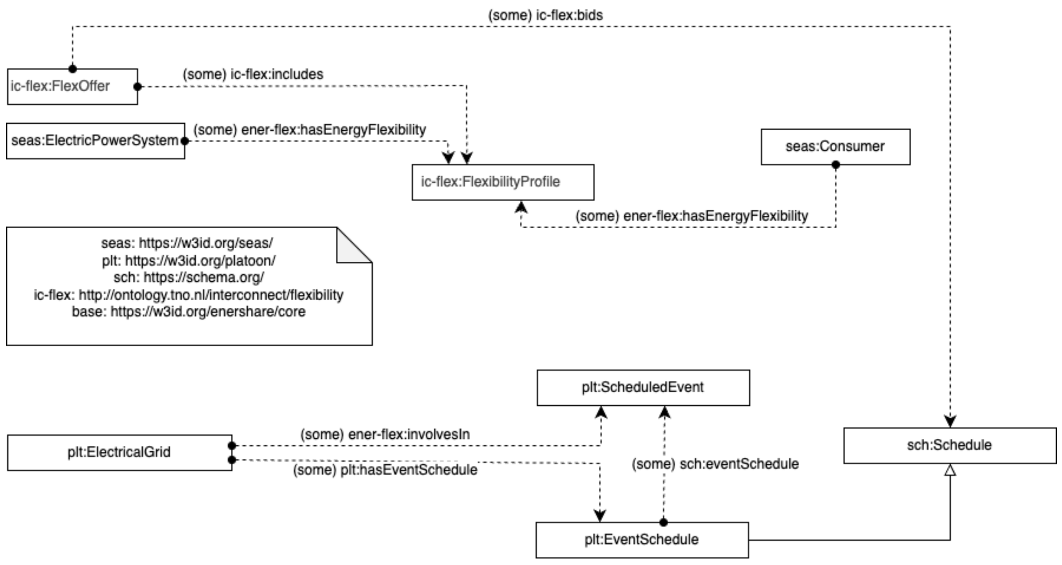

(some) ic-flex:bids
ic-flex:FlexOffer
(some) ic-flex:includes
seas:ElectricPowerSystem
(some) ener-flex:hasEnergyFlexibility
ic-flex:FlexibilityProfile
seas:Consumer
(some) ener-flex:hasEnergyFlexibility
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ic-flex: http://ontology.tno.nl/interconnect/flexibility
base: https://w3id.org/enershare/core
plt:ScheduledEvent
plt:ElectricalGrid
(some) ener-flex:involvesIn
(some) plt:hasEventSchedule
(some) sch:eventSchedule
sch:Schedule
plt:EventSchedule

Figure 35 : Pilot 2 – Flexibility profile

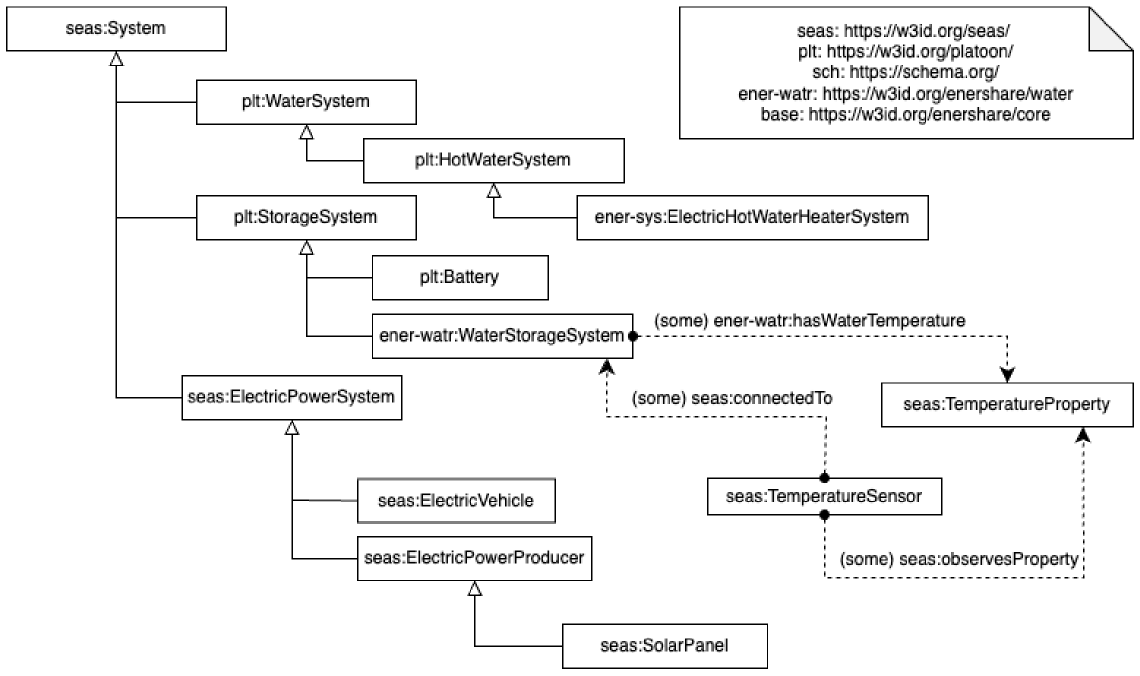

seas:System
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-watr: https://w3id.org/enershare/water
base: https://w3id.org/enershare/core
plt:WaterSystem
plt:HotWaterSystem
plt:StorageSystem
ener-sys:ElectricHotWaterHeaterSystem
plt:Battery
ener-watr:WaterStorageSystem
(some) ener-watr:hasWaterTemperature
seas:ElectricPowerSystem
(some) seas:connectedTo
seas:TemperatureProperty
seas:ElectricVehicle
seas:TemperatureSensor
seas:ElectricPowerProducer
(some) seas:observesProperty
seas:SolarPanel

Figure 36: Pilot 2 – Systems taxonomy extract

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

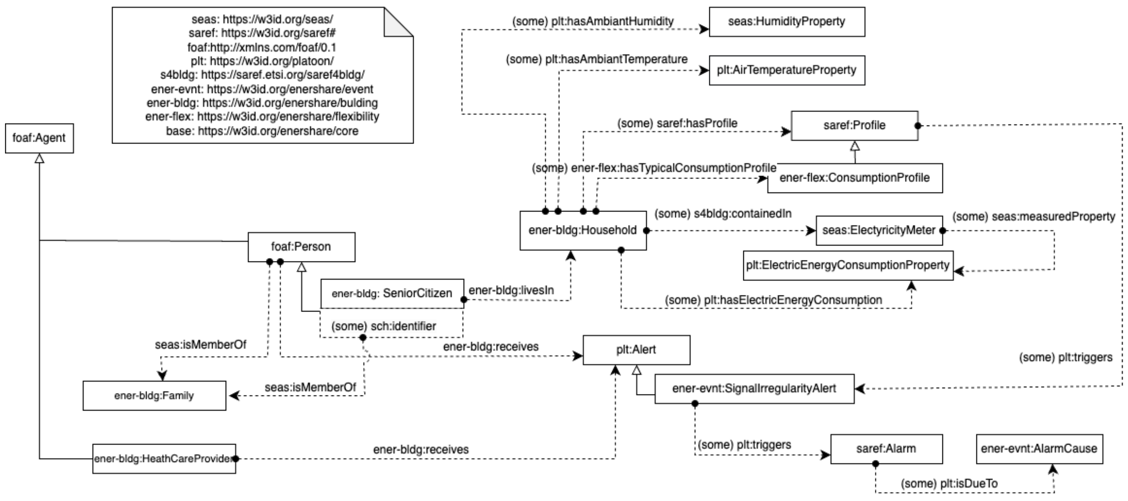

seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
foaf:http://xmlns.com/foaf/0.1
plt: https://w3id.org/platoon/
s4bldg: https://saref.etsi.org/saref4bldg/
ener-evnt: https://w3id.org/enershare/event
ener-bldg: https://w3id.org/enershare/bulding
ener-flex: https://w3id.org/enershare/flexibility
base: https://w3id.org/enershare/core
foaf:Agent
foaf:Person
ener-bldg: SeniorCitizen
(some) sch:identifier
ener-bldg:livesIn
seas:isMemberOf
ener-bldg:Family
seas:isMemberOf
ener-bldg:receives
ener-bldg:HeathCareProvider
ener-bldg:receives
(some) plt:hasAmbiantHumidity
seas:HumidityProperty
(some) plt:hasAmbiantTemperature
plt:AirTemperatureProperty
(some) saref:hasProfile
saref:Profile
(some) ener-flex:hasTypicalConsumptionProfile
ener-flex:ConsumptionProfile
ener-bldg:Household
(some) s4bldg:containedIn
seas:ElectyricityMeter
(some) seas:measuredProperty
plt:ElectricEnergyConsumptionProperty
(some) plt:hasElectricEnergyConsumption
plt:Alert
ener-evnt:SignalIrregularityAlert
(some) plt:triggers
(some) plt:triggers
saref:Alarm
ener-evnt:AlarmCause
(some) plt:isDueTo

Figure 37: Pilot 2 – Household

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

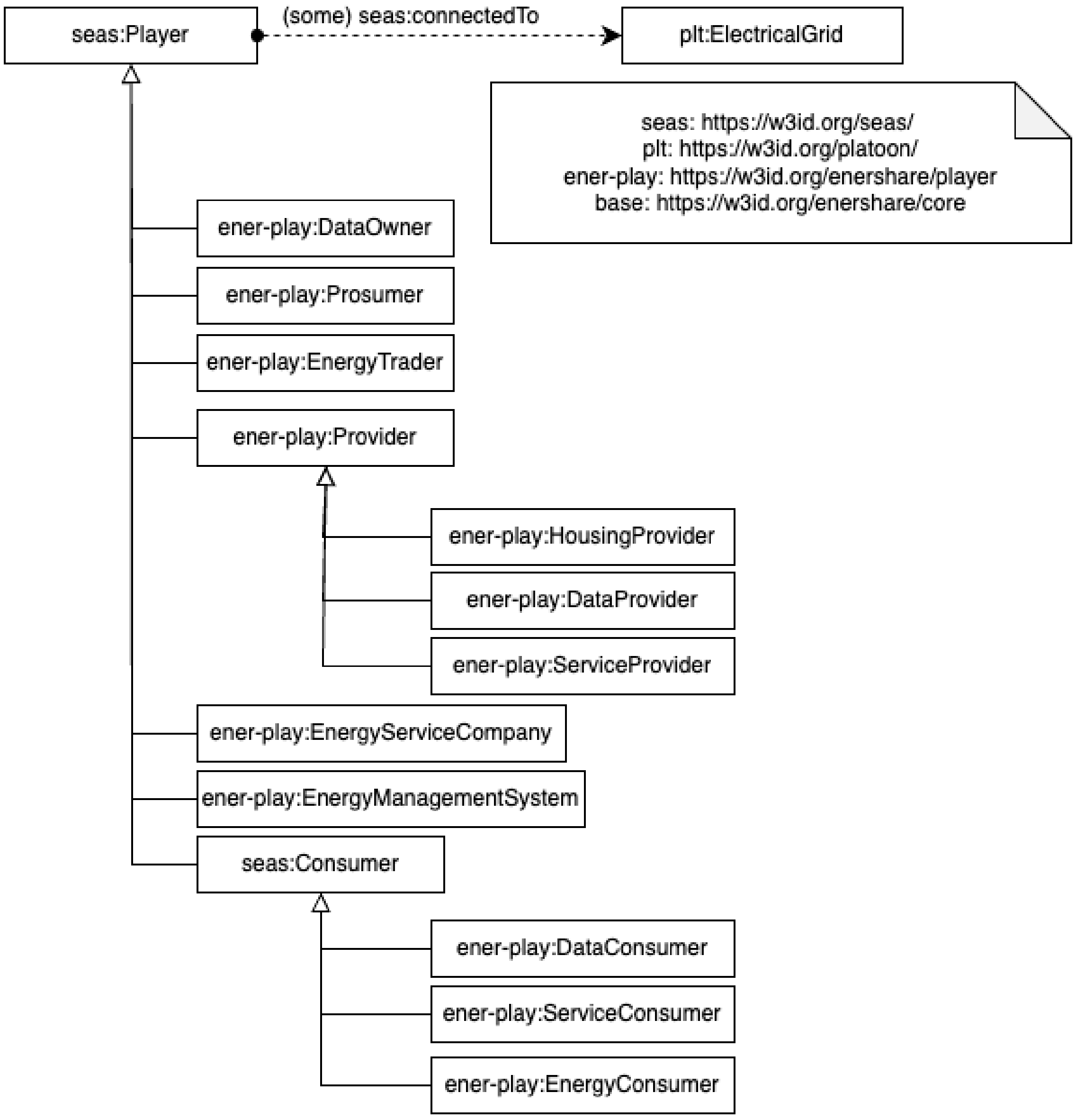

seas:Player
(some) seas:connectedTo
plt:ElectricalGrid
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
ener-play: https://w3id.org/enershare/player
base: https://w3id.org/enershare/core
ener-play:DataOwner
ener-play:Prosumer
ener-play:EnergyTrader
ener-play:Provider
ener-play:HousingProvider
ener-play:DataProvider
ener-play:ServiceProvider
ener-play:EnergyServiceCompany
ener-play:EnergyManagementSystem
seas:Consumer
ener-play:DataConsumer
ener-play:ServiceConsumer
ener-play:EnergyConsumer

Figure 38: Pilot 2 - Player Taxonomy

Enershare has received funding from European Union's Horizon Europe Research and Innovation programme under the Grant Agreement No 101069831

7.3 Pilot 3: Optimal multi-energy vector planning -electricity vs heat [Slovenia] - COMS, ENVIRODUAL, ELES, KPV, EKL

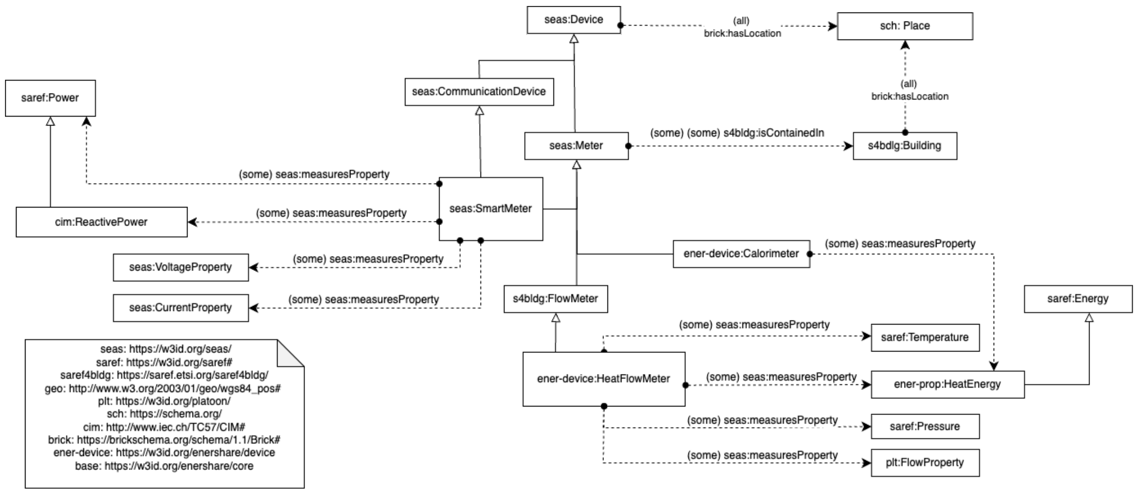

seas:Device
(all) brick:hasLocation
sch: Place
(all) brick:hasLocation
saref:Power
seas:CommunicationDevice
seas:Meter
(some) (some) s4bldg:isContainedIn
s4bdlg:Building
(some) seas:measuresProperty
seas:SmartMeter
cim:ReactivePower
(some) seas:measuresProperty
ener-device:Calorimeter
(some) seas:measuresProperty
seas:VoltageProperty
(some) seas:measuresProperty
seas:CurrentProperty
(some) seas:measuresProperty
s4bldg:FlowMeter
saref:Energy
(some) seas:measuresProperty
saref:Temperature
ener-device:HeatFlowMeter
(some) seas:measuresProperty
ener-prop:HeatEnergy
(some) seas:measuresProperty
saref:Pressure
(some) seas:measuresProperty
plt:FlowProperty
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
saref4bldg: https://saref.etsi.org/saref4bldg/
geo: http://www.w3.org/2003/01/geo/wgs84_pos#
plt: https://w3id.org/platoon/
sch: https://schema.org/
cim: http://www.iec.ch/TC57/CIM#
brick: https://brickschema.org/schema/1.1/Brick#
ener-device: https://w3id.org/enershare/device
base: https://w3id.org/enershare/core

Figure 39: Pilot 3 – Meter Context

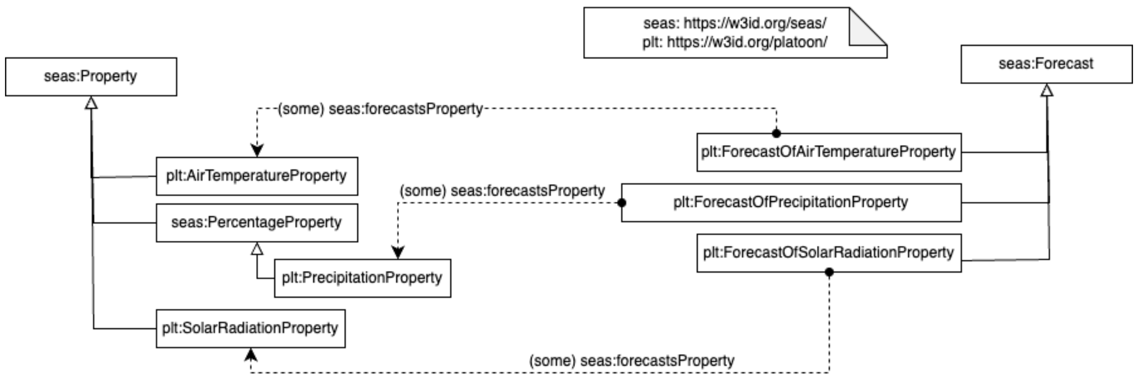

seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
seas:Property
seas:Forecast
(some) seas:forecastsProperty
plt:ForecastOfAirTemperatureProperty
plt:AirTemperatureProperty
(some) seas:forecastsProperty
plt:ForecastOfPrecipitationProperty
seas:PercentageProperty
plt:ForecastOfSolarRadiationProperty
plt:PrecipitationProperty
plt:SolarRadiationProperty
(some) seas:forecastsProperty

Figure 40: Pilot 3 - Weather & Forecasts

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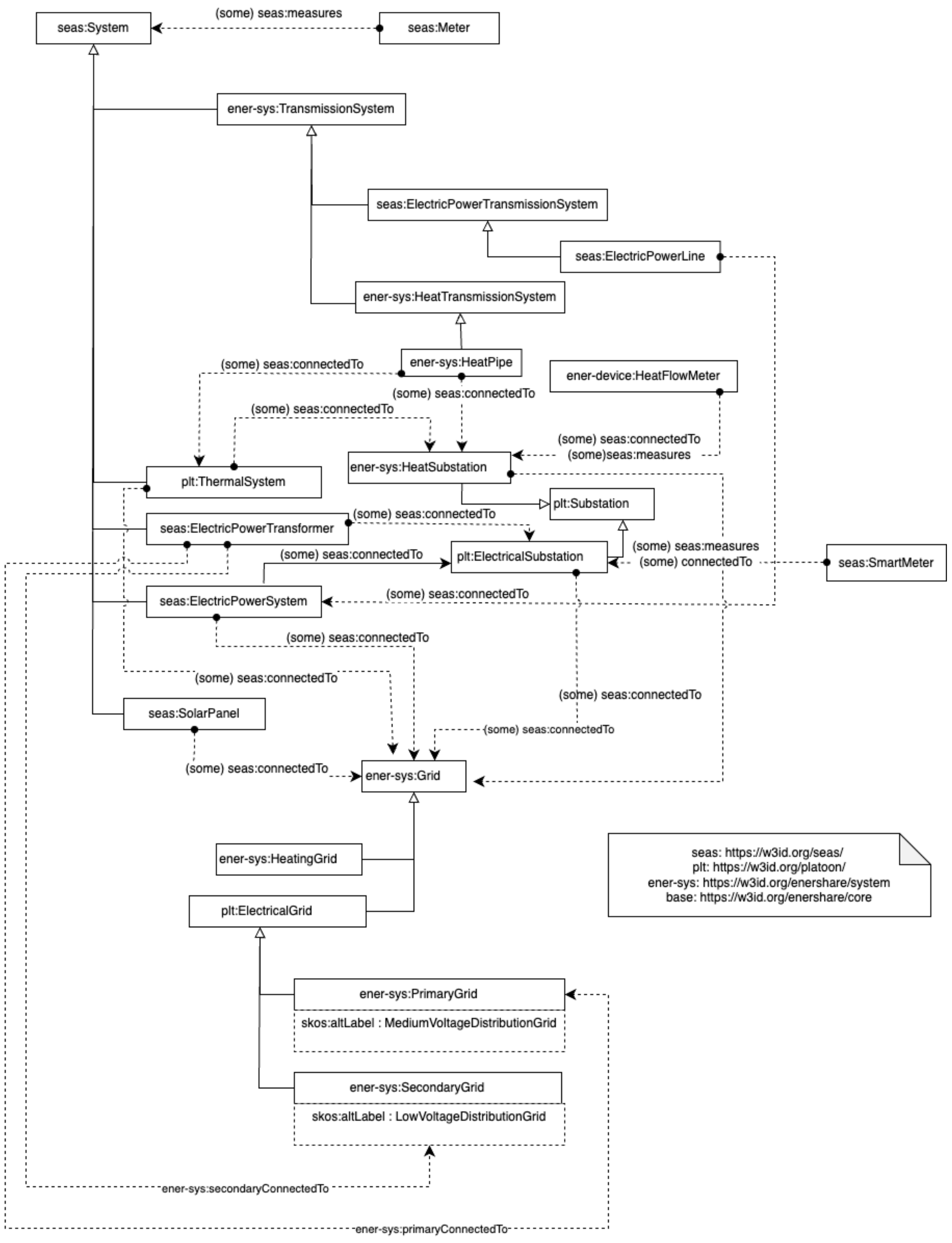

Figure 41: Pilot 3 – System Context

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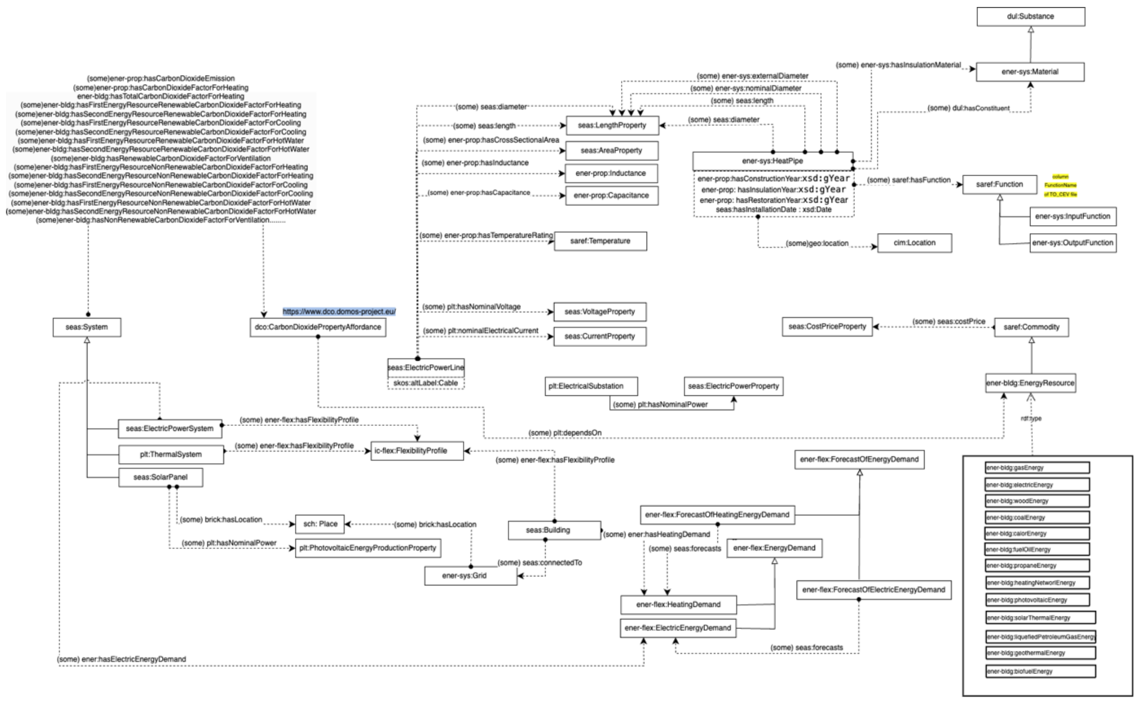
Figure 42: Pilot 3 – Properties

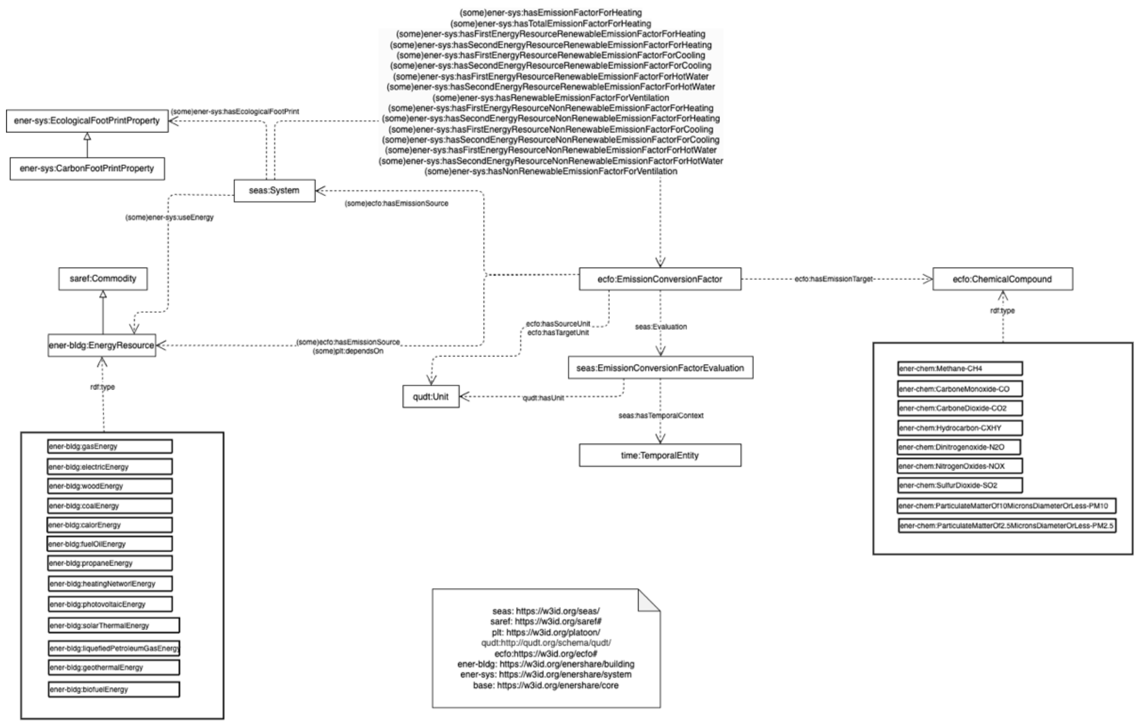
Figure 43: Pilot 3 - Emission Factor

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7.4 Pilot 4: Digital Twin for optimal data-driven Power-to-Gas optimal planning [Greece] - NTUA, DEPA

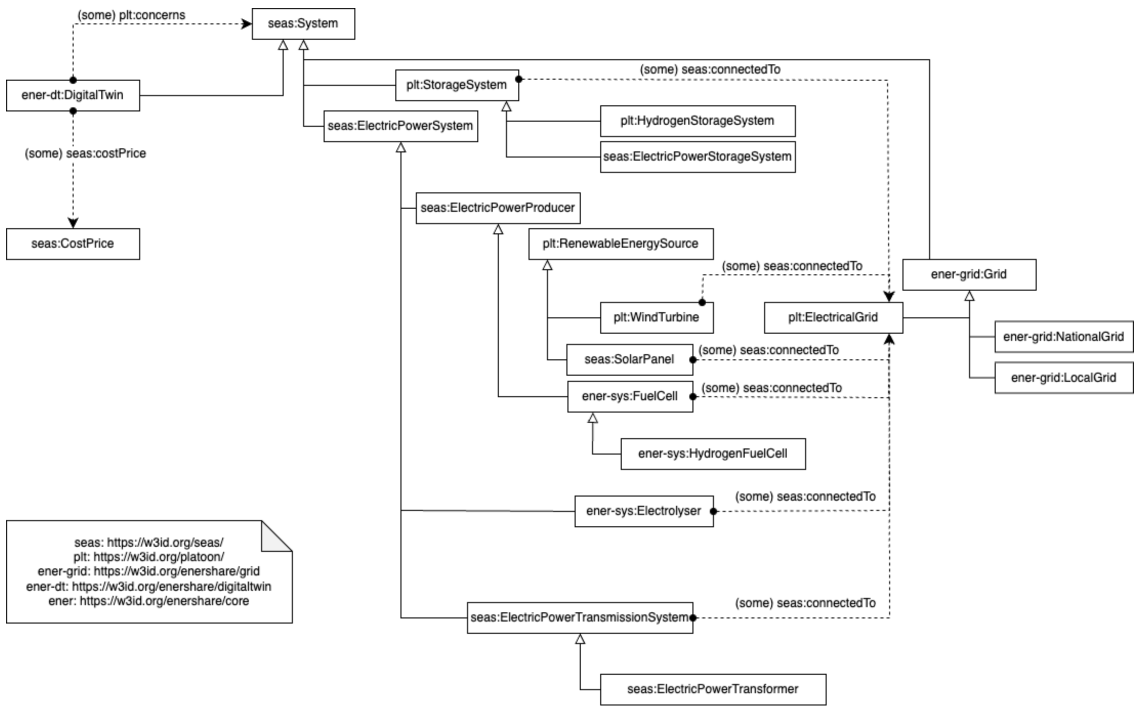

Figure 44: Pilot 4 - Grid Topology

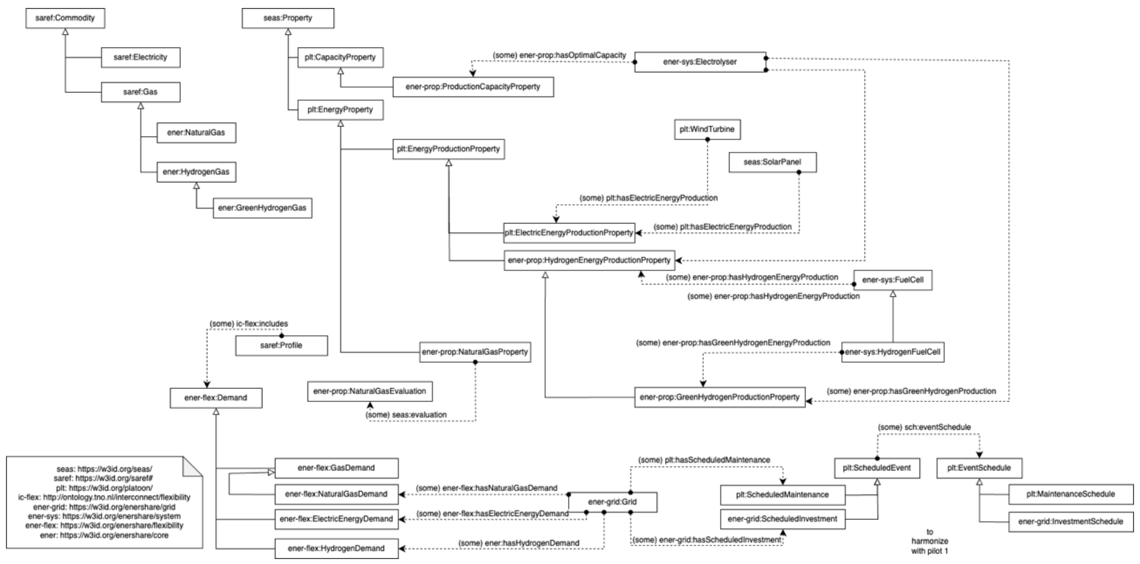
saref:Commodity
saref:Electricity
saref:Gas
ener:NaturalGas
ener:HydrogenGas
ener:GreenHydrogenGas
seas:Property
plt:CapacityProperty
ener-prop:ProductionCapacityProperty
plt:EnergyProperty
plt:EnergyProductionProperty
(some) ener-prop:hasOptimalCapacity
ener-sys:Electrolyser
plt:WindTurbine
seas:SolarPanel
(some) plt:hasElectricEnergyProduction
plt:ElectricEnergyProductionProperty
(some) plt:hasElectricEnergyProduction
ener-prop:HydrogenEnergyProductionProperty
(some) ener-prop:hasHydrogenEnergyProduction
ener-sys:FuelCell
(some) ener-prop:hasHydrogenEnergyProduction
(some) ic-flex:includes
saref:Profile
ener-prop:NaturalGasProperty
(some) ener-prop:hasGreenHydrogenEnergyProduction
ener-sys:HydrogenFuelCell
ener-flex:Demand
ener-prop:NaturalGasEvaluation
(some) seas:evaluation
ener-prop:GreenHydrogenProductionProperty
(some) ener-prop:hasGreenHydrogenProduction
(some) sch:eventSchedule
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
ic-flex: http://ontology.tno.nl/interconnect/flexibility
ener-grid: https://w3id.org/enershare/grid
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener: https://w3id.org/enershare/core
ener-flex:GasDemand
ener-flex:NaturalGasDemand
(some) ener-flex:hasNaturalGasDemand
(some) plt:hasScheduledMaintenance
plt:ScheduledEvent
plt:EventSchedule
ener-grid:Grid
plt:ScheduledMaintenance
plt:MaintenanceSchedule
ener-flex:ElectricEnergyDemand
(some) ener-flex:hasElectricEnergyDemand
ener-grid:ScheduledInvestment
ener-grid:InvestmentSchedule
ener-flex:HydrogenDemand
(some) ener:hasHydrogenDemand
(some) ener-grid:hasScheduledInvestment
to harmonize with pilot 1

Figure 45: Pilot 4 - Energy properties and demand

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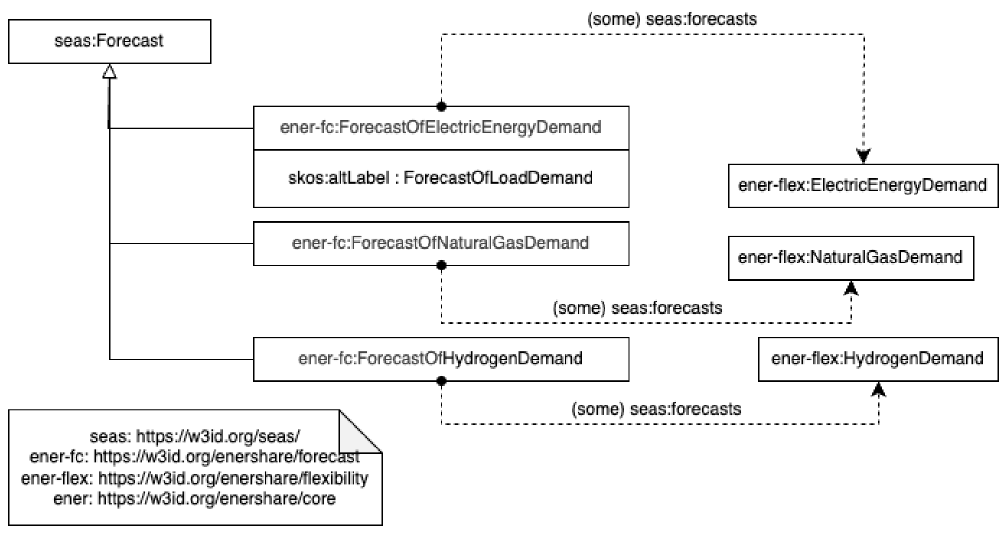
seas:Forecast
(some) seas:forecasts
ener-fc:ForecastOfElectricEnergyDemand
skos:altLabel : ForecastOfLoadDemand
ener-flex:ElectricEnergyDemand
ener-fc:ForecastOfNaturalGasDemand
ener-flex:NaturalGasDemand
(some) seas:forecasts
ener-fc:ForecastOfHydrogenDemand
ener-flex:HydrogenDemand
(some) seas:forecasts
seas: https://w3id.org/seas/
ener-fc: https://w3id.org/enershare/forecast
ener-flex: https://w3id.org/enershare/flexibility
ener: https://w3id.org/enershare/core

Figure 46: Pilot 4: Demand Forecast

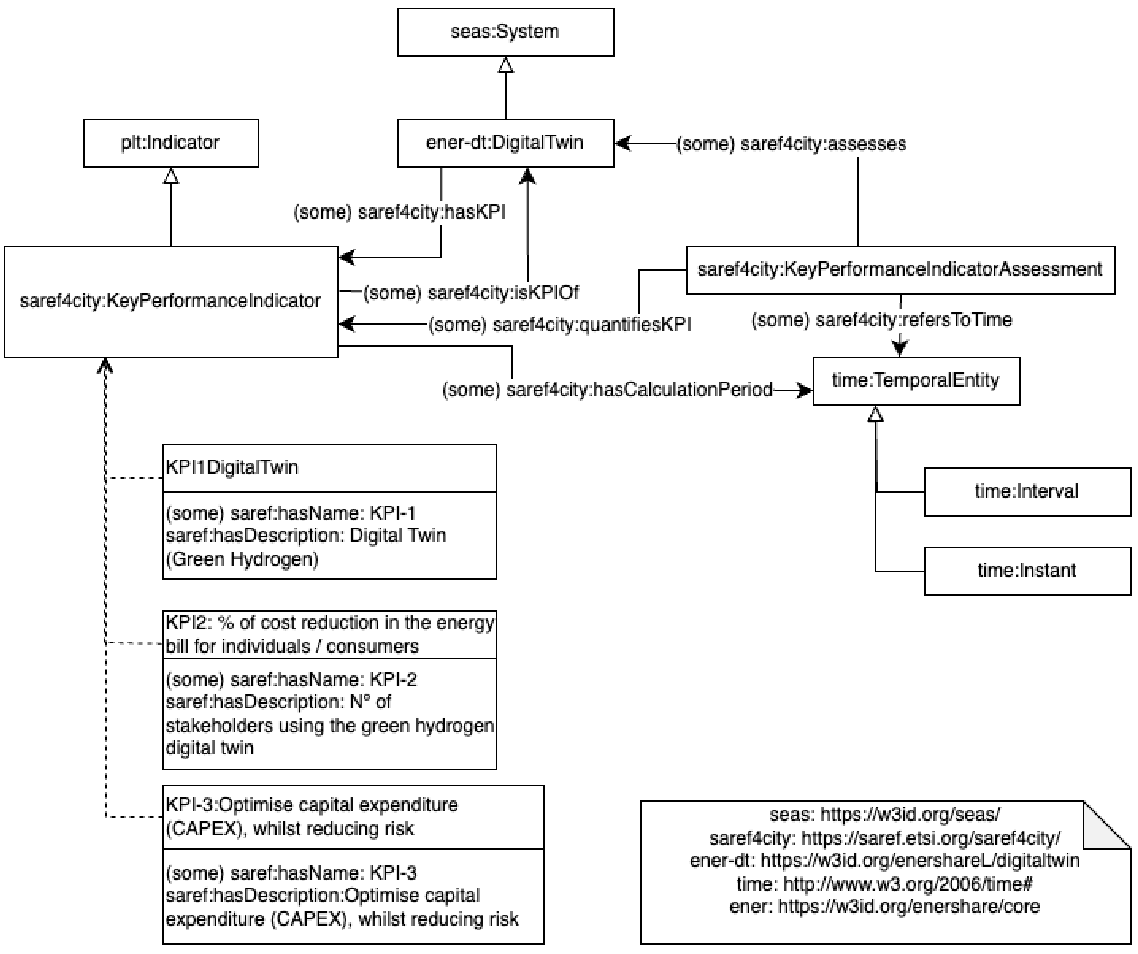
seas:System
plt:Indicator
ener-dt:DigitalTwin
(some) saref4city:assesses
(some) saref4city:hasKPI
saref4city:KeyPerformanceIndicator
(some) saref4city:isKPIOf
saref4city:KeyPerformanceIndicatorAssessment
(some) saref4city:quantifiesKPI
(some) saref4city:refersToTime
(some) saref4city:hasCalculationPeriod
time:TemporalEntity
KPI1DigitalTwin
(some) saref:hasName: KPI-1
saref:hasDescription: Digital Twin (Green Hydrogen)
time:Interval
time:Instant
KPI2: % of cost reduction in the energy bill for individuals / consumers
(some) saref:hasName: KPI-2
saref:hasDescription: N° of stakeholders using the green hydrogen digital twin
KPI-3:Optimise capital expenditure (CAPEX), whilst reducing risk
(some) saref:hasName: KPI-3
saref:hasDescription:Optimise capital expenditure (CAPEX), whilst reducing risk
seas: https://w3id.org/seas/
saref4city: https://saref.etsi.org/saref4city/
ener-dt: https://w3id.org/enershareL/digitaltwin
time: http://www.w3.org/2006/time#
ener: https://w3id.org/enershare/core

Figure 47: Pilot 4 – KPI

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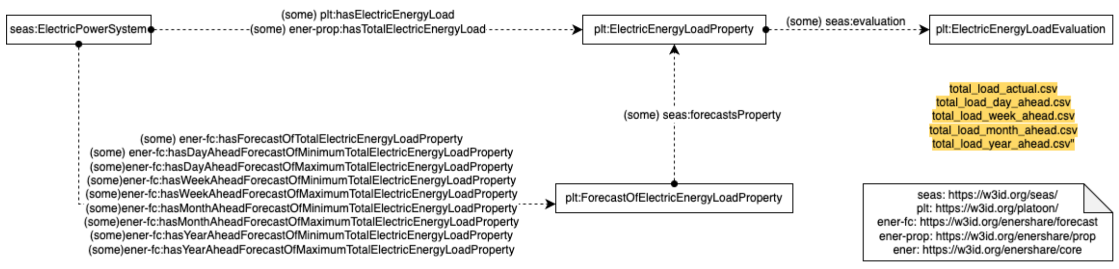
seas:ElectricPowerSystem
(some) plt:hasElectricEnergyLoad
(some) ener-prop:hasTotalElectricEnergyLoad
plt:ElectricEnergyLoadProperty
(some) seas:evaluation
plt:ElectricEnergyLoadEvaluation
(some) seas:forecastsProperty
total_load_actual.csv
total_load_day_ahead.csv
total_load_week_ahead.csv
total_load_month_ahead.csv
total_load_year_ahead.csv"
(some) ener-fc:hasForecastOfTotalElectricEnergyLoadProperty
(some) ener-fc:hasDayAheadForecastOfMinimumTotalElectricEnergyLoadProperty
(some)ener-fc:hasDayAheadForecastOfMaximumTotalElectricEnergyLoadProperty
(some)ener-fc:hasWeekAheadForecastOfMinimumTotalElectricEnergyLoadProperty
(some)ener-fc:hasWeekAheadForecastOfMaximumTotalElectricEnergyLoadProperty
(some)ener-fc:hasMonthAheadForecastOfMinimumTotalElectricEnergyLoadProperty
(some)ener-fc:hasMonthAheadForecastOfMaximumTotalElectricEnergyLoadProperty
(some)ener-fc:hasYearAheadForecastOfMinimumTotalElectricEnergyLoadProperty
(some)ener-fc:hasYearAheadForecastOfMaximumTotalElectricEnergyLoadProperty
plt:ForecastOfElectricEnergyLoadProperty
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
ener-fc: https://w3id.org/enershare/forecast
ener-prop: https://w3id.org/enershare/prop
ener: https://w3id.org/enershare/core

Figure 48: Pilot 4 - Forecast of Load Energy (based on CSV files)

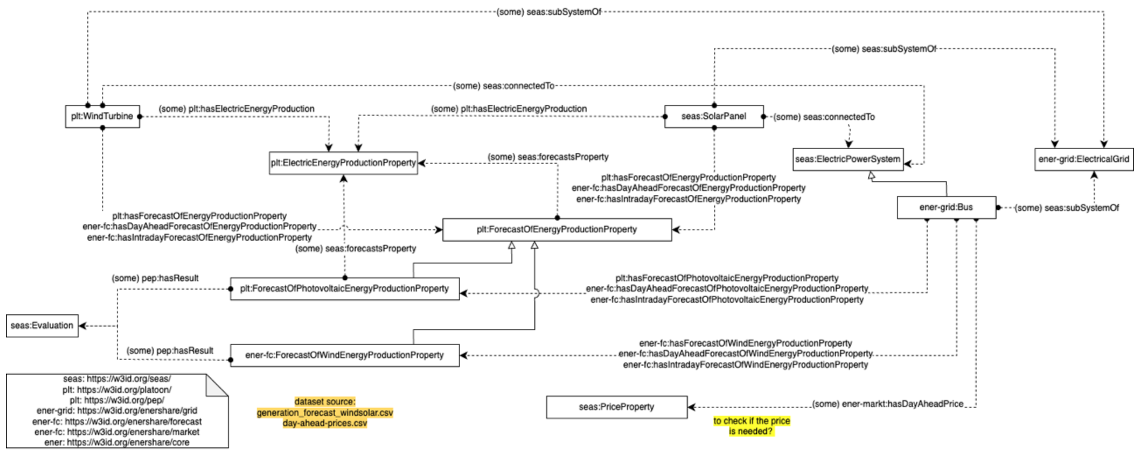
(some) seas:subSystemOf
(some) seas:subSystemOf
(some) seas:connectedTo
plt:WindTurbine
(some) plt:hasElectricEnergyProduction
(some) plt:hasElectricEnergyProduction
seas:SolarPanel
(some) seas:connectedTo
seas:ElectricPowerSystem
ener-grid:ElectricalGrid
plt:ElectricEnergyProductionProperty
(some) seas:forecastsProperty
plt:hasForecastOfEnergyProductionProperty
ener-fc:hasDayAheadForecastOfEnergyProductionProperty
ener-fc:hasIntradayForecastOfEnergyProductionProperty
ener-grid:Bus
(some) seas:subSystemOf
plt:hasForecastOfEnergyProductionProperty
ener-fc:hasDayAheadForecastOfEnergyProductionProperty
ener-fc:hasIntradayForecastOfEnergyProductionProperty
plt:ForecastOfEnergyProductionProperty
(some) seas:forecastsProperty
(some) pep:hasResult
plt:ForecastOfPhotovoltaicEnergyProductionProperty
plt:hasForecastOfPhotovoltaicEnergyProductionProperty
ener-fc:hasDayAheadForecastOfPhotovoltaicEnergyProductionProperty
ener-fc:hasIntradayForecastOfPhotovoltaicEnergyProductionProperty
seas:Evaluation
(some) pep:hasResult
ener-fc:ForecastOfWindEnergyProductionProperty
ener-fc:hasForecastOfWindEnergyProductionProperty
ener-fc:hasDayAheadForecastOfWindEnergyProductionProperty
ener-fc:hasIntradayForecastOfWindEnergyProductionProperty
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
plt: https://w3id.org/pep/
ener-grid: https://w3id.org/enershare/grid
ener-fc: https://w3id.org/enershare/forecast
ener-fc: https://w3id.org/enershare/market
ener: https://w3id.org/enershare/core
dataset source:
generation_forecast_windsolar.csv
day-ahead-prices.csv
seas:PriceProperty
(some) ener-markt:hasDayAheadPrice
to check if the price
is needed?

Figure 49: Pilot 4 - Generation Forecast for wind and solar energy

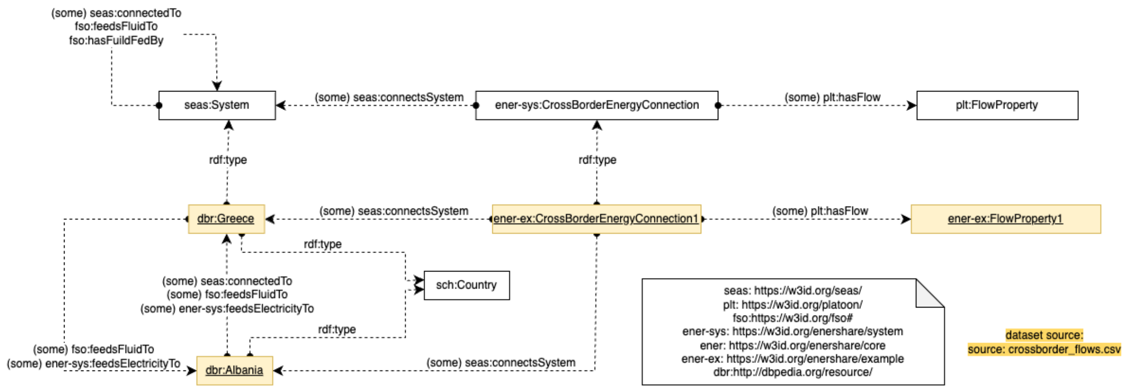
(some) seas:connectedTo
fso:feedsFluidTo
fso:hasFuildFedBy
seas:System
(some) seas:connectsSystem
ener-sys:CrossBorderEnergyConnection
(some) plt:hasFlow
plt:FlowProperty
rdf:type
rdf:type
dbr:Greece
(some) seas:connectsSystem
ener-ex:CrossBorderEnergyConnection1
(some) plt:hasFlow
ener-ex:FlowProperty1
rdf:type
sch:Country
(some) seas:connectedTo
(some) fso:feedsFluidTo
(some) ener-sys:feedsElectricityTo
rdf:type
(some) fso:feedsFluidTo
(some) ener-sys:feedsElectricityTo
dbr:Albania
(some) seas:connectsSystem
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
fso:https://w3id.org/fso#
ener-sys: https://w3id.org/enershare/system
ener: https://w3id.org/enershare/core
ener-ex: https://w3id.org/enershare/example
dbr:http://dbpedia.org/resource/
dataset source:
source: crossborder_flows.csv

Figure 50: Pilot 4 - Flow energy supply

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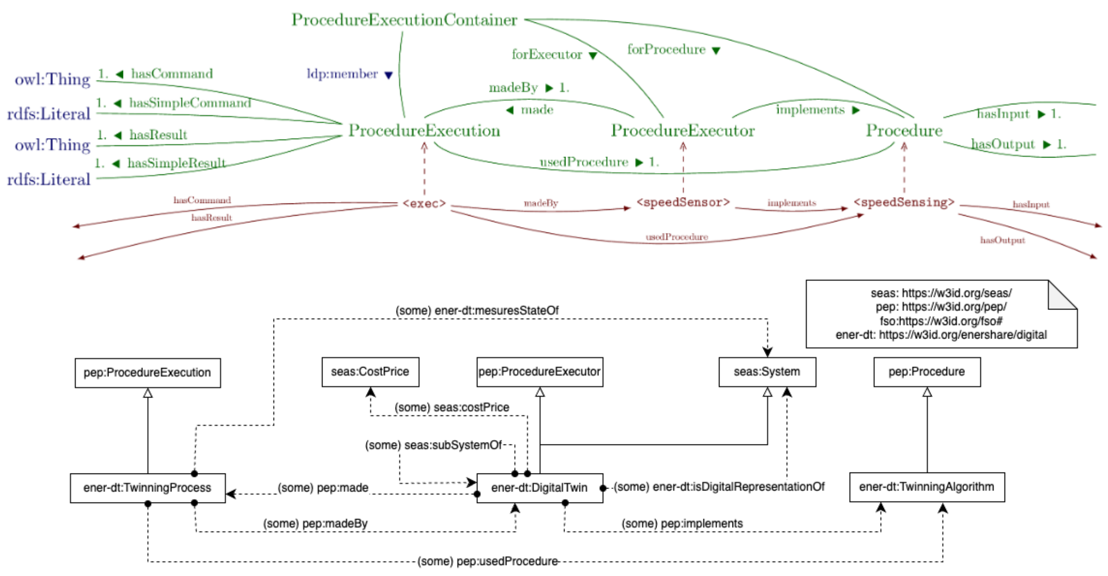
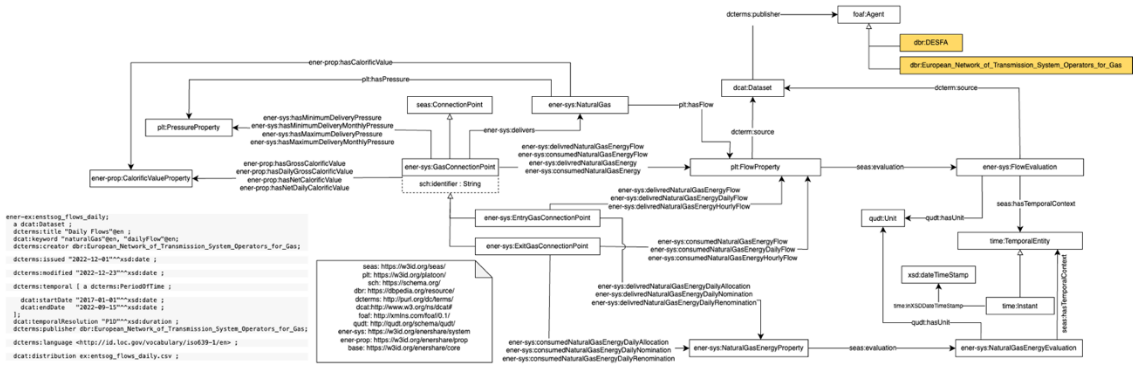


Figure 51: Pilot 4 - Digital Twin


```
ener-ex:enstsog_flows_daily;
  a dcat:Dataset ;
  dcterms:title "Daily Flows"@en ;
  dcat:keyword "naturalGas"@en, "dailyFlow"@en;
  dcterms:creator dbr:European_Network_of_Transmission_System_Operators_for_Gas;

  dcterms:issued "2022-12-01"^^xsd:date ;

  dcterms:modified "2022-12-23"^^xsd:date ;

  dcterms:temporal [ a dcterms:PeriodOfTime ;

    dcat:startDate "2017-01-01"^^xsd:date ;
    dcat:endDate   "2022-09-15"^^xsd:date ;
  ];
  dcat:temporalResolution "P1D"^^xsd:duration ;
  dcterms:publisher dbr:European_Network_of_Transmission_System_Operators_for_Gas;

  dcterms:language <http://id.loc.gov/vocabulary/iso639-1/en> ;

  dcat:distribution ex:entsog_flows_daily.csv ;
```

```
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
dbr: https://dbpedia.org/resource/
dcterms: http://purl.org/dc/terms/
dcat:http://www.w3.org/ns/dcat#
foaf: http://xmlns.com/foaf/0.1/
qudt: http://qudt.org/schema/qudt/
ener-sys: https://w3id.org/enershare/system
ener-prop: https://w3id.org/enershare/prop
base: https://w3id.org/enershare/core
```
dcterms:publisher
foaf:Agent
dbr:DESFA
dbr:European_Network_of_Transmission_System_Operators_for_Gas
ener-prop:hasCalorificValue
plt:hasPressure
dcat:Dataset
dcterm:source
seas:ConnectionPoint
ener-sys:NaturalGas
plt:hasFlow
plt:PressureProperty
ener-sys:hasMinimumDeliveryPressure
ener-sys:hasMinimumDeliveryMonthlyPressure
ener-sys:hasMaximumDeliveryPressure
ener-sys:hasMaximumDeliveryMonthlyPressure
ener-sys:delivers
dcterm:source
ener-sys:delivredNaturalGasEnergyFlow
ener-sys:consumedNaturalGasEnergyFlow
ener-sys:delivredNaturalGasEnergy
ener-sys:consumedNaturalGasEnergy
ener-prop:CalorificValueProperty
ener-prop:hasGrossCalorificValue
ener-prop:hasDailyGrossCalorificValue
ener-prop:hasNetCalorificValue
ener-prop:hasNetDailyCalorificValue
ener-sys:GasConnectionPoint
sch:identifier : String
plt:FlowProperty
seas:evaluation
ener-sys:FlowEvaluation
ener-sys:delivredNaturalGasEnergyFlow
ener-sys:delivredNaturalGasEnergyDailyFlow
ener-sys:delivredNaturalGasEnergyHourlyFlow
seas:hasTemporalContext
ener-sys:EntryGasConnectionPoint
qudt:Unit
qudt:hasUnit
time:TemporalEntity
ener-sys:ExitGasConnectionPoint
ener-sys:consumedNaturalGasEnergyFlow
ener-sys:consumedNaturalGasEnergyDailyFlow
ener-sys:consumedNaturalGasEnergyHourlyFlow
xsd:dateTimeStamp
time:inXSDDateTimeStamp
time:Instant
seas:hasTemporalContext
ener-sys:delivredNaturalGasEnergyDailyAllocation
ener-sys:delivredNaturalGasEnergyDailyNomination
ener-sys:delivredNaturalGasEnergyDailyRenomination
qudt:hasUnit
ener-sys:consumedNaturalGasEnergyDailyAllocation
ener-sys:consumedNaturalGasEnergyDailyNomination
ener-sys:consumedNaturalGasEnergyDailyRenomination
ener-sys:NaturalGasEnergyProperty
seas:evaluation
ener-sys:NaturalGasEnergyEvaluation

Figure 52: Pilot 4 - Natural Gas deliveries

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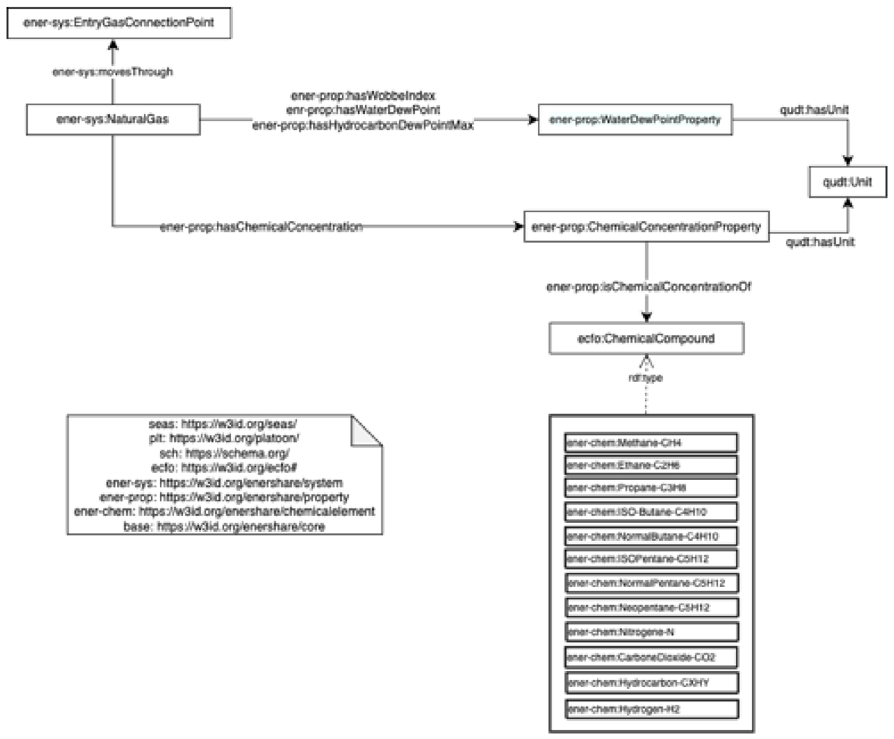
ener-sys:EntryGasConnectionPoint
ener-sys:movesThrough
ener-sys:NaturalGas
ener-prop:hasWobbeIndex
enr-prop:hasWaterDewPoint
ener-prop:hasHydrocarbonDewPointMax
ener-prop:WaterDewPointProperty
qudt:hasUnit
qudt:Unit
ener-prop:hasChemicalConcentration
ener-prop:ChemicalConcentrationProperty
qudt:hasUnit
ener-prop:isChemicalConcentrationOf
ecfo:ChemicalCompound
rdf:type
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ecfo: https://w3id.org/ecfo#
ener-sys: https://w3id.org/enershare/system
ener-prop: https://w3id.org/enershare/property
ener-chem: https://w3id.org/enershare/chemicalelement
base: https://w3id.org/enershare/core
ener-chem:Methane-CH4
ener-chem:Ethane-C2H6
ener-chem:Propane-C3H8
ener-chem:ISO-Butane-C4H10
ener-chem:NormalButane-C4H10
ener-chem:ISOPentane-C5H12
ener-chem:NormalPentane-C5H12
ener-chem:Neopentane-C5H12
ener-chem:Nitrogene-N
ener-chem:CarboneDioxide-CO2
ener-chem:Hydrocarbon-CXHY
ener-chem:Hydrogen-H2

Figure 53: Pilot 4 - Gas Chemical concentration

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7.5 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

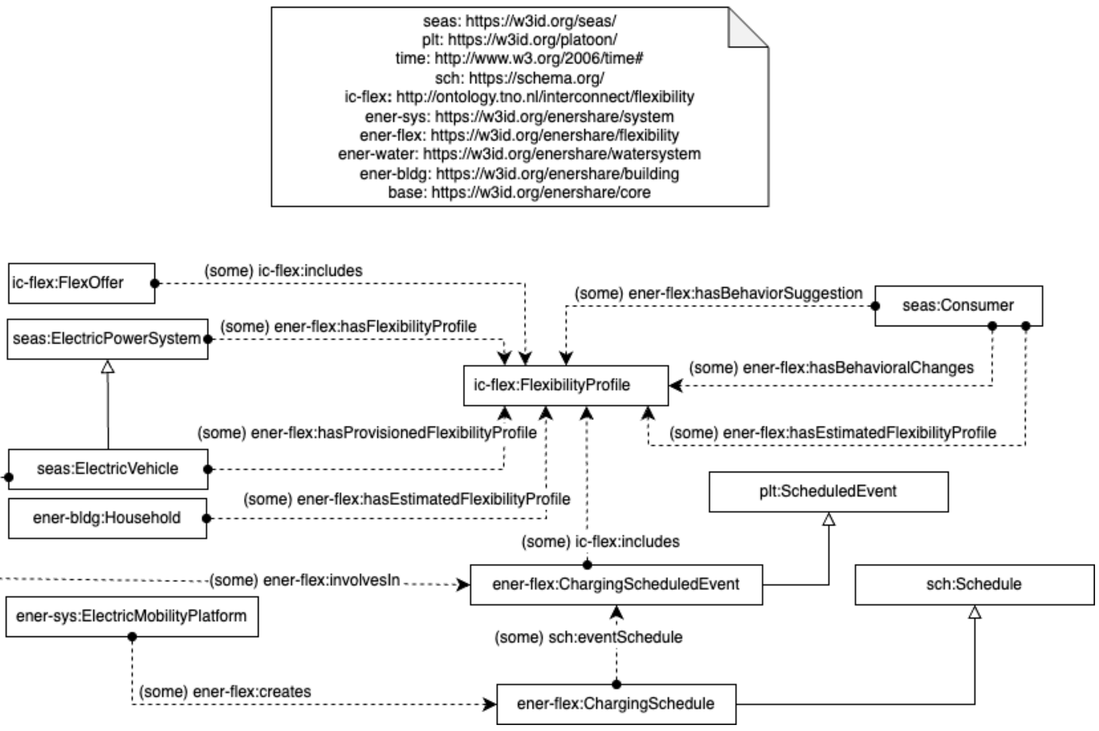
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
time: http://www.w3.org/2006/time#
sch: https://schema.org/
ic-flex: http://ontology.tno.nl/interconnect/flexibility
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener-water: https://w3id.org/enershare/watersystem
ener-bldg: https://w3id.org/enershare/building
base: https://w3id.org/enershare/core
ic-flex:FlexOffer
(some) ic-flex:includes
seas:ElectricPowerSystem
(some) ener-flex:hasFlexibilityProfile
(some) ener-flex:hasBehaviorSuggestion
seas:Consumer
ic-flex:FlexibilityProfile
(some) ener-flex:hasBehavioralChanges
(some) ener-flex:hasProvisionedFlexibilityProfile
(some) ener-flex:hasEstimatedFlexibilityProfile
seas:ElectricVehicle
ener-bldg:Household
(some) ener-flex:hasEstimatedFlexibilityProfile
plt:ScheduledEvent
(some) ic-flex:includes
(some) ener-flex:involvesIn
ener-flex:ChargingScheduledEvent
sch:Schedule
ener-sys:ElectricMobilityPlatform
(some) sch:eventSchedule
(some) ener-flex:creates
ener-flex:ChargingSchedule

Figure 54: Pilot 5 – Flexibility

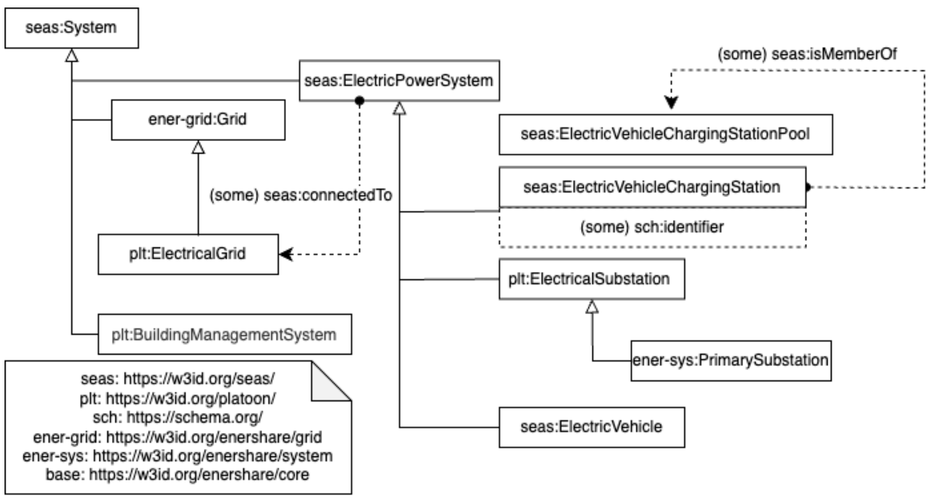
seas:System
seas:ElectricPowerSystem
(some) seas:isMemberOf
ener-grid:Grid
seas:ElectricVehicleChargingStationPool
(some) seas:connectedTo
seas:ElectricVehicleChargingStation
(some) sch:identifier
plt:ElectricalGrid
plt:ElectricalSubstation
plt:BuildingManagementSystem
ener-sys:PrimarySubstation
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-grid: https://w3id.org/enershare/grid
ener-sys: https://w3id.org/enershare/system
base: https://w3id.org/enershare/core
seas:ElectricVehicle

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Figure 55: Pilot 5 - Systems Elements

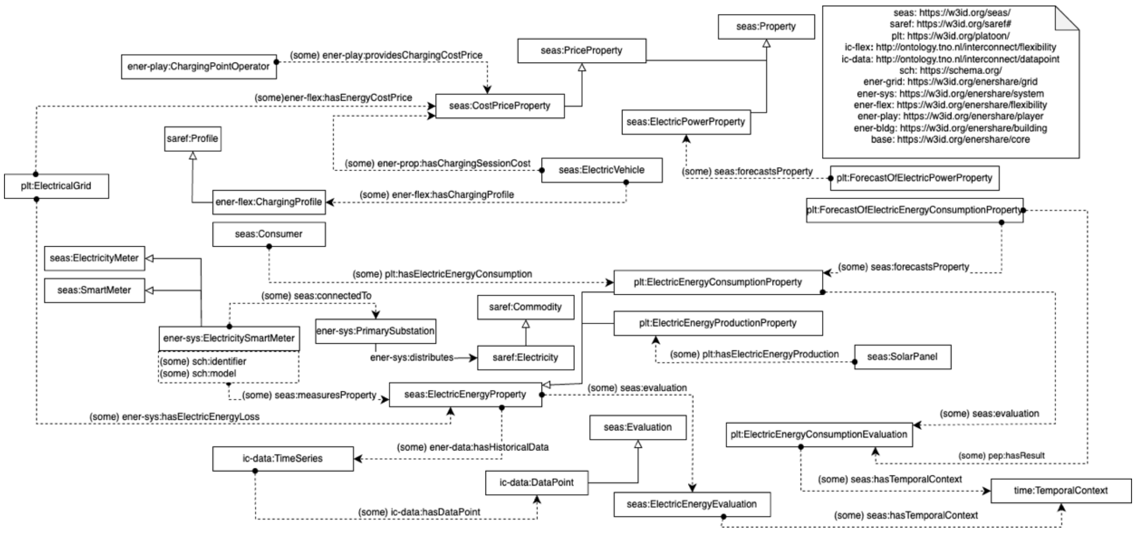
seas:Property
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
ic-flex: http://ontology.tno.nl/interconnect/flexibility
ic-data: http://ontology.tno.nl/interconnect/datapoint
sch: https://schema.org/
ener-grid: https://w3id.org/enershare/grid
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener-play: https://w3id.org/enershare/player
ener-bldg: https://w3id.org/enershare/building
base: https://w3id.org/enershare/core
seas:PriceProperty
ener-play:ChargingPointOperator
(some) ener-play:providesChargingCostPrice
(some)ener-flex:hasEnergyCostPrice
seas:CostPriceProperty
seas:ElectricPowerProperty
saref:Profile
(some) ener-prop:hasChargingSessionCost
seas:ElectricVehicle
(some) seas:forecastsProperty
plt:ForecastOfElectricPowerProperty
plt:ElectricalGrid
ener-flex:ChargingProfile
(some) ener-flex:hasChargingProfile
plt:ForecastOfElectricEnergyConsumptionProperty
seas:Consumer
seas:ElectricityMeter
seas:SmartMeter
(some) plt:hasElectricEnergyConsumption
plt:ElectricEnergyConsumptionProperty
(some) seas:forecastsProperty
(some) seas:connectedTo
saref:Commodity
ener-sys:ElectricitySmartMeter
ener-sys:PrimarySubstation
plt:ElectricEnergyProductionProperty
ener-sys:distributes
saref:Electricity
(some) plt:hasElectricEnergyProduction
seas:SolarPanel
(some) sch:identifier
(some) sch:model
(some) seas:measuresProperty
seas:ElectricEnergyProperty
(some) seas:evaluation
(some) ener-sys:hasElectricEnergyLoss
seas:Evaluation
(some) seas:evaluation
plt:ElectricEnergyConsumptionEvaluation
(some) ener-data:hasHistoricalData
ic-data:TimeSeries
(some) pep:hasResult
ic-data:DataPoint
(some) seas:hasTemporalContext
time:TemporalContext
seas:ElectricEnergyEvaluation
(some) ic-data:hasDataPoint
(some) seas:hasTemporalContext

Figure 56: Pilot 5 – Properties

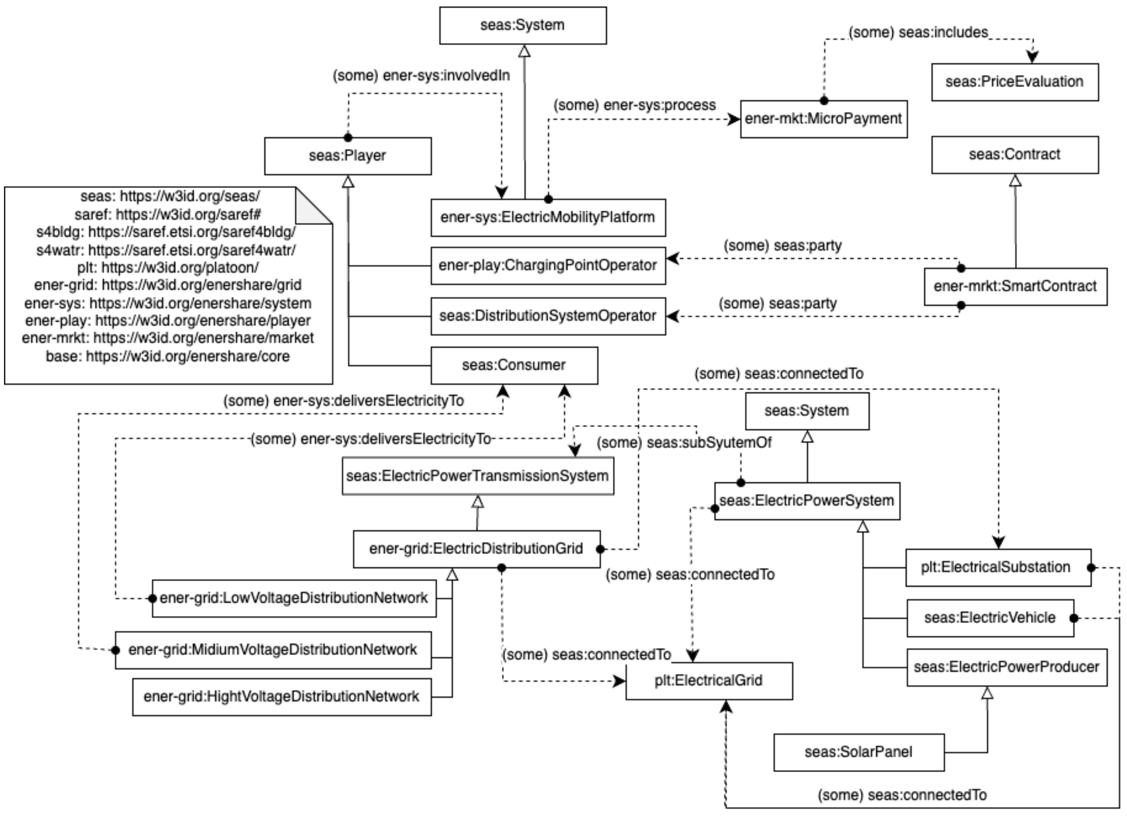
seas:System
(some) seas:includes
seas:PriceEvaluation
(some) ener-sys:involvedIn
(some) ener-sys:process
ener-mkt:MicroPayment
seas:Player
seas:Contract
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
s4watr: https://saref.etsi.org/saref4watr/
plt: https://w3id.org/platoon/
ener-grid: https://w3id.org/enershare/grid
ener-sys: https://w3id.org/enershare/system
ener-play: https://w3id.org/enershare/player
ener-mrkt: https://w3id.org/enershare/market
base: https://w3id.org/enershare/core
ener-sys:ElectricMobilityPlatform
(some) seas:party
ener-play:ChargingPointOperator
ener-mrkt:SmartContract
(some) seas:party
seas:DistributionSystemOperator
seas:Consumer
(some) seas:connectedTo
(some) ener-sys:deliversElectricityTo
seas:System
(some) ener-sys:deliversElectricityTo
(some) seas:subSyutemOf
seas:ElectricPowerTransmissionSystem
seas:ElectricPowerSystem
ener-grid:ElectricDistributionGrid
plt:ElectricalSubstation
(some) seas:connectedTo
ener-grid:LowVoltageDistributionNetwork
seas:ElectricVehicle
ener-grid:MidiumVoltageDistributionNetwork
(some) seas:connectedTo
seas:ElectricPowerProducer
plt:ElectricalGrid
ener-grid:HightVoltageDistributionNetwork
seas:SolarPanel
(some) seas:connectedTo

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Figure 57: Pilot 5 - Grid Topology & System

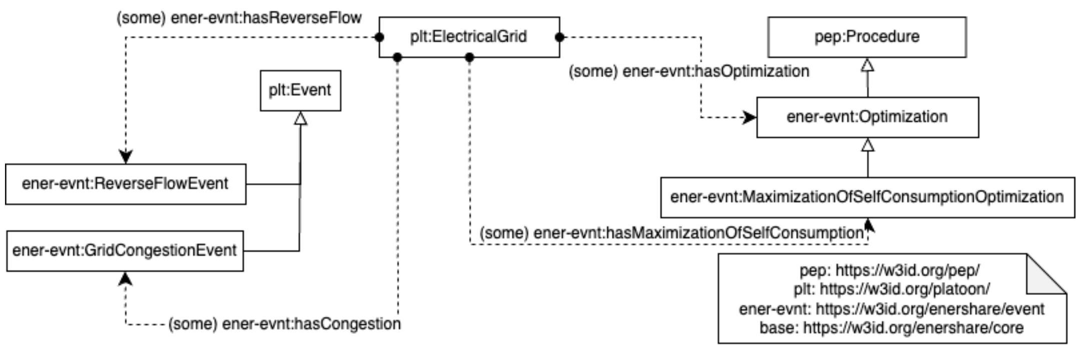
(some) ener-evnt:hasReverseFlow
plt:ElectricalGrid
pep:Procedure
(some) ener-evnt:hasOptimization
plt:Event
ener-evnt:Optimization
ener-evnt:ReverseFlowEvent
ener-evnt:MaximizationOfSelfConsumptionOptimization
ener-evnt:GridCongestionEvent
(some) ener-evnt:hasMaximizationOfSelfConsumption
pep: https://w3id.org/pep/
plt: https://w3id.org/platoon/
ener-evnt: https://w3id.org/enershare/event
base: https://w3id.org/enershare/core
(some) ener-evnt:hasCongestion

Figure 58: Pilot 5 - Grid Event

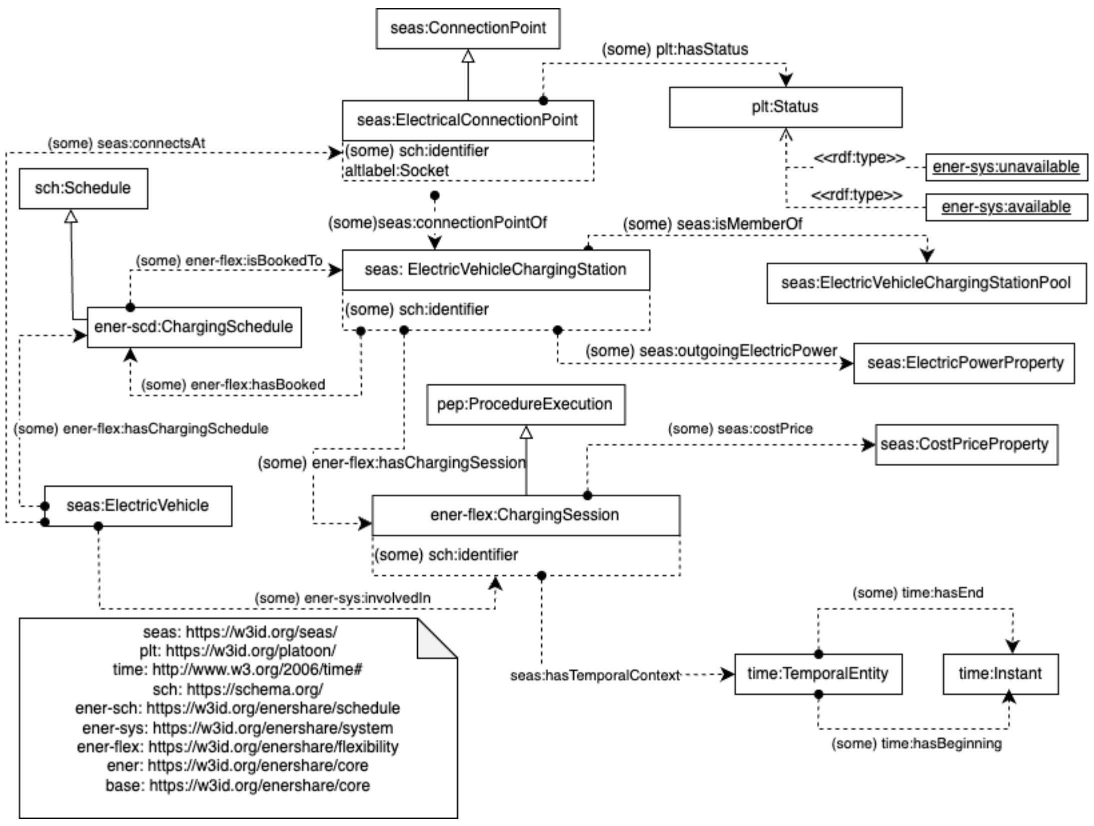
seas:ConnectionPoint
(some) plt:hasStatus
seas:ElectricalConnectionPoint
plt:Status
(some) seas:connectsAt
(some) sch:identifier
altlabel:Socket
<<rdf:type>>
ener-sys:unavailable
sch:Schedule
<<rdf:type>>
ener-sys:available
(some)seas:connectionPointOf
(some) seas:isMemberOf
(some) ener-flex:isBookedTo
seas: ElectricVehicleChargingStation
seas:ElectricVehicleChargingStationPool
(some) sch:identifier
ener-scd:ChargingSchedule
(some) seas:outgoingElectricPower
seas:ElectricPowerProperty
(some) ener-flex:hasBooked
pep:ProcedureExecution
(some) ener-flex:hasChargingSchedule
(some) seas:costPrice
seas:CostPriceProperty
(some) ener-flex:hasChargingSession
seas:ElectricVehicle
ener-flex:ChargingSession
(some) sch:identifier
(some) ener-sys:involvedIn
(some) time:hasEnd
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
time: http://www.w3.org/2006/time#
sch: https://schema.org/
ener-sch: https://w3id.org/enershare/schedule
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener: https://w3id.org/enershare/core
base: https://w3id.org/enershare/core
seas:hasTemporalContext
time:TemporalEntity
time:Instant
(some) time:hasBeginning

Figure 59: Pilot 5 - Charging station

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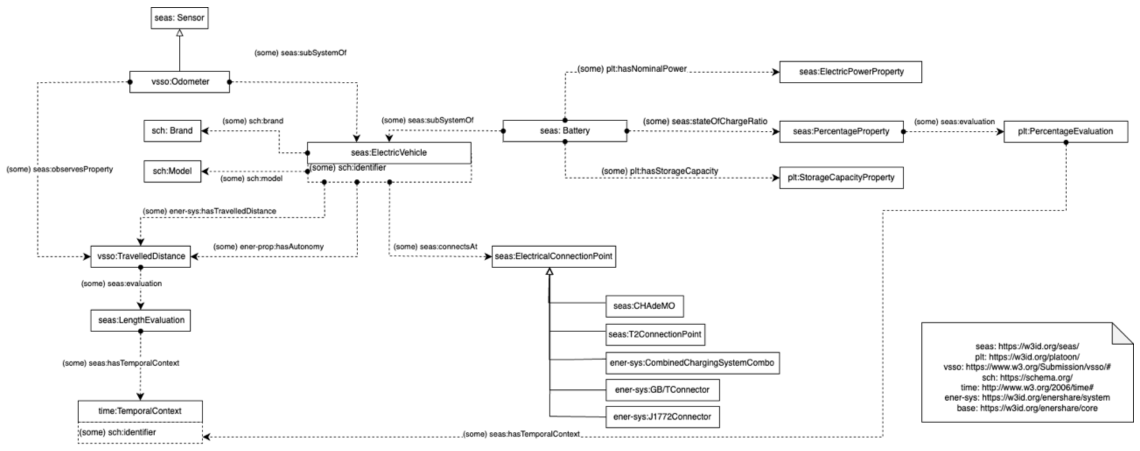
seas: Sensor
vsso:Odometer
(some) seas:subSystemOf
sch: Brand
(some) sch:brand
sch:Model
(some) sch:model
seas:ElectricVehicle
(some) sch:identifier
(some) seas:observesProperty
(some) ener-sys:hasTravelledDistance
vsso:TravelledDistance
(some) ener-prop:hasAutonomy
(some) seas:connectsAt
seas:ElectricalConnectionPoint
(some) seas:evaluation
seas:LengthEvaluation
(some) seas:hasTemporalContext
time:TemporalContext
(some) sch:identifier
(some) seas:subSystemOf
seas: Battery
(some) plt:hasNominalPower
seas:ElectricPowerProperty
(some) seas:stateOfChargeRatio
seas:PercentageProperty
(some) seas:evaluation
plt:PercentageEvaluation
(some) plt:hasStorageCapacity
plt:StorageCapacityProperty
seas:CHAdeMO
seas:T2ConnectionPoint
ener-sys:CombinedChargingSystemCombo
ener-sys:GB/TConnector
ener-sys:J1772Connector
(some) seas:hasTemporalContext
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
vsso: https://www.w3.org/Submission/vsso/#
sch: https://schema.org/
time: http://www.w3.org/2006/time#
ener-sys: https://w3id.org/enershare/system
base: https://w3id.org/enershare/core

Figure 60: Pilot 5 - Electric Vehicle Context

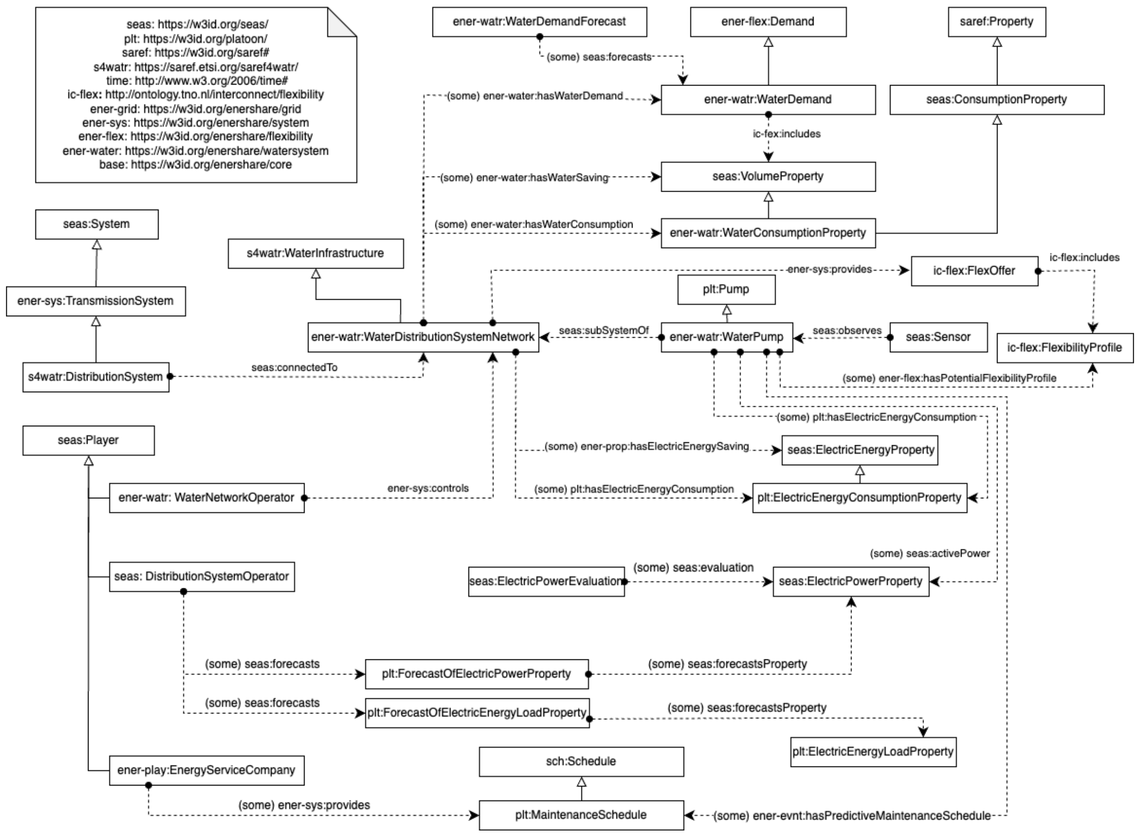
seas: https://w3id.org/seas/
plt: https://w3id.org/platoon/
saref: https://w3id.org/saref#
s4watr: https://saref.etsi.org/saref4watr/
time: http://www.w3.org/2006/time#
ic-flex: http://ontology.tno.nl/interconnect/flexibility
ener-grid: https://w3id.org/enershare/grid
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener-water: https://w3id.org/enershare/watersystem
base: https://w3id.org/enershare/core
ener-watr:WaterDemandForecast
(some) seas:forecasts
ener-flex:Demand
saref:Property
(some) ener-water:hasWaterDemand
ener-watr:WaterDemand
seas:ConsumptionProperty
ic-fex:includes
(some) ener-water:hasWaterSaving
seas:VolumeProperty
(some) ener-water:hasWaterConsumption
ener-watr:WaterConsumptionProperty
seas:System
s4watr:WaterInfrastructure
ener-sys:provides
ic-flex:FlexOffer
ic-flex:includes
ener-sys:TransmissionSystem
plt:Pump
ener-watr:WaterDistributionSystemNetwork
seas:subSystemOf
ener-watr:WaterPump
seas:observes
seas:Sensor
ic-flex:FlexibilityProfile
s4watr:DistributionSystem
seas:connectedTo
(some) ener-flex:hasPotentialFlexibilityProfile
(some) plt:hasElectricEnergyConsumption
seas:Player
(some) ener-prop:hasElectricEnergySaving
seas:ElectricEnergyProperty
ener-watr: WaterNetworkOperator
ener-sys:controls
(some) plt:hasElectricEnergyConsumption
plt:ElectricEnergyConsumptionProperty
(some) seas:activePower
seas: DistributionSystemOperator
seas:ElectricPowerEvaluation
(some) seas:evaluation
seas:ElectricPowerProperty
(some) seas:forecasts
plt:ForecastOfElectricPowerProperty
(some) seas:forecastsProperty
(some) seas:forecasts
plt:ForecastOfElectricEnergyLoadProperty
(some) seas:forecastsProperty
plt:ElectricEnergyLoadProperty
sch:Schedule
ener-play:EnergyServiceCompany
(some) ener-sys:provides
plt:MaintenanceSchedule
(some) ener-evnt:hasPredictiveMaintenanceSchedule

Figure 61: Pilot 5- Water System

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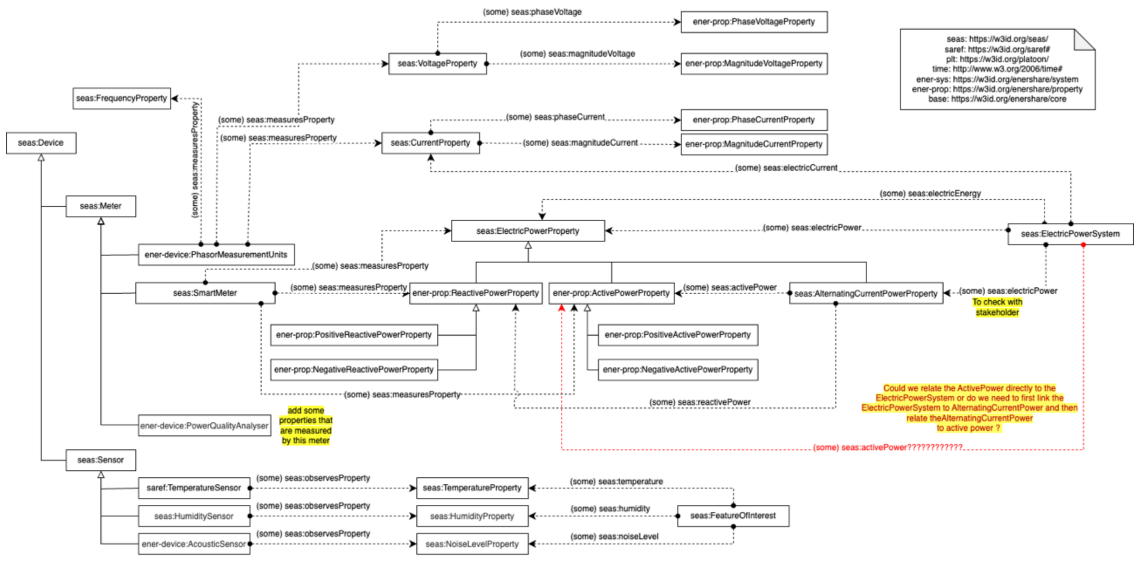
(some) seas:phaseVoltage
ener-prop:PhaseVoltageProperty
seas:VoltageProperty
(some) seas:magnitudeVoltage
ener-prop:MagnitudeVoltageProperty
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
time: http://www.w3.org/2006/time#
ener-sys: https://w3id.org/enershare/system
ener-prop: https://w3id.org/enershare/property
base: https://w3id.org/enershare/core
seas:FrequencyProperty
(some) seas:measuresProperty
seas:Device
seas:CurrentProperty
(some) seas:phaseCurrent
ener-prop:PhaseCurrentProperty
(some) seas:magnitudeCurrent
ener-prop:MagnitudeCurrentProperty
(some) seas:electricCurrent
(some) seas:electricEnergy
seas:Meter
seas:ElectricPowerProperty
(some) seas:electricPower
seas:ElectricPowerSystem
ener-device:PhasorMeasurementUnits
seas:SmartMeter
ener-prop:ReactivePowerProperty
ener-prop:ActivePowerProperty
(some) seas:activePower
seas:AlternatingCurrentPowerProperty
To check with stakeholder
ener-prop:PositiveReactivePowerProperty
ener-prop:NegativeReactivePowerProperty
ener-prop:PositiveActivePowerProperty
ener-prop:NegativeActivePowerProperty
(some) seas:reactivePower
Could we relate the ActivePower directly to the ElectricPowerSystem or do we need to first link the ElectricPowerSystem to AlternatingCurrentPower and then relate theAlternatingCurrentPower to active power ?
ener-device:PowerQualityAnalyser
add some properties that are measured by this meter
(some) seas:activePower????????????
seas:Sensor
saref:TemperatureSensor
(some) seas:observesProperty
seas:TemperatureProperty
(some) seas:temperature
seas:HumiditySensor
seas:HumidityProperty
(some) seas:humidity
seas:FeatureOfInterest
ener-device:AcousticSensor
seas:NoiseLevelProperty
(some) seas:noiseLevel

Figure 62: Pilot 5 - Device & Properties

7.6 Pilot 6: Aggregation of available flexibility from the behind-the-meter consumers (Sweden) – FORTUM

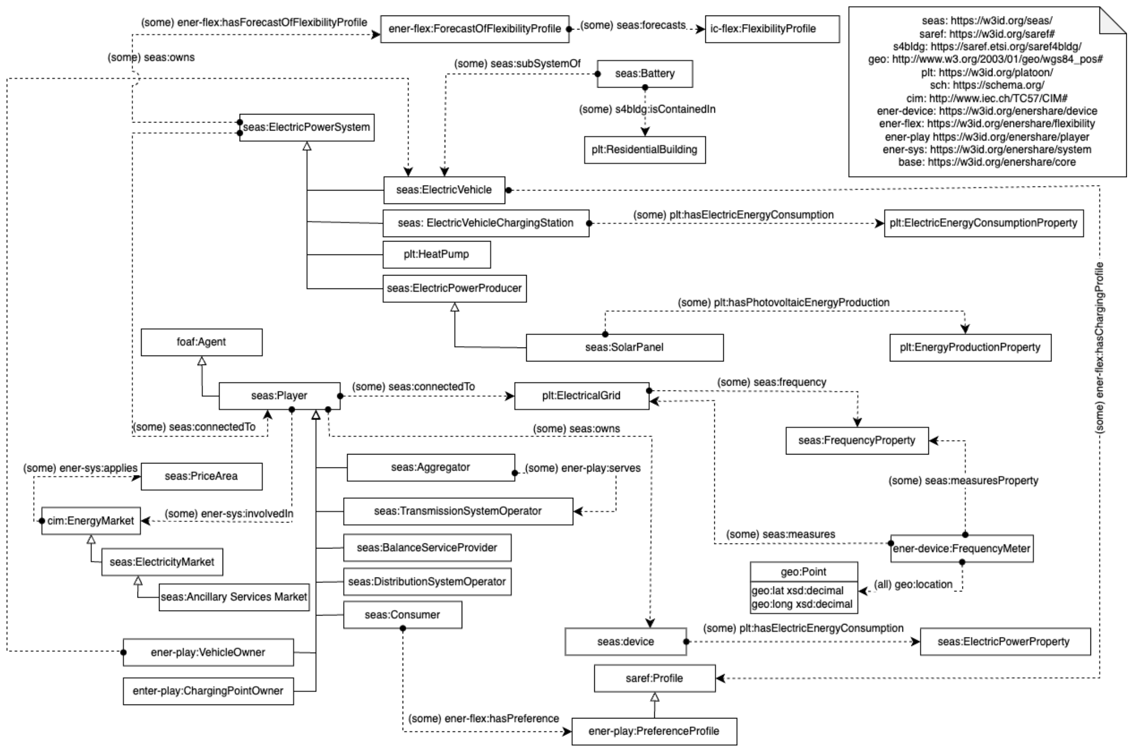
(some) ener-flex:hasForecastOfFlexibilityProfile
ener-flex:ForecastOfFlexibilityProfile
(some) seas:forecasts
ic-flex:FlexibilityProfile
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
geo: http://www.w3.org/2003/01/geo/wgs84_pos#
plt: https://w3id.org/platoon/
sch: https://schema.org/
cim: http://www.iec.ch/TC57/CIM#
ener-device: https://w3id.org/enershare/device
ener-flex: https://w3id.org/enershare/flexibility
ener-play https://w3id.org/enershare/player
ener-sys: https://w3id.org/enershare/system
base: https://w3id.org/enershare/core
(some) seas:owns
(some) seas:subSystemOf
seas:Battery
(some) s4bldg:isContainedIn
plt:ResidentialBuilding
seas:ElectricPowerSystem
seas:ElectricVehicle
seas: ElectricVehicleChargingStation
(some) plt:hasElectricEnergyConsumption
plt:ElectricEnergyConsumptionProperty
plt:HeatPump
seas:ElectricPowerProducer
(some) plt:hasPhotovoltaicEnergyProduction
(some) ener-flex:hasChargingProfile
foaf:Agent
seas:SolarPanel
plt:EnergyProductionProperty
seas:Player
(some) seas:connectedTo
plt:ElectricalGrid
(some) seas:frequency
(some) seas:connectedTo
(some) seas:owns
seas:FrequencyProperty
(some) ener-sys:applies
seas:PriceArea
seas:Aggregator
(some) ener-play:serves
(some) seas:measuresProperty
cim:EnergyMarket
(some) ener-sys:involvedIn
seas:TransmissionSystemOperator
(some) seas:measures
ener-device:FrequencyMeter
seas:ElectricityMarket
seas:BalanceServiceProvider
geo:Point
geo:lat xsd:decimal
geo:long xsd:decimal
(all) geo:location
seas:Ancillary Services Market
seas:DistributionSystemOperator
seas:Consumer
(some) plt:hasElectricEnergyConsumption
ener-play:VehicleOwner
seas:device
seas:ElectricPowerProperty
enter-play:ChargingPointOwner
saref:Profile
(some) ener-flex:hasPreference
ener-play:PreferenceProfile

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Figure 63: Pilot 6 - Grid Context

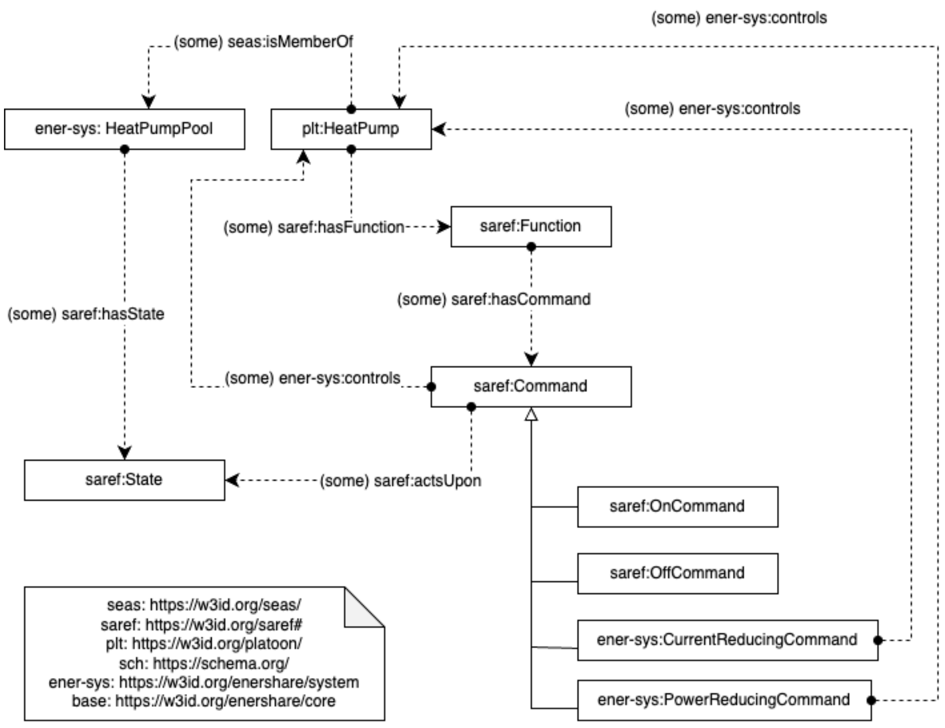

Figure 64: Pilot 6 - Heat Pump & Command

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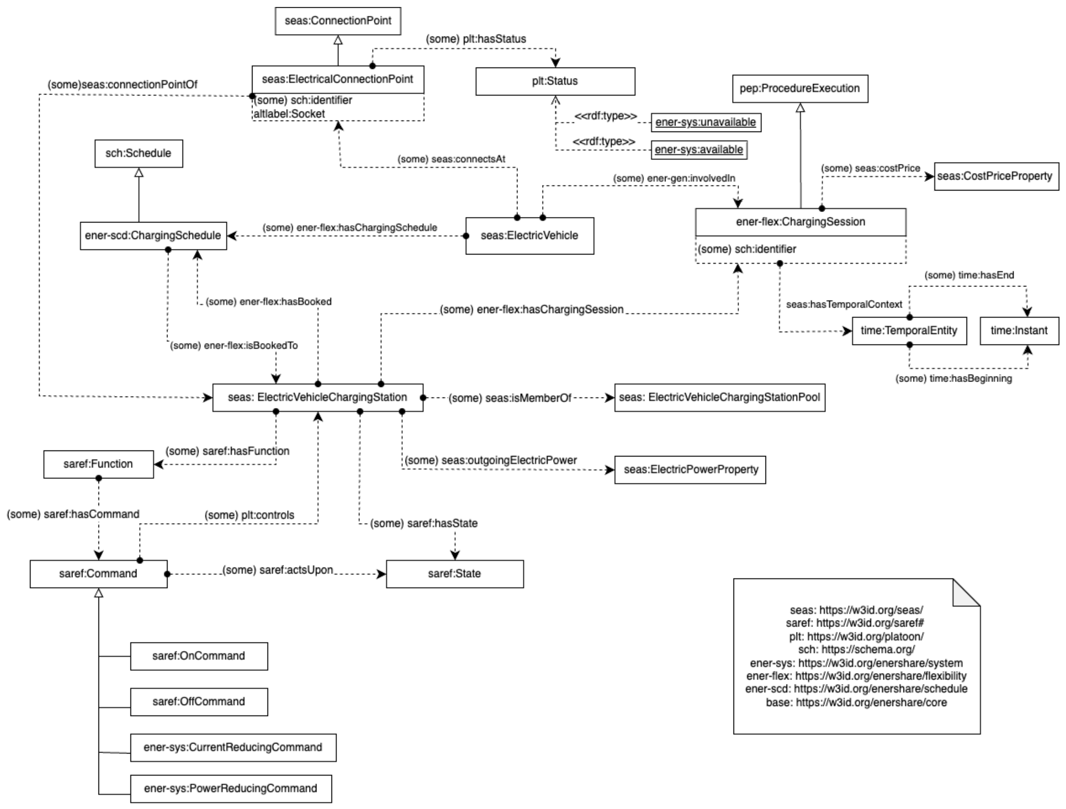
seas:ConnectionPoint
(some) plt:hasStatus
seas:ElectricalConnectionPoint
(some) sch:identifier
altlabel:Socket
plt:Status
pep:ProcedureExecution
(some)seas:connectionPointOf
<<rdf:type>>
ener-sys:unavailable
<<rdf:type>>
ener-sys:available
sch:Schedule
(some) seas:connectsAt
(some) ener-gen:involvedIn
(some) seas:costPrice
seas:CostPriceProperty
ener-scd:ChargingSchedule
(some) ener-flex:hasChargingSchedule
seas:ElectricVehicle
ener-flex:ChargingSession
(some) sch:identifier
(some) time:hasEnd
(some) ener-flex:hasBooked
(some) ener-flex:hasChargingSession
seas:hasTemporalContext
time:TemporalEntity
time:Instant
(some) ener-flex:isBookedTo
(some) time:hasBeginning
seas: ElectricVehicleChargingStation
(some) seas:isMemberOf
seas: ElectricVehicleChargingStationPool
(some) saref:hasFunction
saref:Function
(some) seas:outgoingElectricPower
seas:ElectricPowerProperty
(some) saref:hasCommand
(some) plt:controls
(some) saref:hasState
saref:Command
(some) saref:actsUpon
saref:State
saref:OnCommand
saref:OffCommand
ener-sys:CurrentReducingCommand
ener-sys:PowerReducingCommand
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-sys: https://w3id.org/enershare/system
ener-flex: https://w3id.org/enershare/flexibility
ener-scd: https://w3id.org/enershare/schedule
base: https://w3id.org/enershare/core

Figure 65: Pilot 6 - Electric Vehicle & Charging Station

7.7 Pilot 7: Cross-value chain services for energy-data driven green financing [Latvia] - LEIF, NTUA

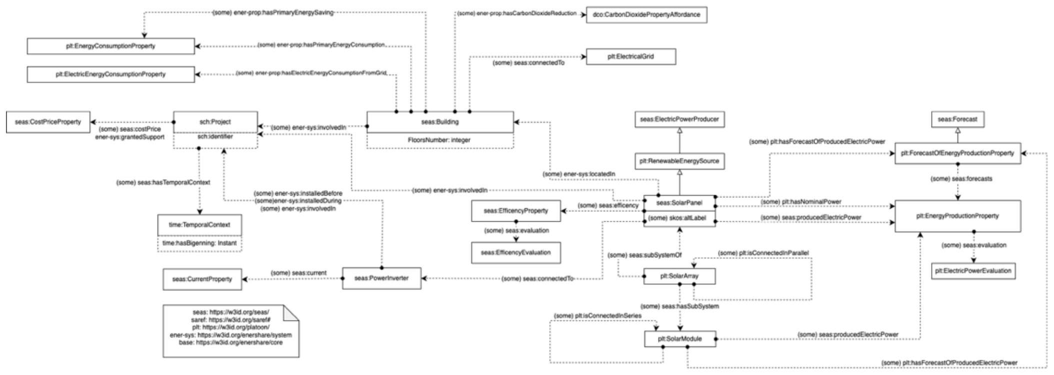
(some) ener-prop:hasPrimaryEnergySaving
(some) ener-prop:hasCarbonDioxideReduction
dco:CarbonDioxidePropertyAffordance
plt:EnergyConsumptionProperty
(some) ener-prop:hasPrimaryEnergyConsumption
plt:ElectricEnergyConsumptionProperty
(some) ener-prop:hasElectricEnergyConsumptionFromGrid
(some) seas:connectedTo
plt:ElectricalGrid
seas:CostPriceProperty
(some) seas:costPrice
ener-sys:grantedSupport
sch:Project
sch:identifier
(some) ener-sys:involvedIn
seas:Building
FloorsNumber: integer
seas:ElectricPowerProducer
seas:Forecast
(some) plt:hasForecastOfProducedElectricPower
plt:ForecastOfEnergyProductionProperty
plt:RenewableEnergySource
(some) ener-sys:locatedIn
(some) seas:forecasts
(some) seas:hasTemporalContext
(some) ener-sys:installedBefore
(some)ener-sys:installedDuring
(some) ener-sys:involvedIn
(some) ener-sys:involvedIn
seas:SolarPanel
(some) skos:altLabel
(some) plt:hasNominalPower
seas:EfficencyProperty
(some) seas:efficency
(some) seas:producedElectricPower
plt:EnergyProductionProperty
time:TemporalContext
time:hasBigenning: Instant
(some) seas:evaluation
seas:EfficencyEvaluation
(some) seas:subSystemOf
(some) plt:isConnectedInParallel
(some) seas:evaluation
plt:ElectricPowerEvaluation
seas:CurrentProperty
(some) seas:current
seas:PowerInverter
(some) seas:connectedTo
plt:SolarArray
(some) seas:hasSubSystem
(some) plt:isConnectedInSeries
plt:SolarModule
(some) seas:producedElectricPower
(some) plt:hasForecastOfProducedElectricPower
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
ener-sys: https://w3id.org/enershare/system
base: https://w3id.org/enershare/core

Figure 66: Pilot 7 - Solar Panel installed on building

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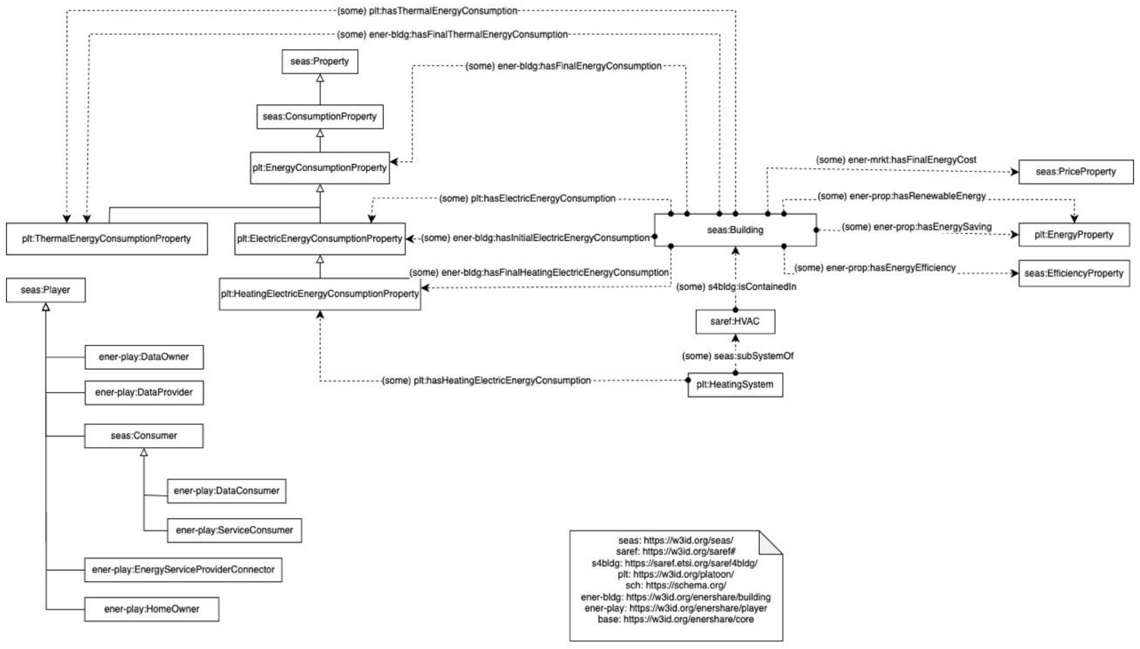
(some) plt:hasThermalEnergyConsumption
(some) ener-bldg:hasFinalThermalEnergyConsumption
seas:Property
(some) ener-bldg:hasFinalEnergyConsumption
seas:ConsumptionProperty
plt:EnergyConsumptionProperty
(some) ener-mrkt:hasFinalEnergyCost
seas:PriceProperty
(some) plt:hasElectricEnergyConsumption
(some) ener-prop:hasRenewableEnergy
plt:ThermalEnergyConsumptionProperty
plt:ElectricEnergyConsumptionProperty
(some) ener-bldg:hasInitialElectricEnergyConsumption
seas:Building
(some) ener-prop:hasEnergySaving
plt:EnergyProperty
(some) ener-bldg:hasFinalHeatingElectricEnergyConsumption
(some) ener-prop:hasEnergyEfficiency
seas:EfficiencyProperty
seas:Player
plt:HeatingElectricEnergyConsumptionProperty
(some) s4bldg:isContainedIn
saref:HVAC
(some) seas:subSystemOf
ener-play:DataOwner
ener-play:DataProvider
(some) plt:hasHeatingElectricEnergyConsumption
plt:HeatingSystem
seas:Consumer
ener-play:DataConsumer
ener-play:ServiceConsumer
ener-play:EnergyServiceProviderConnector
ener-play:HomeOwner
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
plt: https://w3id.org/platoon/
sch: https://schema.org/
ener-bldg: https://w3id.org/enershare/building
ener-play: https://w3id.org/enershare/player
base: https://w3id.org/enershare/core

Figure 67: Pilot 7-Building consumption and Actors

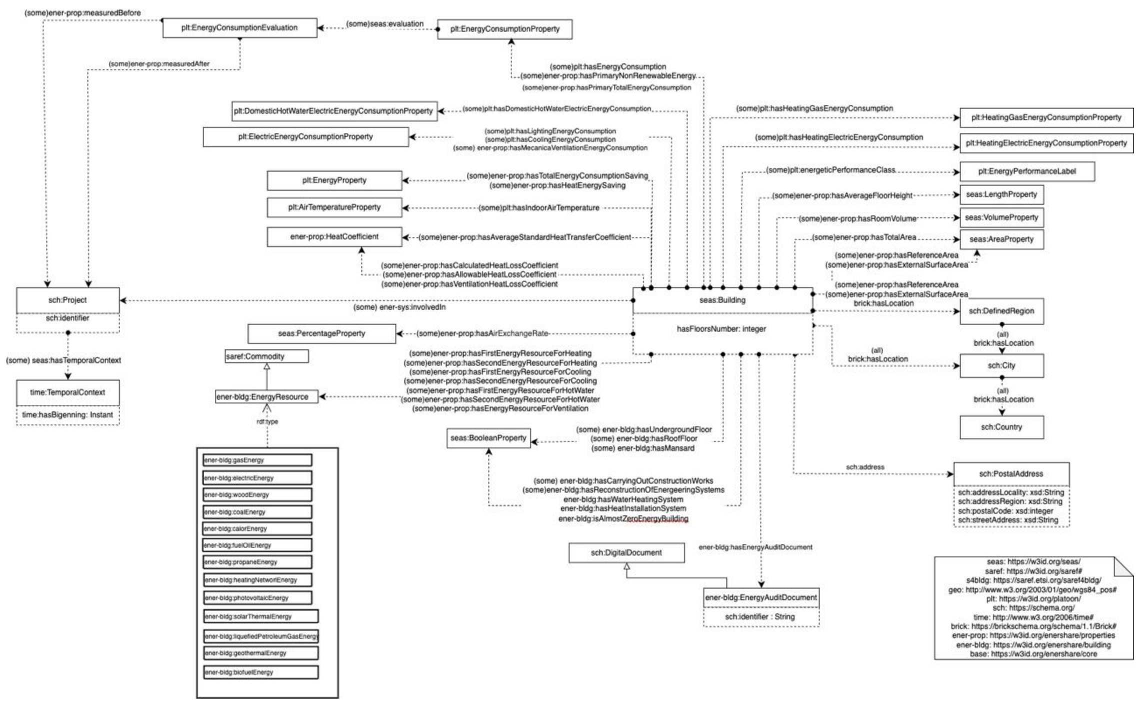
(some)ener-prop:measuredBefore
plt:EnergyConsumptionEvaluation
(some)seas:evaluation
plt:EnergyConsumptionProperty
(some)ener-prop:measuredAfter
(some)plt:hasEnergyConsumption
(some)ener-prop:hasPrimaryNonRenewableEnergy
(some)ener-prop:hasPrimaryTotalEnergyConsumption
plt:DomesticHotWaterElectricEnergyConsumptionProperty
(some)plt:hasDomesticHotWaterElectricEnergyConsumption
(some)plt:hasHeatingGasEnergyConsumption
plt:HeatingGasEnergyConsumptionProperty
plt:ElectricEnergyConsumptionProperty
(some)plt:hasLightingEnergyConsumption
(some)plt:hasCoolingEnergyConsumption
(some) ener-prop:hasMecanicaVentilationEnergyConsumption
(some)plt:hasHeatingElectricEnergyConsumption
plt:HeatingElectricEnergyConsumptionProperty
(some)plt:energeticPerformanceClass
plt:EnergyPerformanceLabel
plt:EnergyProperty
(some)ener-prop:hasTotalEnergyConsumptionSaving
(some)ener-prop:hasHeatEnergySaving
(some)ener-prop:hasAverageFloorHeight
seas:LengthProperty
plt:AirTemperatureProperty
(some)plt:hasIndoorAirTemperature
(some)ener-prop:hasRoomVolume
seas:VolumeProperty
ener-prop:HeatCoefficient
(some)ener-prop:hasAverageStandardHeatTransferCoefficient
(some)ener-prop:hasTotalArea
seas:AreaProperty
(some)ener-prop:hasCalculatedHeatLossCoefficient
(some)ener-prop:hasAllowableHeatLossCoefficient
(some)ener-prop:hasVentilationHeatLossCoefficient
(some)ener-prop:hasReferenceArea
(some)ener-prop:hasExternalSurfaceArea
sch:Project
sch:identifier
(some) ener-sys:involvedIn
seas:Building
brick:hasLocation
sch:DefinedRegion
hasFloorsNumber: integer
seas:PercentageProperty
(some)ener-prop:hasAirExchangeRate
(some) seas:hasTemporalContext
saref:Commodity
(some)ener-prop:hasFirstEnergyResourceForHeating
(some)ener-prop:hasSecondEnergyResourceForHeating
(some)ener-prop:hasFirstEnergyResourceForCooling
(some)ener-prop:hasSecondEnergyResourceForCooling
(some)ener-prop:hasFirstEnergyResourceForHotWater
(some)ener-prop:hasSecondEnergyResourceForHotWater
(some)ener-prop:hasEnergyResourceForVentilation
(all) brick:hasLocation
sch:City
time:TemporalContext
time:hasBigenning: Instant
ener-bldg:EnergyResource
rdf:type
sch:Country
ener-bldg:gasEnergy
ener-bldg:electricEnergy
ener-bldg:woodEnergy
ener-bldg:coalEnergy
ener-bldg:calorEnergy
ener-bldg:fuelOilEnergy
ener-bldg:propaneEnergy
ener-bldg:heatingNetworkEnergy
ener-bldg:photovoltaicEnergy
ener-bldg:solarThermalEnergy
ener-bldg:liquefiedPetroleumGasEnergy
ener-bldg:geothermalEnergy
ener-bldg:biofuelEnergy
seas:BooleanProperty
(some) ener-bldg:hasUndergroundFloor
(some) ener-bldg:hasRoofFloor
(some) ener-bldg:hasMansard
sch:address
sch:PostalAddress
sch:addressLocality: xsd:String
sch:addressRegion: xsd:String
sch:postalCode: xsd:integer
sch:streetAddress: xsd:String
(some) ener-bldg:hasCarryingOutConstructionWorks
(some)ener-bldg:hasReconstructionOfEnergeeringSystems
ener-bldg:hasWaterHeatingSystem
ener-bldg:hasHeatInstallationSystem
ener-bldg:isAlmostZeroEnergyBuilding
sch:DigitalDocument
ener-bldg:hasEnergyAuditDocument
ener-bldg:EnergyAuditDocument
sch:identifier : String
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4bldg: https://saref.etsi.org/saref4bldg/
geo: http://www.w3.org/2003/01/geo/wgs84_pos#
plt: https://w3id.org/platoon/
sch: https://schema.org/
time: http://www.w3.org/2006/time#
brick: https://brickschema.org/schema/1.1/Brick#
ener-prop: https://w3id.org/enershare/properties
ener-bldg: https://w3id.org/enershare/building
base: https://w3id.org/enershare/core

Figure 68: Pilot 7 - Building properties

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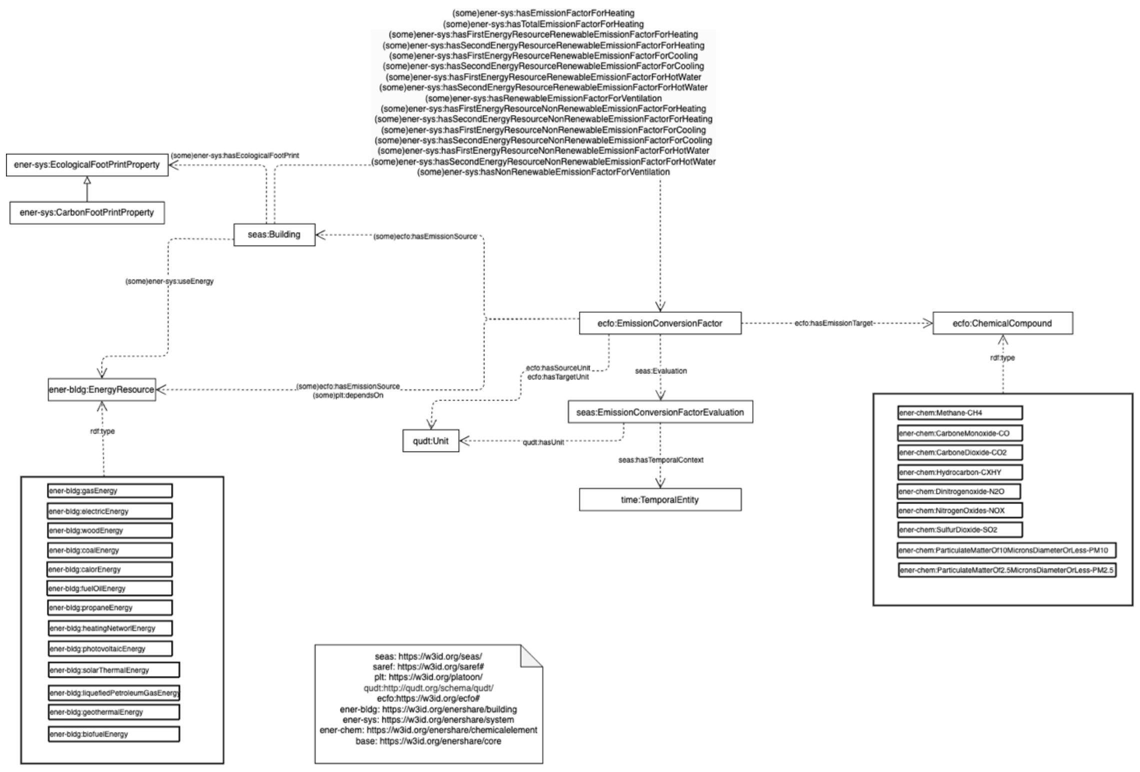
(some)ener-sys:hasEmissionFactorForHeating
(some)ener-sys:hasTotalEmissionFactorForHeating
(some)ener-sys:hasFirstEnergyResourceRenewableEmissionFactorForHeating
(some)ener-sys:hasSecondEnergyResourceRenewableEmissionFactorForHeating
(some)ener-sys:hasFirstEnergyResourceRenewableEmissionFactorForCooling
(some)ener-sys:hasSecondEnergyResourceRenewableEmissionFactorForCooling
(some)ener-sys:hasFirstEnergyResourceRenewableEmissionFactorForHotWater
(some)ener-sys:hasSecondEnergyResourceRenewableEmissionFactorForHotWater
(some)ener-sys:hasRenewableEmissionFactorForVentilation
(some)ener-sys:hasFirstEnergyResourceNonRenewableEmissionFactorForHeating
(some)ener-sys:hasSecondEnergyResourceNonRenewableEmissionFactorForHeating
(some)ener-sys:hasFirstEnergyResourceNonRenewableEmissionFactorForCooling
(some)ener-sys:hasSecondEnergyResourceNonRenewableEmissionFactorForCooling
(some)ener-sys:hasFirstEnergyResourceNonRenewableEmissionFactorForHotWater
(some)ener-sys:hasSecondEnergyResourceNonRenewableEmissionFactorForHotWater
(some)ener-sys:hasNonRenewableEmissionFactorForVentilation
ener-sys:EcologicalFootPrintProperty
(some)ener-sys:hasEcologicalFootPrint
ener-sys:CarbonFootPrintProperty
seas:Building
(some)ecfo:hasEmissionSource
(some)ener-sys:useEnergy
ecfo:EmissionConversionFactor
ecfo:hasEmissionTarget
ecfo:ChemicalCompound
rdf:type
ecfo:hasSourceUnit
ecfo:hasTargetUnit
seas:Evaluation
ener-bldg:EnergyResource
(some)ecfo:hasEmissionSource
(some)plt:dependsOn
seas:EmissionConversionFactorEvaluation
qudt:Unit
qudt:hasUnit
seas:hasTemporalContext
time:TemporalEntity
rdf:type
ener-chem:Methane-CH4
ener-chem:CarboneMonoxide-CO
ener-chem:CarboneDioxide-CO2
ener-chem:Hydrocarbon-CXHY
ener-chem:Dinitrogenoxide-N2O
ener-chem:NitrogenOxides-NOX
ener-chem:SulfurDioxide-SO2
ener-chem:ParticulateMatterOf10MicronsDiameterOrLess-PM10
ener-chem:ParticulateMatterOf2.5MicronsDiameterOrLess-PM2.5
ener-bldg:gasEnergy
ener-bldg:electricEnergy
ener-bldg:woodEnergy
ener-bldg:coalEnergy
ener-bldg:calorEnergy
ener-bldg:fuelOilEnergy
ener-bldg:propaneEnergy
ener-bldg:heatingNetworlEnergy
ener-bldg:photovoltaicEnergy
ener-bldg:solarThermalEnergy
ener-bldg:liquefiedPetroleumGasEnergy
ener-bldg:geothermalEnergy
ener-bldg:biofuelEnergy
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
plt: https://w3id.org/platoon/
qudt:http://qudt.org/schema/qudt/
ecfo:https://w3id.org/ecfo#
ener-bldg: https://w3id.org/enershare/building
ener-sys: https://w3id.org/enershare/system
ener-chem: https://w3id.org/enershare/chemicalelement
base: https://w3id.org/enershare/core

Figure 69: Pilot 7 - Emission Factor

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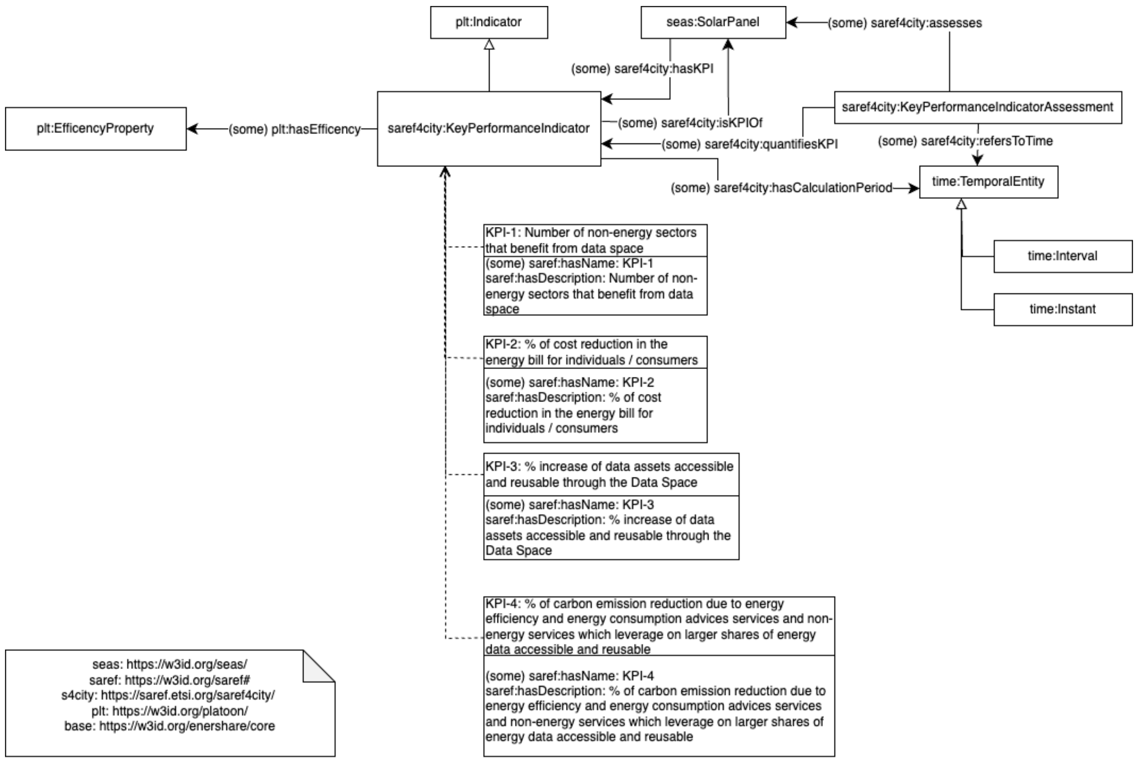
plt:Indicator
seas:SolarPanel
(some) saref4city:assesses
(some) saref4city:hasKPI
saref4city:KeyPerformanceIndicatorAssessment
plt:EfficencyProperty
(some) plt:hasEfficency
saref4city:KeyPerformanceIndicator
(some) saref4city:isKPIOf
(some) saref4city:quantifiesKPI
(some) saref4city:refersToTime
(some) saref4city:hasCalculationPeriod
time:TemporalEntity
time:Interval
time:Instant
KPI-1: Number of non-energy sectors that benefit from data space
(some) saref:hasName: KPI-1
saref:hasDescription: Number of non-energy sectors that benefit from data space
KPI-2: % of cost reduction in the energy bill for individuals / consumers
(some) saref:hasName: KPI-2
saref:hasDescription: % of cost reduction in the energy bill for individuals / consumers
KPI-3: % increase of data assets accessible and reusable through the Data Space
(some) saref:hasName: KPI-3
saref:hasDescription: % increase of data assets accessible and reusable through the Data Space
KPI-4: % of carbon emission reduction due to energy efficiency and energy consumption advices services and non-energy services which leverage on larger shares of energy data accessible and reusable
(some) saref:hasName: KPI-4
saref:hasDescription: % of carbon emission reduction due to energy efficiency and energy consumption advices services and non-energy services which leverage on larger shares of energy data accessible and reusable
seas: https://w3id.org/seas/
saref: https://w3id.org/saref#
s4city: https://saref.etsi.org/saref4city/
plt: https://w3id.org/platoon/
base: https://w3id.org/enershare/core

Figure 70: Pilot 7 - KPI

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8 Appendix: Examples of data transformation and compliance

This appendix contains data models, mapping rules and shapes files that can be used as input and output to test the data transformation service and the data compliance service.

8.1 Data transformation example

Example to transform the JSON file in Table 12 given the mapping rules in Table 13. The output, which is compliant with ENERSHARE's ontology is shown in Turtle serialization in Table 14 and in JSON-LD compact serialization in Table 15.

The process time for this transformation takes around 3 to 4 seconds in an Intel(R) Core(TM) i7-8850H CPU. Hence, for real-time constraints these transformations are not recommended and, if necessary, a GPU should be used.

```
curl -X 'POST' \

'http://XXX.XX.XX.XX:XXXX/transformationService/convertFile?json_file_url=https%3A%2F
%2Fgit.code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fmappings%2Fpilot1_windturbine_simplejson.json&mapping_file_url=https%
3A%2F%2Fgit.code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fmappings%2Fpilot1-windturbine-mapping-
json.ttl&serialize_format=turtle' \
  -H 'accept: application/json' \
  -d ''
```

Table 12: Simple JSON file with the data structure of a wind turbine

```
{
        "windturbine": {
                "timestamp": "2019-08-24T00:00:00Z",
                "windfarm_id": "FRBRT",
                "windturbine_id": "91840",
                "nacelle_temperature": "27.54 Cel",
                "blade_pitch_angle": "450 deg",
                "windspeed": "9.32 m/s",
                "generator_active_power": "495.7 kW",
                "generator_current": "417.18 A",
```

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```
                "generator_torque": "3370.42 N.m",
                "stator_winding_temperature": "27.54 Cel"
        }
}
```

Table 13: Mapping rules to transform the JSON into a semantic model compliant with ENERSHARE's ontology

```
@prefix rr: <http://www.w3.org/ns/r2rml#> .
@prefix rml: <http://semweb.mmlab.be/ns/rml#> .
@prefix ql: <http://semweb.mmlab.be/ns/ql#> .
@prefix brick: <https://brickschema.org/schema/1.1/Brick#> .
@prefix cdt: <http://w3id.org/lindt/custom_datatypes#> .
@prefix plt: <https://w3id.org/platoon/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix seas: <https://w3id.org/seas/> .
@prefix time: <http://www.w3.org/2006/time#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<#WindFarm> a rr:TriplesMap;
rml:logicalSource [
    rml:source "pilot1_windturbine_simplejson.json";
    rml:referenceFormulation ql:JSONPath;
    rml:iterator "$"
];

rr:subjectMap [
    rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}";
    rr:class plt:WindFarm
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [
       rml:reference "windturbine.windfarm_id"
    ]
].

<#Time> a rr:TriplesMap;
rml:logicalSource [
    rml:source "pilot1_windturbine_simplejson.json";
    rml:referenceFormulation ql:JSONPath;
    rml:iterator "$"
];

rr:subjectMap [
```

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```
    rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}";
    rr:class time:Instant
];

rr:predicateObjectMap [
    rr:predicate time:inXSDDateTime ;
    rr:objectMap [
       rml:reference "windturbine.timestamp";
       rr:datatype  xsd:dateTime
    ]
].

<#OnshoreWindTurbine> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:OnshoreWindTurbine;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [
        rml:reference "windturbine.windturbine_id"
    ]
];

rr:predicateObjectMap [
    rr:predicate brick:hasLocation ;
    rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}"
    ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageWindSpeed ;
        rr:objectMap [
        rr:termType rr:IRI;
           rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/windspeed/aver
age"
```

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```
        ]
];

rr:predicateObjectMap [
        rr:predicate seas:isMemberOf ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}"
        ]
].

<#WindSpeedProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:WindSpeedProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/windspeed/aver
age"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "wind speed average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/windspeed/aver
age/evaluation/{windturbine.timestamp}"
        ]
] .

<#WindSpeedEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
```

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```
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/windspeed/aver
age/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.windspeed";
       rr:datatype  cdt:speed
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#StatorWinding> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:StatorWinding;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/generator/stato
r/statorwinding"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "StatorWinding" ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageTemperature ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/stator/statorwinding/pr
operty/temperature/average"
        ]
```

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```
];

rr:predicateObjectMap [
        rr:predicate seas:subSystemOf ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/generator/stato
r"
        ]
].

<#Blade> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:Blade;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/blade/1"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "Blade Axis_1" ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAveragePitchAngle ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/blade/1/property/pitcha
ngle/average"
        ]
];

rr:predicateObjectMap [
        rr:predicate seas:subSystemOf ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}"
        ]
].
```

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```
<#PitchAngleProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:PitchAngleProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/blade/1/property/pitcha
ngle/average"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "Pitch Angle average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/blade/1/property/pitcha
ngle/average/evaluation/{windturbine.timestamp}"
        ]
] .

<#PitchAngleEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/blade/1/property/pitcha
ngle/average/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.blade_pitch_angle";
       rr:datatype  cdt:angle
    ]
];
```

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```
rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#Nacelle> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:Nacelle;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "Nacelle" ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageTemperature ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/property/temper
ature/average"
        ]
];

rr:predicateObjectMap [
        rr:predicate seas:subSystemOf ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}"
        ]
].

<#Generator> a rr:TriplesMap;
rml:logicalSource [
```

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```
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:Generator;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/generator"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "Generator" ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageActivePower ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/activepower/av
erage"
        ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageCurrent ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/current/averag
e"
        ]
];

rr:predicateObjectMap [
        rr:predicate plt:hasAverageTorque ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/torque/average
"
        ]
];
rr:predicateObjectMap [
        rr:predicate seas:subSystemOf ;
        rr:objectMap [
        rr:termType rr:IRI;
```

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```
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle"
        ]
].

<#Stator> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:Stator;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/generator/stato
r"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "Stator" ]
];

rr:predicateObjectMap [
        rr:predicate seas:subSystemOf ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/generator"
        ]
].

<#NacelleTemperatureProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:TemperatureProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/property/temper
ature/average"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
```

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```
    rr:objectMap [ rr:constant "nacelle temperature average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/property/temper
ature/average/evaluation/{windturbine.timestamp}"
        ]
] .

<#NacelleTemperatureEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
     rr:class seas:TemperatureEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/nacelle/property/temper
ature/average/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.nacelle_temperature";
       rr:datatype  cdt:temperature
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#ElectricPowerProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
```

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```
];

rr:subjectMap [
     rr:class seas:ElectricPowerProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/activepower/av
erage"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "windTurbine active power average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/activepower/av
erage/evaluation/{windturbine.timestamp}"
        ]
] .

<#ElectricPowerEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:ElectricPowerEvaluation;
     rr:class seas:AverageEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/activepower/av
erage/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.generator_active_power";
       rr:datatype  cdt:power
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
```

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```
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#CurrentProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:CurrentProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/current/averag
e"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "windTurbine current average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/current/averag
e/evaluation/{windturbine.timestamp}"
        ]
] .

<#CurrentEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
     rr:class seas:CurrentEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/current/averag
e/evaluation/{windturbine.timestamp}"
];
```

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```
rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.generator_current";
       rr:datatype  cdt:electricCurrent
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#TorqueProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class plt:TorqueProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/torque/average
"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "windTurbine torque average" ]
];

rr:predicateObjectMap [
        rr:predicate seas:evaluation ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/torque/average
/evaluation/{windturbine.timestamp}"
        ]
] .

<#TorqueEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
```

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```
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
     rr:class plt:TorqueEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/property/torque/average
/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.generator_torque";
       rr:datatype  cdt:energy
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
        rr:termType rr:IRI;
        rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].

<#StatorWindingTemperatureProperty> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:TemperatureProperty;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/stator/statorwinding/pr
operty/temperature/average"
];

rr:predicateObjectMap [
    rr:predicate rdfs:label ;
    rr:objectMap [ rr:constant "stator winding temperature average"
]
];

rr:predicateObjectMap [
```

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```
        rr:predicate seas:evaluation ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/stator/statorwinding/pr
operty/temperature/average/evaluation/{windturbine.timestamp}"
        ]
] .

<#StatorWindingTemperatureEvaluation> a rr:TriplesMap;
rml:logicalSource [
     rml:source "pilot1_windturbine_simplejson.json";
     rml:referenceFormulation ql:JSONPath;
     rml:iterator "$"
];

rr:subjectMap [
     rr:class seas:AverageEvaluation;
     rr:class seas:TemperatureEvaluation;
     rr:template
"http://engie.com/enershare/resource/windfarm/{windturbine.windfarm_
id}/windturbine/{windturbine.windturbine_id}/stator/statorwinding/pr
operty/temperature/average/evaluation/{windturbine.timestamp}"
];

rr:predicateObjectMap [
        rr:predicate seas:evaluatedSimpleValue ;
        rr:objectMap [
       rml:reference "windturbine.stator_winding_temperature";
       rr:datatype  cdt:temperature
    ]
];

rr:predicateObjectMap [
        rr:predicate seas:hasTemporalContext ;
        rr:objectMap [
         rr:termType rr:IRI;
         rr:template
"http://engie.com/enershare/resource/timestamp/{windturbine.timestam
p}"
        ]
].
```

Table 14: Output model (compliant with ENERSHARE's ontology) in Turtle

```
@prefix ns1: <https://w3id.org/seas/> .
@prefix ns2: <https://w3id.org/platoon/> .
@prefix ns3: <https://brickschema.org/schema/1.1/Brick#> .
@prefix ns4: <http://www.w3.org/2006/time#> .
```

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```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1> a ns2:Blade ;
    rdfs:label "Blade Axis_1" ;
    ns2:hasAveragePitchAngle
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average> ;
    ns1:subSystemOf
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator/statorwinding> a ns2:StatorWinding ;
    rdfs:label "StatorWinding" ;
    ns2:hasAverageTemperature
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average> ;
    ns1:subSystemOf
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average> a ns1:PitchAngleProperty ;
    rdfs:label "Pitch Angle average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average/evaluation/2019_08_24t00:00:00
z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average/evaluation/2019_08_24t00:00:00
z> a ns1:AverageEvaluation ;
    ns1:evaluatedSimpleValue "450
deg"^^<http://w3id.org/lindt/custom_datatypes#angle> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle> a ns2:Nacelle ;
    rdfs:label "Nacelle" ;
    ns2:hasAverageTemperature
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average> ;
    ns1:subSystemOf
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator> a ns2:Generator ;
    rdfs:label "Generator" ;
```

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```
    ns2:hasAverageActivePower
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average> ;
    ns2:hasAverageCurrent
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average> ;
    ns2:hasAverageTorque
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average> ;
    ns1:subSystemOf
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator> a ns2:Stator ;
    rdfs:label "Stator" ;
    ns1:subSystemOf
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average> a ns1:TemperatureProperty ;
    rdfs:label "nacelle temperature average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average/evaluation/2019_08_24t00:00:0
0z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average/evaluation/2019_08_24t00:00:0
0z> a ns1:AverageEvaluation,
        ns1:TemperatureEvaluation ;
    ns1:evaluatedSimpleValue "27.54
Cel"^^<http://w3id.org/lindt/custom_datatypes#temperature> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average> a ns1:ElectricPowerProperty ;
    rdfs:label "windTurbine active power average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average/evaluation/2019_08_24t00:00:00z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average/evaluation/2019_08_24t00:00:00z> a
ns1:AverageEvaluation,
        ns1:ElectricPowerEvaluation ;
    ns1:evaluatedSimpleValue "495.7
kW"^^<http://w3id.org/lindt/custom_datatypes#power> ;
```

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```
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average> a ns1:CurrentProperty ;
    rdfs:label "windTurbine current average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average/evaluation/2019_08_24t00:00:00z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average/evaluation/2019_08_24t00:00:00z> a
ns1:AverageEvaluation,
        ns1:CurrentEvaluation ;
    ns1:evaluatedSimpleValue "417.18
A"^^<http://w3id.org/lindt/custom_datatypes#electricCurrent> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average> a ns2:TorqueProperty ;
    rdfs:label "windTurbine torque average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average/evaluation/2019_08_24t00:00:00z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average/evaluation/2019_08_24t00:00:00z> a
ns2:TorqueEvaluation,
        ns1:AverageEvaluation ;
    ns1:evaluatedSimpleValue "3370.42
N.m"^^<http://w3id.org/lindt/custom_datatypes#energy> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average> a ns1:WindSpeedProperty ;
    rdfs:label "wind speed average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average/evaluation/2019_08_24t00:00:00z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average/evaluation/2019_08_24t00:00:00z> a
ns1:AverageEvaluation ;
    ns1:evaluatedSimpleValue "9.32
m/s"^^<http://w3id.org/lindt/custom_datatypes#speed> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.
```

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```
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average> a
ns1:TemperatureProperty ;
    rdfs:label "stator winding temperature average" ;
    ns1:evaluation
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average/evaluation/2019_
08_24t00:00:00z> .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average/evaluation/2019_
08_24t00:00:00z> a ns1:AverageEvaluation,
        ns1:TemperatureEvaluation ;
    ns1:evaluatedSimpleValue "27.54
Cel"^^<http://w3id.org/lindt/custom_datatypes#temperature> ;
    ns1:hasTemporalContext
<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
.

<http://engie.com/enershare/resource/windfarm/frbrt> a ns2:WindFarm
;
    rdfs:label "FRBRT" .

<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0> a ns2:OnshoreWindTurbine ;
    rdfs:label "91840" ;
    ns3:hasLocation
<http://engie.com/enershare/resource/windfarm/frbrt> ;
    ns2:hasAverageWindSpeed
<http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average> ;
    ns1:isMemberOf
<http://engie.com/enershare/resource/windfarm/frbrt> .

<http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z>
a ns4:Instant ;
    ns4:inXSDDateTime "2019-08-24T00:00:00+00:00"^^xsd:dateTime .
```

Table 15: Output model (compliant with ENERSHARE's ontology) in JSON-LD

```
{
  "@context": {
    "owl": "http://www.w3.org/2002/07/owl#",
    "rdf": "http://www.w3.org/1999/02/22-rdf-syntax-ns#",
    "rdfs": "http://www.w3.org/2000/01/rdf-schema#",
    "xsd": "http://www.w3.org/2001/XMLSchema#"
  },
  "@graph": [
    {
```

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```
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator/statorwinding",
      "@type": "https://w3id.org/platoon/StatorWinding",
      "https://w3id.org/platoon/hasAverageTemperature": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average"
      },
      "https://w3id.org/seas/subSystemOf": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator"
      },
      "rdfs:label": "StatorWinding"
    },
    {
      "@id": "http://engie.com/enershare/resource/windfarm/frbrt",
      "@type": "https://w3id.org/platoon/WindFarm",
      "rdfs:label": "FRBRT"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle",
      "@type": "https://w3id.org/platoon/Nacelle",
      "https://w3id.org/platoon/hasAverageTemperature": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average"
      },
      "https://w3id.org/seas/subSystemOf": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0"
      },
      "rdfs:label": "Nacelle"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average",
      "@type": "https://w3id.org/seas/PitchAngleProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average/evaluation/2019_08_24t00:00:00
z"
      },
      "rdfs:label": "Pitch Angle average"
    },
    {
```

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```
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average",
      "@type": "https://w3id.org/seas/CurrentProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average/evaluation/2019_08_24t00:00:00z"
      },
      "rdfs:label": "windTurbine current average"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1",
      "@type": "https://w3id.org/platoon/Blade",
      "https://w3id.org/platoon/hasAveragePitchAngle": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average"
      },
      "https://w3id.org/seas/subSystemOf": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0"
      },
      "rdfs:label": "Blade Axis_1"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average",
      "@type": "https://w3id.org/seas/TemperatureProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average/evaluation/2019_08_24t00:00:0
0z"
      },
      "rdfs:label": "nacelle temperature average"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average/evaluation/2019_08_24t00:00:00z",
      "@type": [
        "https://w3id.org/seas/AverageEvaluation",
        "https://w3id.org/seas/ElectricPowerEvaluation"
      ],
      "https://w3id.org/seas/evaluatedSimpleValue": {
        "@type": "http://w3id.org/lindt/custom_datatypes#power",
        "@value": "495.7 kW"
      },
```

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```
      "https://w3id.org/seas/hasTemporalContext": {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
      }
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average/evaluation/2019_
08_24t00:00:00z",
      "@type": [
        "https://w3id.org/seas/AverageEvaluation",
        "https://w3id.org/seas/TemperatureEvaluation"
      ],
      "https://w3id.org/seas/evaluatedSimpleValue": {
        "@type":
"http://w3id.org/lindt/custom_datatypes#temperature",
        "@value": "27.54 Cel"
      },
      "https://w3id.org/seas/hasTemporalContext": {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
      }
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average",
      "@type": "https://w3id.org/platoon/TorqueProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average/evaluation/2019_08_24t00:00:00z"
      },
      "rdfs:label": "windTurbine torque average"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/property/temperature/average/evaluation/2019_08_24t00:00:0
0z",
      "@type": [
        "https://w3id.org/seas/TemperatureEvaluation",
        "https://w3id.org/seas/AverageEvaluation"
      ],
      "https://w3id.org/seas/evaluatedSimpleValue": {
        "@type":
"http://w3id.org/lindt/custom_datatypes#temperature",
        "@value": "27.54 Cel"
      },
      "https://w3id.org/seas/hasTemporalContext": {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
```

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```
      }
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average",
      "@type": "https://w3id.org/seas/TemperatureProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/stator/statorwinding/property/temperature/average/evaluation/2019_
08_24t00:00:00z"
      },
      "rdfs:label": "stator winding temperature average"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average",
      "@type": "https://w3id.org/seas/ElectricPowerProperty",
      "https://w3id.org/seas/evaluation": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average/evaluation/2019_08_24t00:00:00z"
      },
      "rdfs:label": "windTurbine active power average"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0",
      "@type": "https://w3id.org/platoon/OnshoreWindTurbine",
      "https://brickschema.org/schema/1.1/Brick#hasLocation": {
        "@id": "http://engie.com/enershare/resource/windfarm/frbrt"
      },
      "https://w3id.org/platoon/hasAverageWindSpeed": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average"
      },
      "https://w3id.org/seas/isMemberOf": {
        "@id": "http://engie.com/enershare/resource/windfarm/frbrt"
      },
      "rdfs:label": "91840"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/blade/1/property/pitchangle/average/evaluation/2019_08_24t00:00:00
z",
      "@type": "https://w3id.org/seas/AverageEvaluation",
      "https://w3id.org/seas/evaluatedSimpleValue": {
        "@type": "http://w3id.org/lindt/custom_datatypes#angle",
```

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```
          "@value": "450 deg"
        },
        "https://w3id.org/seas/hasTemporalContext": {
          "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
        }
      },
      {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
,
        "@type": "http://www.w3.org/2006/time#Instant",
        "http://www.w3.org/2006/time#inXSDDateTime": {
          "@type": "xsd:dateTime",
          "@value": "2019-08-24T00:00:00+00:00"
        }
      },
      {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average/evaluation/2019_08_24t00:00:00z",
        "@type": "https://w3id.org/seas/AverageEvaluation",
        "https://w3id.org/seas/evaluatedSimpleValue": {
          "@type": "http://w3id.org/lindt/custom_datatypes#speed",
          "@value": "9.32 m/s"
        },
        "https://w3id.org/seas/hasTemporalContext": {
          "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
        }
      },
      {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average",
        "@type": "https://w3id.org/seas/WindSpeedProperty",
        "https://w3id.org/seas/evaluation": {
          "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/windspeed/average/evaluation/2019_08_24t00:00:00z"
        },
        "rdfs:label": "wind speed average"
      },
      {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average/evaluation/2019_08_24t00:00:00z",
        "@type": [
          "https://w3id.org/seas/AverageEvaluation",
          "https://w3id.org/seas/CurrentEvaluation"
        ],
        "https://w3id.org/seas/evaluatedSimpleValue": {
```

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```
        "@type":
"http://w3id.org/lindt/custom_datatypes#electricCurrent",
        "@value": "417.18 A"
      },
      "https://w3id.org/seas/hasTemporalContext": {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
      }
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator",
      "@type": "https://w3id.org/platoon/Generator",
      "https://w3id.org/platoon/hasAverageActivePower": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/activepower/average"
      },
      "https://w3id.org/platoon/hasAverageCurrent": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/current/average"
      },
      "https://w3id.org/platoon/hasAverageTorque": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average"
      },
      "https://w3id.org/seas/subSystemOf": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle"
      },
      "rdfs:label": "Generator"
    },
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/property/torque/average/evaluation/2019_08_24t00:00:00z",
      "@type": [
        "https://w3id.org/seas/AverageEvaluation",
        "https://w3id.org/platoon/TorqueEvaluation"
      ],
      "https://w3id.org/seas/evaluatedSimpleValue": {
        "@type": "http://w3id.org/lindt/custom_datatypes#energy",
        "@value": "3370.42 N.m"
      },
      "https://w3id.org/seas/hasTemporalContext": {
        "@id":
"http://engie.com/enershare/resource/timestamp/2019_08_24t00:00:00z"
      }
    },
```

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```
    {
      "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator/stator",
      "@type": "https://w3id.org/platoon/Stator",
      "https://w3id.org/seas/subSystemOf": {
        "@id":
"http://engie.com/enershare/resource/windfarm/frbrt/windturbine/9184
0/nacelle/generator"
      },
      "rdfs:label": "Stator"
    }
  ]
}
End process

Process finished with exit code 0
```

8.2 Data compliance example

Example to check the compliance of the generated model (Table 15) with ENERSHARE's ontology using the Shapes file in Table 16.

```
curl -X 'POST' \
'http://XXX.XX.XX.XX:XXXX/complianceService/validateFile?jsonld_file_url=https%3A%2F%
2Fgit.code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fmappings%2Fpilot1_windturbine_generated.jsonld&shacl_file_url=https%3
A%2F%2Fgit.code.tecnalia.com%2Fopen%2Fenershare%2F-
%2Fraw%2Fmain%2Fshacl%2Fpilot1_anomaly_detection_input.shacl.ttl' \
  -H 'accept: application/json' \
  -d ''
```

Table 16: Shapes file (in SHACL language) to check the compliance of the data model

```
@prefix sh:     <http://www.w3.org/ns/shacl#> .
@prefix rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:   <http://www.w3.org/2000/01/rdf-schema#> .
@prefix plt:    <https://w3id.org/platoon/> .
@prefix xsd:    <http://www.w3.org/2001/XMLSchema#> .
@prefix ontowind:
<http://www.semanticweb.org/ontologies/2011/9/Ontology1318785573683.
owl#> .
@prefix seas:   <https://w3id.org/seas/> .
@prefix brick: <https://brickschema.org/schema/1.1/Brick#> .
@prefix cdt: <http://w3id.org/lindt/custom_datatypes#> .
@prefix time:   <http://www.w3.org/2006/time#> .
@prefix ener: <https://enershare.eu/shapes/p1#> .
```

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```
ener:WindFarmShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:targetClass plt:WindFarm, ontowind:WindPowerPlant .

ener:WindFarmCountShape
    a sh:NodeShape ;
    sh:targetNode plt:WindFarm ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .

ener:WindTurbineShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:isMemberOf ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:property [
        sh:path brick:hasLocation ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:property [
        sh:path plt:hasAverageWindSpeed ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:OnshoreWindTurbine .

ener:BladeShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
```

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```
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:subSystemOf ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:property [
        sh:path plt:hasAveragePitchAngle ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:Blade .

ener:NacelleShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:subSystemOf ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:property [
        sh:path plt:hasAverageTemperature ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:Nacelle .

ener:GeneratorShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:subSystemOf ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:property [
```

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```
            sh:path plt:hasAverageActivePower ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
            sh:nodeKind sh:IRI ;
        ] ;
        sh:property [
            sh:path plt:hasAverageCurrent ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
            sh:nodeKind sh:IRI ;
        ] ;
        sh:property [
            sh:path plt:hasAverageTorque ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
            sh:nodeKind sh:IRI ;
        ] ;
        sh:targetClass plt:Generator .

ener:StatorShape
        a sh:NodeShape ;
        sh:property [
            sh:path rdfs:label ;
            sh:minCount 0 ;
            sh:maxCount 1 ;
            sh:datatype xsd:string ;
        ] ;
        sh:property [
            sh:path seas:subSystemOf ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
            sh:nodeKind sh:IRI ;
        ] ;
        sh:targetClass plt:Stator .

ener:StatorWindingShape
        a sh:NodeShape ;
        sh:property [
            sh:path rdfs:label ;
            sh:minCount 0 ;
            sh:maxCount 1 ;
            sh:datatype xsd:string ;
        ] ;
        sh:property [
            sh:path seas:subSystemOf ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
            sh:nodeKind sh:IRI ;
        ] ;
        sh:property [
            sh:path plt:hasAverageTemperature ;
            sh:minCount 1 ;
            sh:maxCount 1 ;
```

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```
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:StatorWinding .

ener:WindSpeedPropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:WindSpeedProperty .

ener:WindSpeedEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:speed ;
    ] ;
    sh:property [
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:WindSpeedEvaluation .

ener:WindSpeedPropertyCountShape
    a sh:NodeShape ;
    sh:targetNode seas:WindSpeedProperty ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .

ener:TemporalContextShape
    a sh:NodeShape ;
    sh:property [
        sh:path time:inXSDDateTime ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype xsd:dateTime ;
    ] ;
    sh:targetClass time:Instant .
```

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```
ener:ElectricPowerPropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:ElectricPowerProperty .

ener:ElectricPowerEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:power ;
    ] ;
    sh:property [
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:ElectricPowerEvaluation .

ener:ElectricPowerPropertyCountShape
    a sh:NodeShape ;
    sh:targetNode seas:ElectricPowerProperty ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .

ener:CurrentPropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
```

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```
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:CurrentProperty .

ener:CurrentEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:electricCurrent ;
    ] ;
    sh:property [
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:CurrentEvaluation .

ener:CurrentPropertyCountShape
    a sh:NodeShape ;
    sh:targetNode seas:CurrentProperty ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .

ener:TorquePropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:TorqueProperty .

ener:TorqueEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:energy ;
    ] ;
    sh:property [
```

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```
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:TorqueEvaluation .

ener:TorquePropertyCountShape
    a sh:NodeShape ;
    sh:targetNode plt:TorqueProperty ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .

ener:PitchAnglePropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:PitchAngleProperty .

ener:PitchAngleEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:angle ;
    ] ;
    sh:property [
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass plt:PitchAngleEvaluation .

ener:PitchAnglePropertyCountShape
    a sh:NodeShape ;
    sh:targetNode seas:PitchAngleProperty ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
```

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```
    ] .

ener:TemperaturePropertyShape
    a sh:NodeShape ;
    sh:property [
        sh:path rdfs:label ;
        sh:minCount 0 ;
        sh:maxCount 1 ;
        sh:datatype xsd:string ;
    ] ;
    sh:property [
        sh:path seas:evaluation ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:TemperatureProperty .

ener:TemperatureEvaluationShape
    a sh:NodeShape ;
    sh:property [
        sh:path seas:evaluatedSimpleValue ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:datatype cdt:temperature ;
    ] ;
    sh:property [
        sh:path seas:hasTemporalContext ;
        sh:minCount 1 ;
        sh:maxCount 1 ;
        sh:nodeKind sh:IRI ;
    ] ;
    sh:targetClass seas:TemperatureEvaluation .

ener:TemperatureEvaluationPropertyShape
    a sh:NodeShape ;
    sh:targetNode seas:TemperatureEvaluation ;
    sh:property [
        sh:path [ sh:inversePath rdf:type ] ;
        sh:minCount 1 ;
    ] .
```

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