Orchestrating an interoperable sovereign federated Multi-vector Energy data space built on open standards and ready for GAia-X

D4.1 Data ingestion, Common Information Model and semantic interoperability

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List of Acronyms

Abbreviation / acronym	Description
AIME	Agile Interaction model-based Methodology for Energy dataspaces.
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
BUC	Business Use Case
CSDM	Common Semantic Data Model
CQ	Competency Questions
DLSM	Device Language Message Specification
Dx.y	Deliverable number y belonging to WP x
EC	European Commission
GoT	Glossary of Terms
HTTPS	Hypertext Transfer Protocol Secure
IEC	International Electrotechnical Commission
EU	European Union
IM	Interaction Model
JSON-LD	JavaScript Object Notation for Linked Data
MVP	Minimum Viable Product
MQTT	Message Queuing Telemetry Transport
RAM	Reference Architecture Model
REST-APIs	Representational State Transfer Application Programming Interface
UC	Use Case
WP	Work Package

Executive Summary

This deliverable – entitled "D4.1 - Data ingestion, Common Information Model and semantic interoperability" – incorporates the results produced by two tasks “T4.3 - Common Information Model and semantic interoperability” and “T4.2 - Data ingestion and adapters”. Its purpose is to document the implementation for OMEGA-X federated infrastructure from the perspective of these two tasks.

- the Common Semantic Data Model (CSDM) ruling the data exchanges in the OMEGA-X Data Space and formerly called the Common Information Model,
- the Framework for data ingestion and data adapters, to be used for and tailored to the demonstrations on pilot sites.

Common Semantic Data Model (CSDM)

Prior to producing CSDM, a review of key data models and ontologies and an analysis of main interactions of OMEGA-X uses cases have been conducted. An agile development method for ontologies have been specified.

- Eight data models/ontologies have been reviewed: PLATOON/SEDMOON, SEAS, BD4OPEM, Interconnect, SARGON, IEC CIM, DLSM-COSEM, and IEC 61850. Gap analysis has led to the conclusion that none of these models/ontologies fully cover the needs of OMEGA-X use cases.
- Joint workshops have been held during summer with ontologists and use case leaders. They co-designed Interaction Models, that describe the main interactions that should be supported by CSDM.
- AIME (Agile Interaction model-based Methodology for Energy data spaces) is a tailored methodology to develop interaction models and harmonize them into a common CSDM.

This version of the Common Semantic Data Model (CSDM) is composed of two modules: an upper-level ontology describing time series and events and a domain ontology for data sets exchanged inside an Energy Dataspace.

Framework for data ingestion and data adapters

Architecture principles and building blocks for a framework for data ingestion and data adapters have been defined from the analysis of key architectures (e.g., IDSA, Gaia-X, ISO) and the synthesis of requirements from the use case and demonstration leaders.

Some preliminary technical orientations have been taken in support to data interactions inside an Energy Dataspace:

- JSON-LD (JavaScript Object Notation for Linked Data) as the preferred data format solution.
- REST-APIs (REpresentational State Transfer Application Programming Interface) as the preferred data communication API and protocol.

1 Introduction

1.1 Purpose of the Document

This deliverable incorporates inputs from two tasks: T4.2 “Data ingestion and adapters” and T4.3 “Common Information Model and semantic interoperability”.

Deliverable D4.1 documents the implementation for OMEGA-X federated infrastructure of the needed data adapters, tailored to the demo case requirements, and the agreement and implementation of a Common Information Model ruling the data exchange in the Data Space.

Key models/ontologies are reviewed (PLATOON/SEDMOON, BD4OPEM, Interconnect using ETSI SAREF, SARGON, SEAS, IEC CIM, and DLSM-COSEM, IEC 61850). Ontologies such as Interconnect and SEDMOON are mapped to the OMEGA-X Common Semantic Data Model (CSDM).

OMEGA-X Common Semantic Data Model (CSDM) is detailed: methodology, interaction models, glossary of terms and competency questions designed through four use case family workshops (flexibility, renewable, local energy community, and electromobility).

1.2 Relation to other Work in Project

Deliverable OMEGA-X_D4.1 documents the implementation for OMEGA-X federated infrastructure of the needed data adapters, tailored to the demo case requirements, and the agreement and implementation of a Common Information Model ruling the data exchange in the Data Space.

T4.2 “Data ingestion and adapters”. Leader: ATOS IT. Contributors: EDF, ENGIE, EyPESA, REVOLT, PUPIN, EW. Task 4.2 bridges the different data sources with OMEGA-X distributed federated platforms, implementing purpose build stream processing components (data adapters) which achieve data preparation, pre-processing and filtering. This task will answer challenges such as online filtering and compression (without compromising the ability to reason about the underlying activity of interest), information extraction, cleaning and noise elimination. As incoming data are typically of different modalities and in unstructured form, this task will extract the necessary information and represent it in a form that is suitable for analysis and reasoning. Moreover, the extracted information is subject to data integration, to result in a common representation following the results of T4.3 “Common Information Model and semantic interoperability” and allow linking data across sources, eventually achieving data fusion. For structured datasets (based on information data models like IEC CIM, IEC 61850, IEC COSEM), some tools will be proposed to validate them.

T4.3 “Common Information Model and semantic interoperability”. Leader: ENGIE. Contributors: ATOS SP, AWG, Tecnalia, EDF, ELIA, 50Hz, ICOM, OASC, REVOLT, PUPIN, GIREVE.

Task 4.2 develops a first version of the Common Semantic Data Model, based on a Bottom-Up Business Driven approach from the Use Cases considered in pilots, aiming at laying the foundations of interoperability for the Energy Data Space. A first step considers existing data models, standards and ontologies and aligns them with the Use Cases defined in the IEC 62559-2 standard. PLATOON and BD4OPEM projects, the Model Implementation Conformance Statement (MICS) of the IEC 61850 data model for Solar operated by EDF Renewable, INTERCONNECT, EU-SysFlex and TDX-ASSIST to mention a few, have produced a solid basis of Semantic Data models for their respective Use Cases, so they will be analysed in detail.

This wide analysis fosters transversability (doing feedback/gap analysis of previous models for semantic representation of specific use cases). To validate interoperability and test real application and use, the sharing of OMEGA-X Common Semantic Data Model with other consortia for collaborative Ontology Design/Modelling, Alignment, Enrichment & Population principles is imperative. Dedicated Workshops for Cross projects or even cross sectors (other potentially linked Data Spaces) will be set up to foster collaboration and convergence.

One of the key outcomes of this task is to contribute to the core reference model concept as described by the European Smart Grids Task Force Expert Group 1 (standards and interoperability) report “Towards Interoperability within the EU for Electricity and Gas Data Access & Exchange”. Related to this, this task will provide IEC (CIM and 61850) data models formatted as Semantic Data core modules (ontologies) linked to Use Case families. As this Knowledge representation is complex, priority on IEC Alignment/Semantic Extension will be given to the (1) Renewables dimension and (2) Electromobility. The Common Semantic Data Model will not be static and will be updated during the life of the project to take into account changes, concepts, and extensions considered.

1.3 Structure of Document

This document is divided into the following main sections:

- **Chapter 1** presents the purpose of this report and its structure as well as its relation to other project activities.
- **Chapter 2** presents relevant work on existing ontologies and data models.
- **Chapter 3** presents the selected Use Cases from the different UC families (flexibility, renewable, local energy community, electromobility) that have been used to build the first OMEGA-X Common Semantic Data Model (CSDM).
- **Chapter 4** describes AIME, the ontology development methodology of the OMEGA-X Common Semantic Data Model (CSDM).
- **Chapter 5** describes the CSDM that is associated with OMEGA-X MVP.
- **Chapter 6** describes the CSDM framework on data ingestion, adapters and alignment for data spaces.
- **Chapter 7** summarizes the main points of this report, presents the conclusions of the work and the next steps.
- **Annex A** presents the ontology templates (SARGON, Interconnect, Platoon, BD4OPEM, SEAS, DLMS-COSEM, IEC 61850, IEC CIM).
- **Annex B** provides the Data Value Ontology code.
- **Annex C** presents the Energy Data Set Ontology code.
- **Annex D** presents the Interaction Model sequence Diagrams.

1.4 Glossary Adopted in this Document

- **Competency Question (CQs)**. The CQs are questions written in formalized natural language. CQs permit to understand the goal of the ontology (ontology requirement in the ontology life cycle) and what questions the use case pilots want the ontology to answer once it is implemented and in production.

2 Existing Ontologies and Data Models relevant for OMEGA-X

Key models/ontologies are reviewed (PLATOON/SEDMOON, BD4OPEM, Interconnect using ETSI SAREF, SARGON, IEC CIM, and DLSM-COSEM, IEC 61850, and SEAS).

2.1 Platoon/SEDMOON Ontologies in JSON-LD

PLATOON (Digital PLAtform and analytic TOOls for eNergy) is an EU-funded H2020 project (Grant Agreement Number 872592) under the call DT-ICT-11-2019 Big data solutions for energy formed of a consortium of 20 partners from 9 European countries. The project started on 01/01/2020 and finished on 31/12/2022 [1] [2].

PLATOON has developed a federated data platform to allow the exchange of data and services amongst different stakeholders of the energy value chain ensuring data security, sovereignty and privacy based on International Data Spaces (IDS) standard. In addition, PLATOON has developed a suite of innovative data analytics tools that exploits the value from the exchanged data to foster a more efficient operation of the energy system. The developed solution was validated in 8 large scale pilots that cover the whole energy value chain from Renewable energy generation, distribution/transport to end use of energy in smart buildings.

Semantic interoperability is one of the key aspects to allow the multiparty sovereign exchange of data and services. In this sense, PLATOON developed a methodology to define common semantic data models following a bottom-up approach starting from the use cases. The methodology is public and is explained in detail in the public deliverable Methodology is explained in public deliverable “PLATOON D2.7- D2.3-V2-Common data models for energy” [1] [2].

As a result of PLATOON project, SEDMOON (Semantic Data Models Of Energy) open-source ontology was generated following the abovementioned methodology. SEDMOON ontology is a combination of other existing standard ontologies (SAREF, SEAS, OntoWind, etc.) adapted to the requirements of the different pilots and use cases inside the project and extended to include new concepts and properties for the use cases that were not covered in existing standard ontologies. SEDMOON is an open-source ontology under Apache-2.0 licence and is publicly available in [1]. In the context of ontology publication, OWL 2 DL language was used to describe each module, and the TURTLE serialization which is human and machine readable.

SEDMOON has been validated in 8 large scale pilots including European leading industrial partners covering the whole energy value chain from energy renewable energy generation (wind and solar), smart grid management and efficiency energy in smart buildings.

SEDMON ontology is formed of multiple ontological modules categories under 5 main groups:

- Group 1 focused on smart buildings, including its zones, type of building (retail, logistic centre, data centre, etc.) and energy related properties such as energy load, gas/electric consumption, etc.
- Group 2 includes the HVAC equipment, its subsystems (heating, cooling and ventilation system, etc.).
- Group 3 contains the smart/microgrid, electricity generation, balance, storages, and its properties.

- Group 4 details the different components of renewable energy generation plants for wind and Photovoltaic energy.
- Group 5 includes common concepts amongst different domain from the energy sector such as sensors and meters, weather, schedule, failures, etc.

Figure 1 shows the mapping between the abovementioned ontology groups and the different pilots and corresponding use cases. Pilot #1a deals with the optimisation of operation and maintenance of wind farms and is main related to group 4 regarding the renewable energy systems. Pilots #2a, #2b and #4a focus on the efficient management of smart grids and microgrids and are linked to group 3. Besides, pilots #3a, #3b and #3c focus on energy efficiency in smart buildings related to groups 1 and 2. Finally, all pilots share common concepts from group 5 regarding weather, measurement, forecasting, damages, failures, etc.

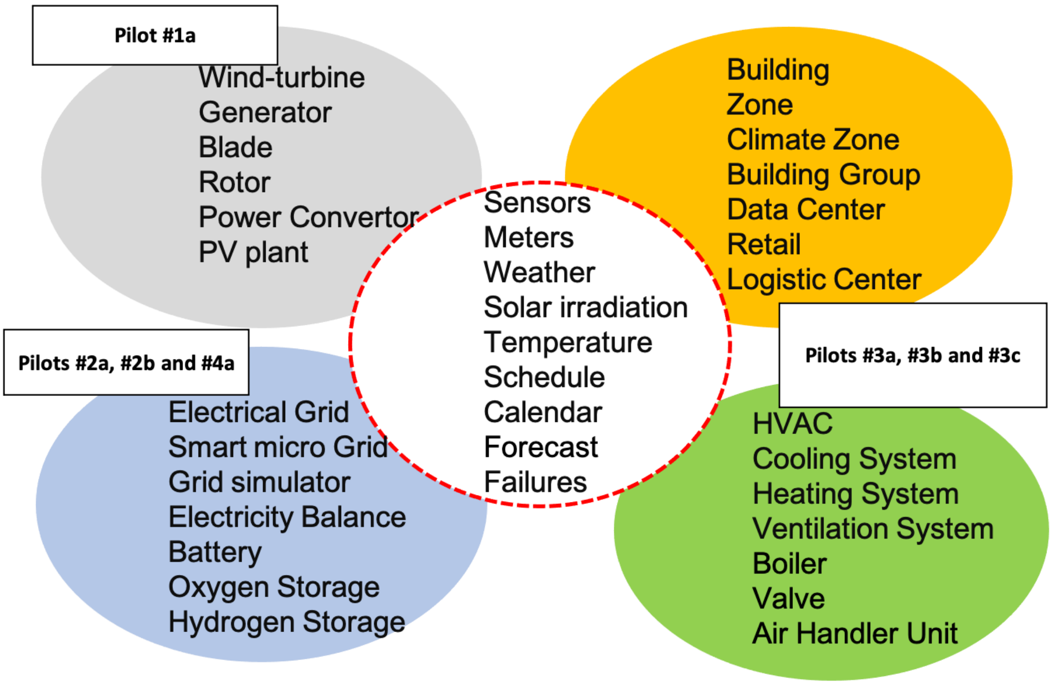


Figure 1 SEDMOON – Overview of the main groups [1] [2]

SEDMON defines in detail several ontological modules for each of the groups listed above. For instance, Figure 2 represents an extract of Building and its occupancy and comfort properties:

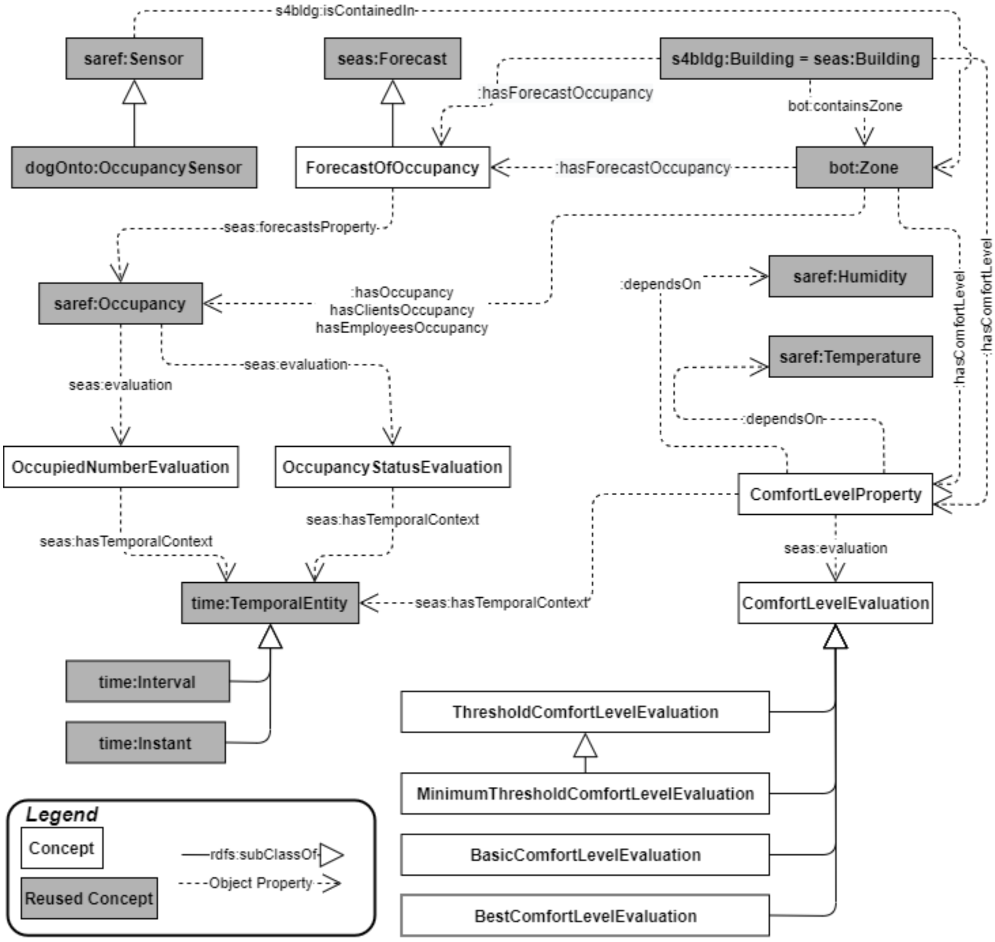


Figure 2 SEDMOON – Building properties [1] [2]

2.2 BD4OPEM Ontologies

The BD4OPEM ontology (Figure 3) is formed by amalgamating various publicly available ontologies, namely IEC CIM, SAREF, SAREF4ENER and OCPP. It has been tailored to meet the specific demands of the diverse pilot projects and use cases within the project, whose diverse origins call for a unique ontology that suits them all and serves them accordingly. As a glimpse of this diversity, the main characteristics of the project (regarding the data model management) can be listed:

- It will encompass services that require an extensive array of data types, such as location information, real-time and historical energy metering data, electricity pricing data, weather data, topographical data, and more. This diversity in data types needs the utilization of various standards to accommodate these different requirements.
- It consists of five distinct pilot projects, each with its own system management, data transfer channels, and potentially employing different languages.

This ontology includes an extensive range of data types and sensors, each associated with a substantial number of measurements. These measurements exhibit distinct interconnections, and in certain instances, certain attributes are shared among multiple measurements.

Due to the limitations of standardized ontologies in addressing the need to reference all the elements that must be modeled, the project has incorporated non-standard ontologies to fulfill these specific requirements. Two such non-standard ontologies employed for this purpose are PQOnt and SmartHomeWeather.

The tool used to design the ontology is Protégé. Protégé is an open-source software designed to assist users in creating ontologies or opening ontologies stored in formats such as OWL, TTL, or RDF. Notably, Protégé has the capability to read OWL and TTL files, which means it can easily access all SAREF TTL ontology files found on the ETSI webpage, along with other ontologies published on the TNO Ontology and Vocabulary Server.

A couple of images have been added to illustrate the BD4OPEM ontology. It is worth noting that no detailed information can be provided due to the confidentiality policies inherit to BD4OPEM project.

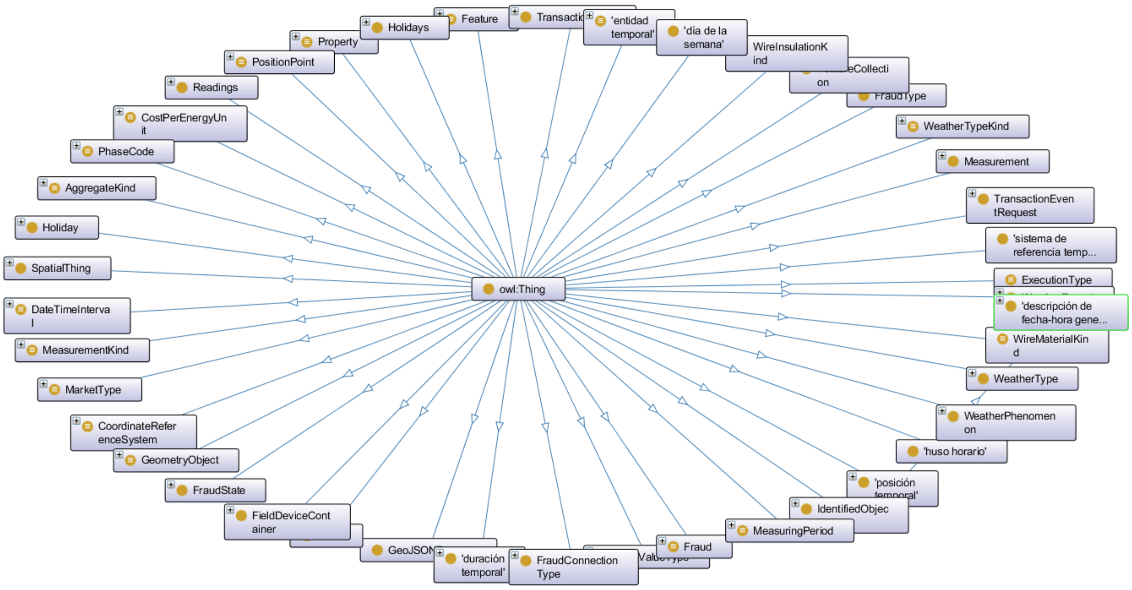


Figure 3 BD4OPEM - Full Ontology

As an example, Class FieldDevice is one of the classes developed in the ontology and it is based on saref:Device, fiware:Device, fiware:DeviceModel and cim:EndDevice. The child classes are depicted in Figure 4.

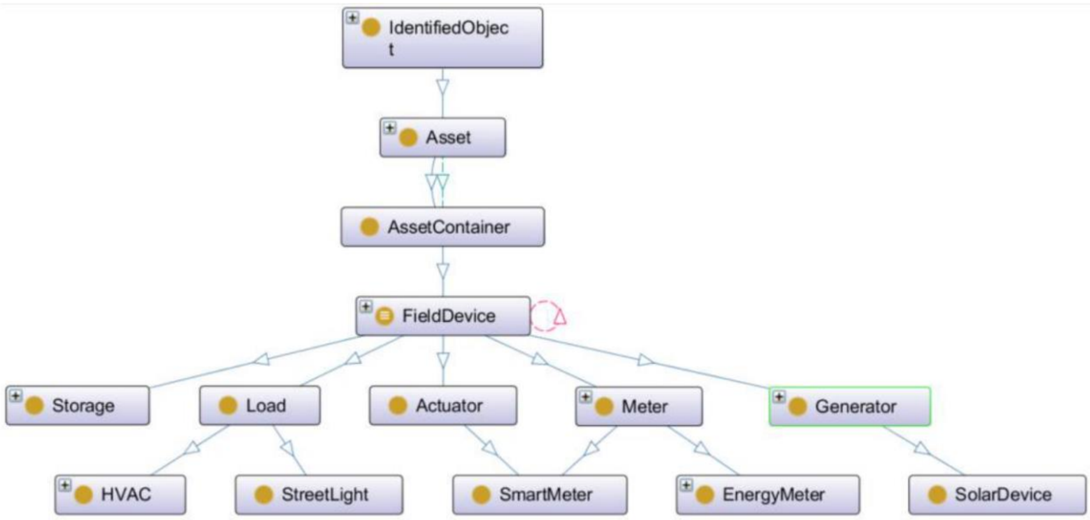


Figure 4 BD4OPEM - Child classes coming from FieldDevice class

The BD4OPEM data model is constructed by integrating various standards, which involves blending classes, attributes, and relationships from these standards. Consequently, a BD4OPEM class may exhibit additional attributes or lack some attributes when compared to the standard class it is derived from. Furthermore, certain standards referenced may offer different approaches to modeling the same class or attribute, and in such cases, only one approach is adopted.

Based on that, any project that could be oriented to the management and semantic harmonization for data related with the energy field could map this ontology to adapt to the specific needs that could have.

The drawback here is that due to the confidentiality policies inherit to BD4OPEM project, the ontology is not publicly available, so for any usage (or just to consult to evaluate if it could be used) some specific agreements should be established with the BD4OPEM consortium and its representatives.

The language used for BD4OPEM ontology development is W3C OWL. Due to the confidentiality policies inherit to BD4OPEM project, the ontology details cannot be shared outside the project scope. So, taking this into account, the ontology has not been registered in any catalog and it is not available online.

There is not any community maintaining the ontology so far; as of today, it is being maintained by the project partners inside the scope of the project and, as BD4OPEM project will end in November 2023, there is an ongoing conversation between some of the partners in the consortium (namely UPC, ICOM and ATOS) to explore the potential commercialization and continue with the development of the marketplace. Even though, there is not a sustainability plan for the BD4OPEM ontology at the time of preparation of this report.

2.3 Interconnect Ontologies

InterConnect (Interoperable Solutions Connecting Smart Homes, Buildings and Grids) ontologies [Interconnect_D2.3] [3] (Figure 5) are designed for the H2020 European project made of more than 50 partners driven by seven pilots to achieve effective digital market for ensuring energy-efficiency at reduced costs that is beneficial to end-users. InterConnect ontologies extends ETSI SmartM2M SAREF, is divided in several modules to facilitate their development and increase usability: 1) data point and time series, 2) forecast, 3) incentive table, 4) power limit, 5) user preferences, 6) flexibility, 7) units of Measures, 8) topology, and 9) devices and sensors.

Interconnect ontologies extend SAREF to address better energy needs such as flexibility.

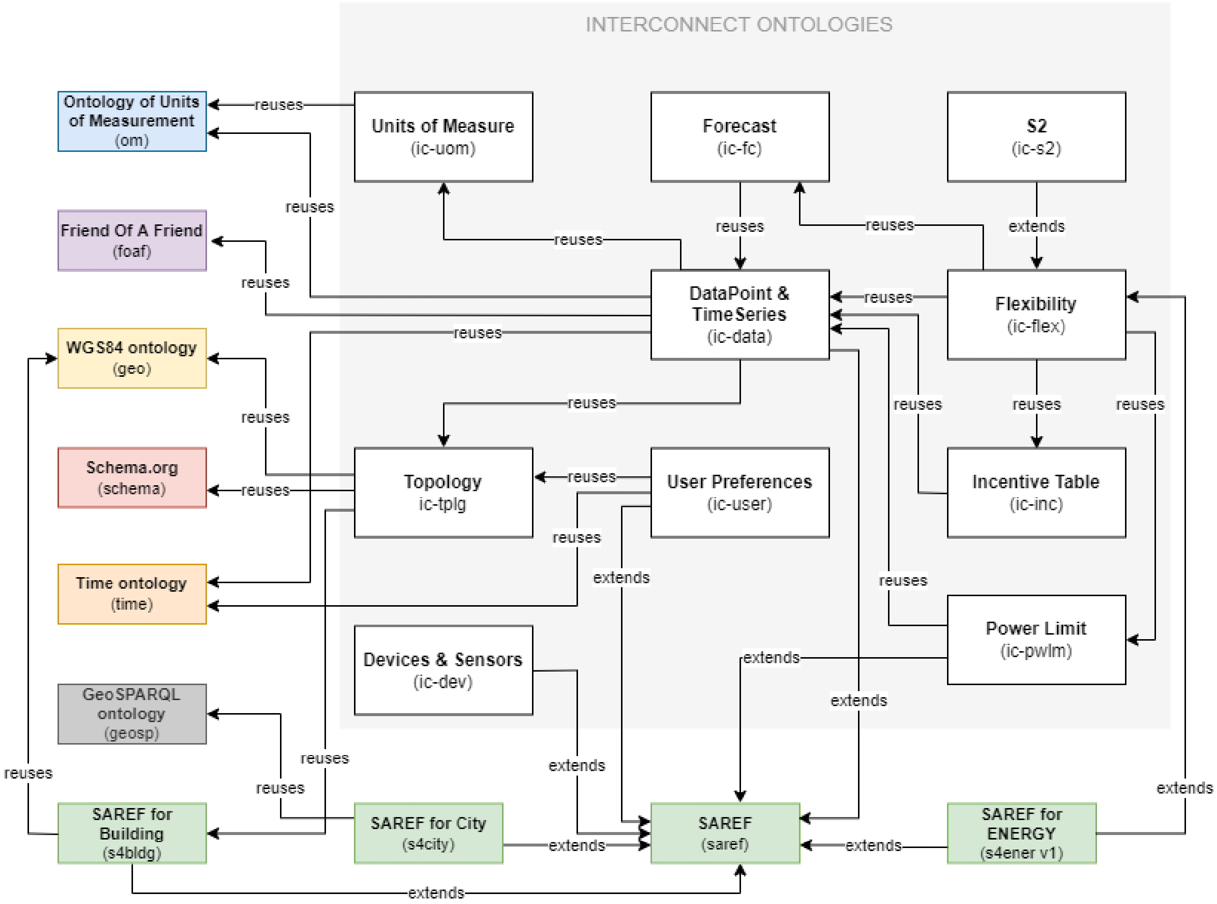


Figure 5 Interconnect ontology

2.4 SARGON (SmArt eneRGy dOmain oNtology)

SARGON [4] is an ontology developed in N5GEH project, a German funding research project which looked into the usage of fifth generation (5G) mobile standard for applications in smart energy technology, with special reference to building energy technology. It aims to add semantic description to the smart assets in building automation and smart grid and the relationships between them. SARGON consists of an extensible dictionary of terms and concepts in and around building and smart grid, a set of relationships for linking and composing concepts together, and a flexible data model permitting seamless integration of SARGON with existing tools and databases. It basically covers devices and custom features, assets and subsystems found across the building stock in a consistent matter. SARGON ontology reuses SAREF ontology classes (version 2.1.2), and took into consideration IEC CIM, IEC 61850 data models.

2.5 IEC CIM

IEC Common Information Model (CIM) (Figure 6) is one of the core standards of the smart grid. It supports European Regulation for electricity networks since 2009 (see CGMES, ESMP profiles developed by ENTSO-E). It is used in many utilities across the world.

It can be used as a canonical data model to exchange information between Applications of a Utility (IEC 61968-1 Interface Reference Model). It can be used to exchange information between utilities.

IEC CIM supports European regulation associated to Implementing act on customer data access through EUMED Market profile (IEC 62325-451-10), and EUMED Metering profile (IEC 61968-9 Ed 3.0 – to be published end of 2023)

IEC CIM is relevant for the following energy domain Energy / Electricity (Renewable, Local energy with IEC 62746, Flexibility – on-going developments, and Power System and related applications).

IEC CIM series are:

- IEC 61970: Network building and associated calculations (Power flow, load flow, short circuit calculations, …)
- IEC 61968 for utility inter-application communication (Planning, Operation, Metering, Customer Management, Asset Management, Operational Planning, …)
- IEC 62325 series or Market related use cases
- IEC 62746 for Systems interface between customer energy management system and the power management system

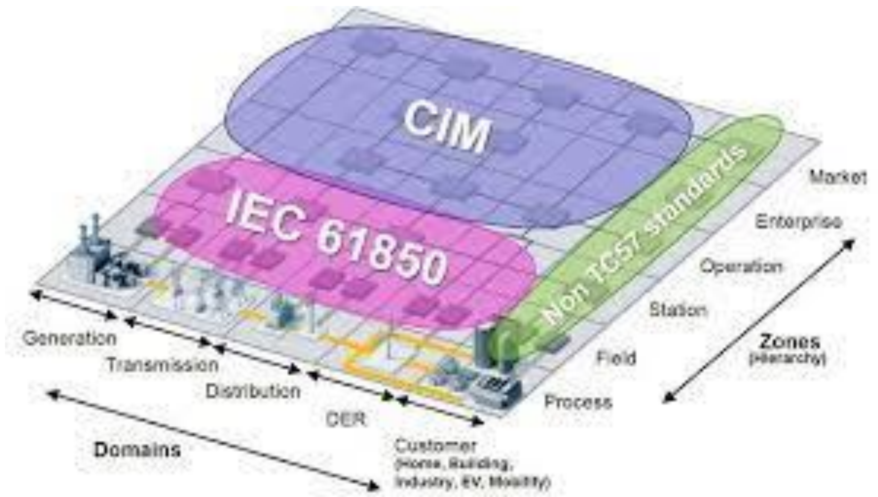


Figure 6 IEC CIM

2.6 IEC 62056 (DLMS-COSEM)

DLMS/COSEM is integrated in over 300 million smart meters worldwide and OBIS parts of the specifications in over 700 million devices, with a continued deployment of over 40 million devices per year.

COSEM is internationally recognized for Advanced Metering Infrastructures (AMI) and other Smart Metering systems. It evolved over time to include various interface classes to support new usages and country requirements. COSEM is used in metering devices deployed throughout Europe, Africa, Asia and North America.

COSEM is in line with Functional reference Architecture for communication in smart metering system developed under EU mandate M/441.

DLMS COSEM covers the following domains: Energy metering and load control, Renewables, Local energy production/management, Electromobility, and Flexibility/Demand-Response.

COSEM defines 104 interface classes to describe:

- Energy-metering-related data, including registers, tariff calendar, peak period, supply control, load management, voltage/current/power measurements, load profile, … It covers metering of several energy carriers: electricity, gas, heat, water.
- Management of the communication interfaces (such as PLC, cellular, radio mesh, …).

Years after years, the 2nd part (communication interfaces) has been growing and now represents ~60% of the defined interface classes.

The main use-cases are smart metering: recording of energy consumption/generation in registers, providing measurements over time intervals, supply control and other switches, apply tariffs etc. It also includes sub-metering and pre-payment metering.

During the last years, the use-cases have been extended to support smart grid, e-mobility.

Relevant use-cases are Meter registration, Remote tariff programming, Meter reading on demand, Meter reading for billing, Meter disconnection and reconnection (supply control), Meter clock synchronization, Quality of supply reporting, Load management by relay, Firmware update, Meter supervision, Consumer Information Push (CIP) using PUSH operation, Communication supervision, Consumer information (via local port or meter display), and Function opt-in/opt-out control.

2.7 IEC 61850

IEC 61850 (Communication networks and systems for power utility automation) is an international standard defining communication protocols for intelligent electronic devices at electrical substations. It is a part of the International Electrotechnical Commission's (IEC) Technical Committee 57 reference architecture for electric power systems. The abstract data models defined in IEC 61850 can be mapped to several protocols. Current mappings in the standard are to Manufacturing Message Specification (MMS), GOOSE (Generic Object-Oriented System Event), SV (Sampled Values) or SMV (Sampled Measure Values), and soon to web services. In the previous version of the standard, GOOSE stood for "Generic Object-Oriented Substation Event, but this old definition is still very common in IEC 61850 documentation. These protocols can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying.

IEC 61850 is designed to answer such questions:

- How to design a substation automation system?
- How to transmit substation data to a SCADA control centre?
- How to control and monitor a substation automation system form a control centre and Scada system?
- What are the protocols used in a substation automation system?
- How to manage Voltage, active Power Reactive Power in a Substation?
- How to model protections in a substation?
- How to model distribution automation functions?

IEC 61850 covers the following domains: Energy/Electricity (Substation Automation, DER Data model, Hydro power plant data model, Wind plant data model, Product data model : HV switchgear and control gear, Product data model : Digital interface for instrument transformers, Feeder Automation, Inverter-based DER, EV, Electric storage systems, Power Quality, Scheduling, Communication to control centre, Network Engineering, and WAN communications).

IEC 61850 covers the following use cases: Fault detection, Fault isolation, Service restoration, Voltage regulation, Volt/var control, Protection Coordination, Load Forecast and Modelling, and DER Integration to the Grid.

2.8 SEAS

SEAS, the Smart Energy Aware Systems ontology [5] (Figure 7) was developed in the ITEA 12004 SEAS Project by Ecole des Mines de Saint Etienne. The SEAS Electric Power System Vocabulary defines electric power systems that consume, produce, or store electricity, electrical connections between electric power systems, where electricity is exchanged, and electrical connection Points of electric power systems, through which electricity flows in/out the power systems. It consists of three main modules, Feature of interest, Evaluation to describe the evaluations and its properties, and the System which describes virtually isolated systems that share connections with other systems. Additional modules are conceived such as Area ontology to describe zones, Battery ontology, Electric power system ontology, Electric Vehicle ontology etc. SEAS has been reused in PLATOON project to develop SEDMOON ontology.

Figure 7 SEAS main ontology modules

2.9 Ontology and Data Models Analysis

Ontologies such as Interconnect and SEDMOON are mapped to the OMEGA-X Common Semantic Data Model (CSDM).

From each ontology/data model template filled in, we filled in this Table 1

Table 1 Comparing ontologies and data models for each family use case (flexibility, renewable, local energy community, electromobility)

Use Case Family /Ontology or Model	PLATOON	BD4OPEM	SARGON	Interconnect	IEC CIM	DLMS-COSEM	SEAS	IEC 61850
Flexibility	YES End use of energy – energy efficiency for smart buildings (concepts that apply to LEC and Flexibility UCF).	Yes	No	Yes	Flexibility: on-going developments	Yes (Demand - Response)	Yes End use of energy – energy efficiency for smart building (concepts that apply to Flexibility UCF).	No
Renewable	Yes Renewable (solar and wind)	Yes	Yes	No	Yes	Yes	Yes Renewable (solar and wind)	Yes (Hydro power plant data model, Wind plant data model)

Use Case Family /Ontology or Model	PLATOON	BD4OPEM	SARGON	Interconnect	IEC CIM	DLMS-COSEM	SEAS	IEC 61850
Local Energy Community	No	Yes	Yes	No	Yes Local energy: to come with IEC 62746	Yes Production/ management	Yes End use of energy – energy efficiency for smart building (concepts that apply to LEC UCF).	No
Electromobility	Yes Smart Grids (concepts regarding TSO/DSO that apply to Electromobility UCF)	Yes	No	No	No	Yes	Yes Smart Grids (concepts regarding TSO/DSO that apply to Electromobility UCF)	Yes (EV)

3 Selected OMEGA-X Use Cases

OMEGA-X project has defined 11 business use cases categorised in 4 main families according to the specific domain: Flexibility, Renewables, Local Energy Communities and Electro-Mobility. Similarly, for each of the business use cases different system use cases have been defined. In each of the system use cases different interactions between different actors are modelled including the exchanged information between these actors. These interaction models have been used to define the common semantic data models.

This section aims to provide a brief summary of each of the use case families and provides a brief description of some of the interaction models that have been defined.

For more information, deliverable OMEGA-X_D3.1 [6] describes in detail different use cases following the IEC 62559-2 standard [7] [8].

3.1 Renewables

The Renewable Family is split into three business cases (Figure 8): 1) PV O&M Optimization (BUC Ren 1.0), 2) Operating PV Smart Grid Integration (BUC Ren 2.0), and 3) Planning PV Smart Grid Integration (BUC Ren 3.0). Similarly, 6 System Use Cases (SUCs) have been defined which define the scenarios and information exchange for the different services that will be developed.

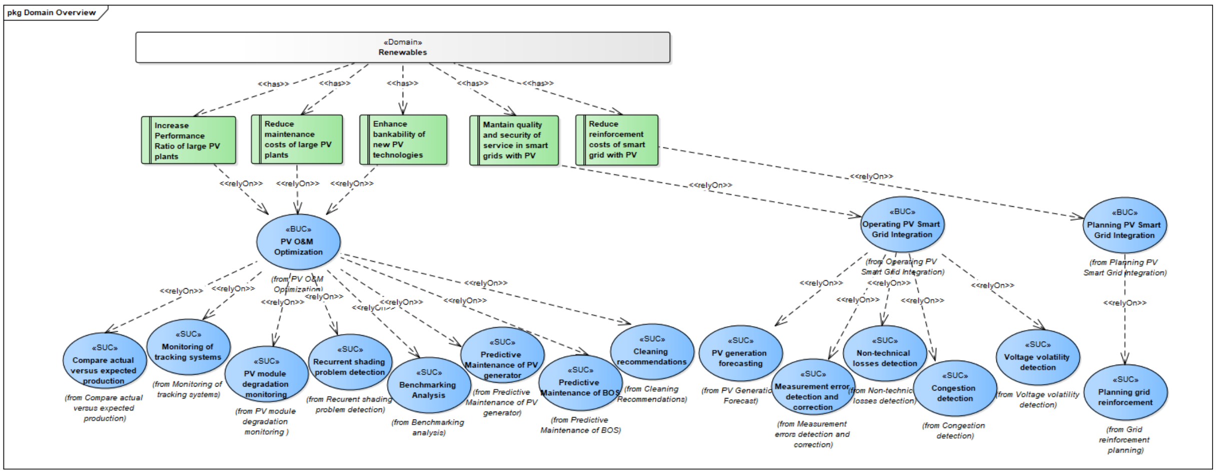


Figure 8 Renewables use case family BUCs and SUCs diagram

Finally, for each of the systems use cases, different interaction models have been defined including the information that needs to be exchanged between specific actors. Figure 9 below shows an example of an interaction model for one of the systems use cases:

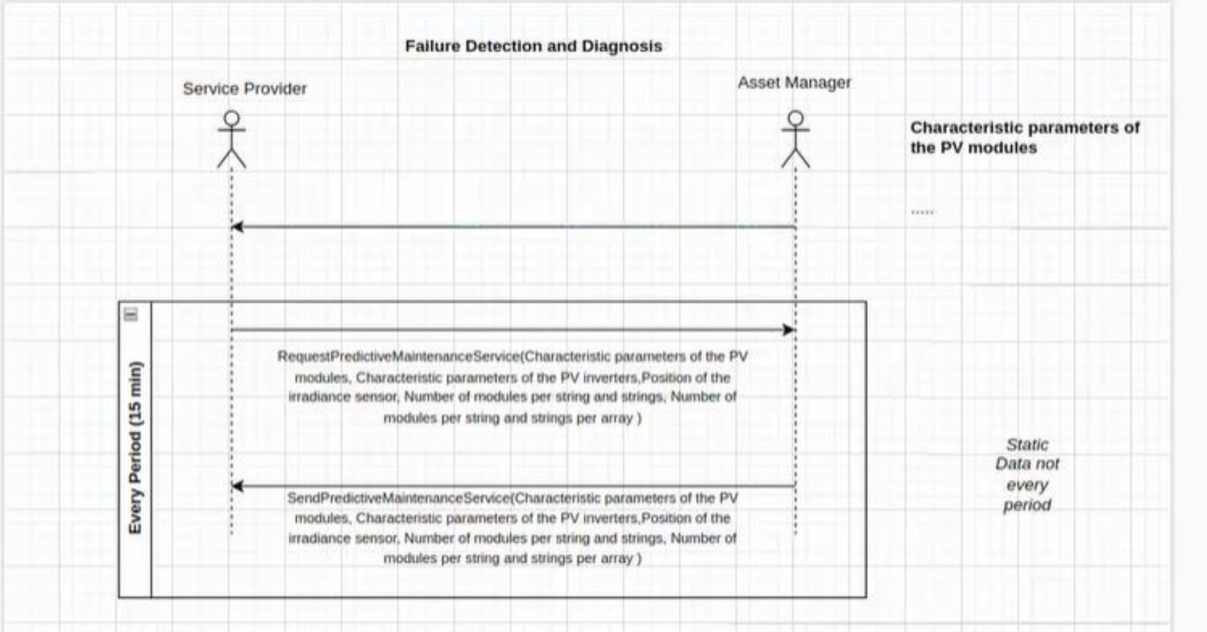


Figure 9 Interaction Model – Failure Detection and Diagnosis

3.2 Local Energy Communities

Local Energy Communities use case family has defined 3 business use cases that consider the different perspectives of LECs: 1) LEC O&M Optimization, 2) LEC Energy Consumption Optimisation through Prosumer Engagement, and 3) LEC Planning Services. Similarly, 12 System Use Cases (SUCs) have been defined which define the scenarios and information exchange for the different services that will be developed.

Finally, for each of the systems use cases, different interaction models have been defined including the information that needs to be exchanged between specific actors. Figure 10 below shows an example of an interaction model for one of the systems use cases:

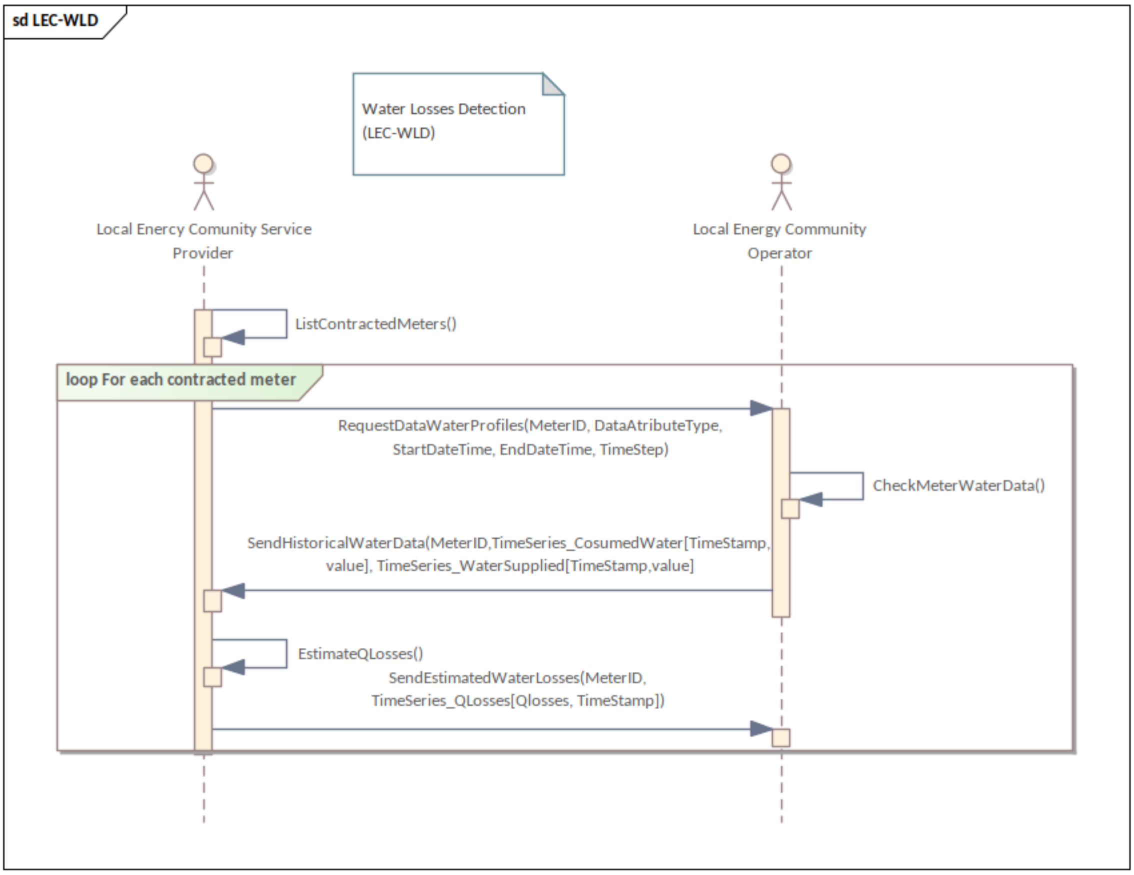


Figure 10 Interaction Model – LEC

3.3 Electromobility

Electromobility use case family (Figure 11) has defined two business use cases: 1) Roaming of booking services and 2) Roaming of self-consumption. In both cases, the aim is to simplify the life of the EV user by facilitating charging services anywhere in Europe, enabling in a simple and fair manner to select the source of electricity (in particular, its own production). Similarly, 13 System Use Cases (SUCs) have been defined which define the scenarios and information exchange for the different services that will be developed.

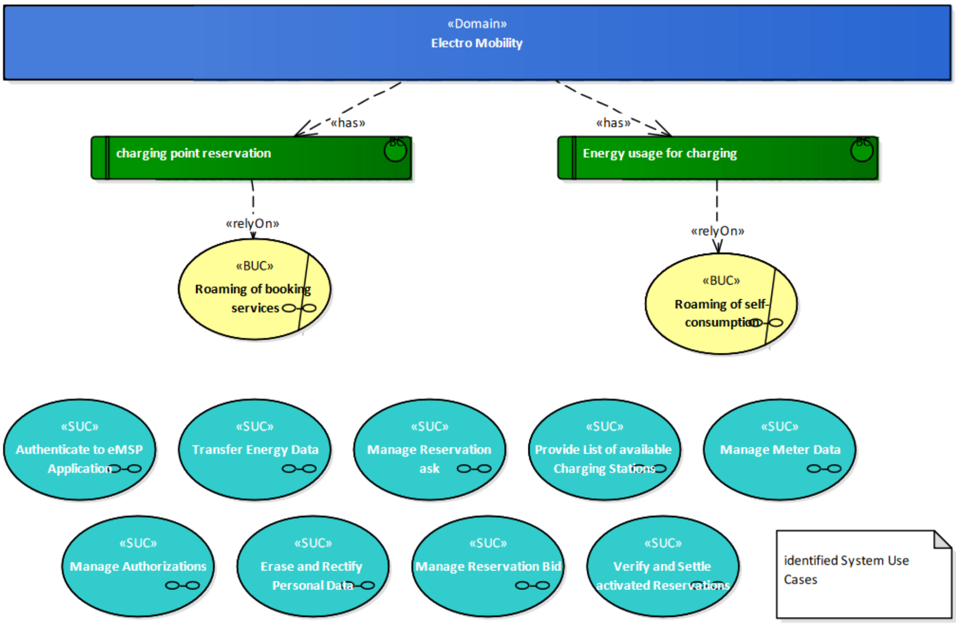


Figure 11 Electromobility use case family BUCs and SUCs diagram

3.4 Flexibility

The Flexibility Use Case Family (Figure 12) is split into three business cases: 1) Flexibility for internal optimization (BUC Flex 1.0), 2) Flexibility for congestion management with bilateral contracts (BUC Flex 2.0) and 3) Flexibility for capacity management with market structures (BUC Flex 3.0). Similarly, 6 System Use Cases (SUCs) have been defined which define the scenarios and information exchange for the different services that will be developed.

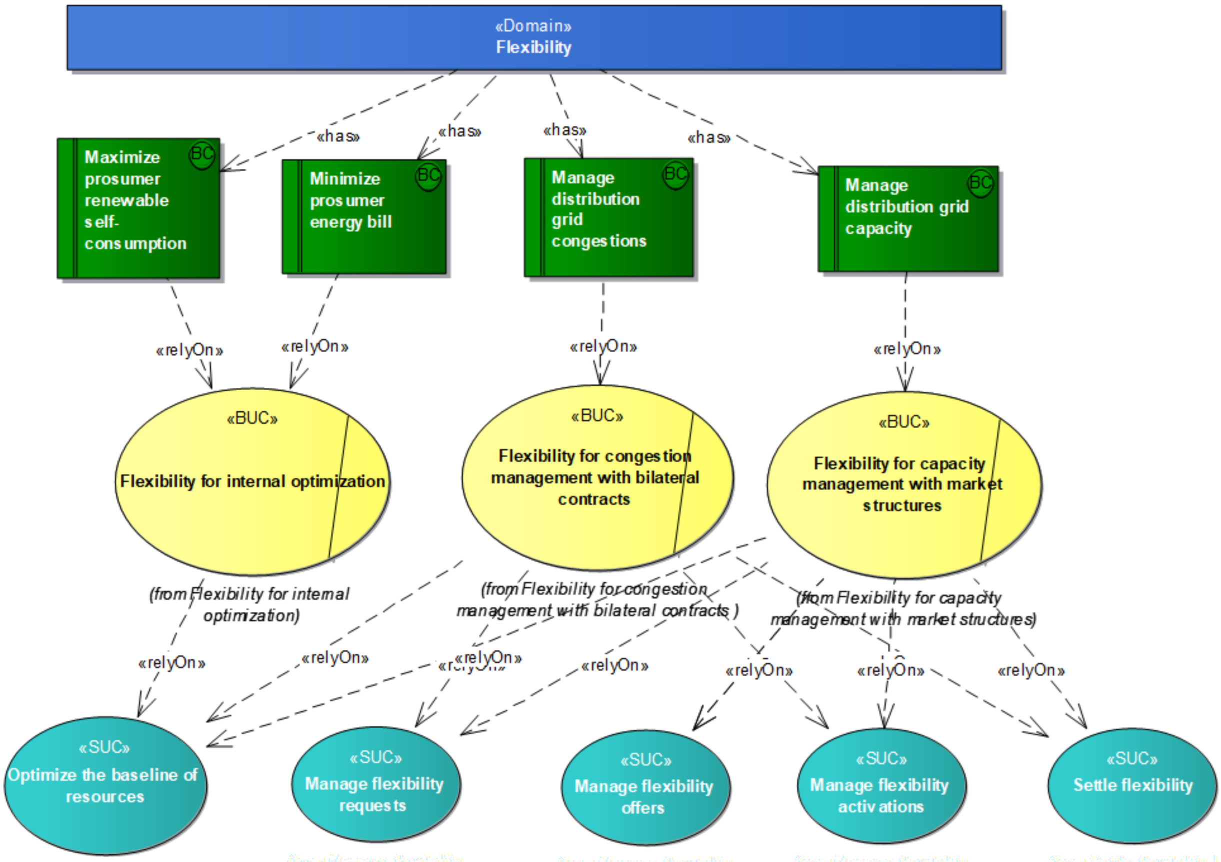


Figure 12 Flexibility use case family BUCs and SUCs diagram

4 AIME: Ontology Development Methodology for the Common Semantic Data Model (CSDM)

One of the main aim of OMEGA-X project is to ease data sharing and data interoperability within energy data spaces. Several levels of interoperability can be defined:

- Technical Interoperability which covers hardware/software communications;
- Syntactic interoperability which deals with messages syntax and data formats;
- Semantic interoperability which focuses on the meaning of the content exchanged or shared;
- Behavioural interoperability which focuses on the expected outcome to interface operations;
- Policy interoperability which focuses on the assurance that interoperating systems follow applicable policies (at regulation or at organization level). Policy interoperability is also related to organizational interoperability and semantic interoperability [9].

To ensure semantic interoperability, a common semantic data model (CSDM) should be conceived. The semantic data model is a conceptual model which encompasses semantic description of the exchanged data in order to add meaning and relationships between them. Based on OMEGA-X T4.3 objectives, the CSDM should:

- Support Bottom-Up Business Driven approach from the Use Cases considered in pilots, aiming at laying the foundations of interoperability for the Energy Data Space
- Consider existing data models, standards and ontologies and align them with the Use Cases defined in the IEC 62559-2 standard.
- Contribute to the core reference model concept as describing by European Smart Grids Task Force Expert Group 1 (standards and interoperability) report “Towards Interoperability within the EU for Electricity and Gas Data Access & Exchange”.
- Be updated during the life cycle of the project, as a first version is produced to cover the needs of the OMEGA-X MVP.

Therefore, AIME (Agile Interaction model-based Methodology for Energy dataspaces), a methodology for CSDM development is being proposed in this report. The methodological principles, the methodology steps and implementation will be detailed in the following sections.

4.1 AIME Principles

In order to propose the ontology of the OMEGA-X CSDM, and based on the main aim of OMEGA-X task T4.3, methodological principles that are needed during the development process of the ontology have been proposed as showed in Table 2

Table 2 AIME principles

AIME Principles	
Principle 1: Agility	This methodology shall be compatible with software developments techniques such as **agile** practices in which sprints and iterations are common techniques: it allows to have in short periods of time several versions of the ontologies which, although they are not complete, can be consumed by users or domain experts
Principle 2: Reusing concepts	This methodology shall focus on the **reuse of concepts** (classes, attributes, etc.) already existing and published in identified/selected former semantic data models.
Principle 3: ontology lifecycle support	This methodology shall include the essential **ontology development life cycle**: Ontological requirements specification; Ontology implementation; Ontology publication- Ontology maintenance.
Principle 4: use case centric	This methodology shall be **Use Case Centric**. Ontology Requirements and scopes are defined based on pilot's use cases.
Principle 5: alignment with standards	This methodology shall ensure alignment of CSDM to IEC61850, IEC CIM, IEC DLMS-COSEM **standards**. Even though these standards are not originally expressed in OWL, they constitute reference models in the energy domain.
Principle 6: modularity of CSDM	This methodology shall ensure the CSDM is **modular**. The ontology shall consist of a set of loosely coupled small ontologies that each focuses on a certain aspects of the domain. Modules may be "top-level", "domain", "application". A "view", or "profile" ontology consists of a set of compatible modules.
Principle 7: FAIR	This methodology shall ensure the FAIRness (Findable, Accessible, Interoperable, Reusable) of the CSDM. It shall use permanent URIs. A documentation shall be published. A code versioning management platform shall be used. It shall include meta-data for provenance of terms.

Relying on these principles, we propose an agile use case centric methodology for ontology development (AIME) essentially composed of 6 iterative steps.

4.2 AIME Methodology workflow

Figure 13 AIME workflow for the development of CSDM depicts the methodology steps to develop the CSDM. More details about each step are described below. For each step, the covered methodological principles, the needed input and the outcomes are given.

Figure 13 AIME workflow for the development of CSDM

4.2.1 Step 0: Select reference ontological and non-ontological resources

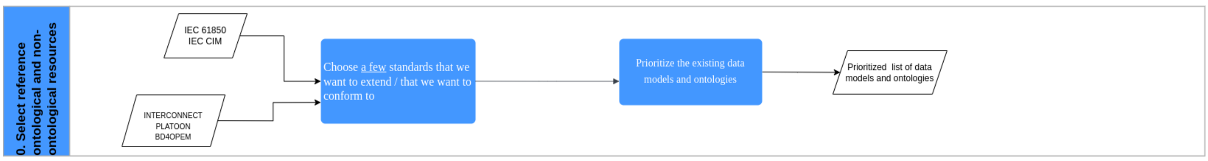


Figure 14 Step 0 of AIME workflow for the development of CSDM

This step consists of choosing the existing semantic data models related to energy domain that we want to extend and to be conform to. These reference models can be ontologies proposed in OMEGA-X sister projects such as SEDMOON (proposed in Platoon project), standards in energy domain such as IEC CIM and IEC 61850, or other ontologies proposed for energy domain such as INTERCONNECT, SEAS and others. In that way, on one hand, we guarantee the reuse of existing models, and on the other hand, we foster transversability by doing feedback/gap analysis of previous models for semantic representation of specific use cases.

Methodological principles: principle 2 and principle 5.

Input: Existing ontologies and data models in energy domain.

Outcomes: Prioritized list of reference data models and ontologies.

4.2.2 Step 1: Select a pilot use case

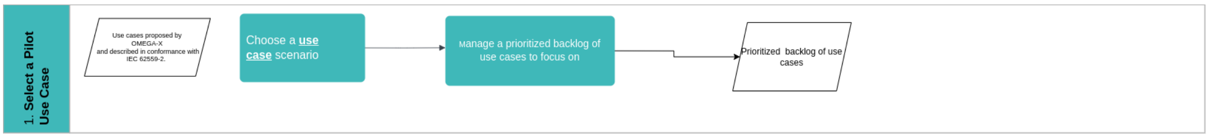


Figure 15 Step 1 of AIME workflow for the development of CSDM

OMEGA-X considers 4 uses case families: Renewable, Local Energy Community (LEC), Flexibility, and Electro-mobility. These use cases are described as Business Use Cases (BUC) and systems use cases (SUC) in OMEGA-X_D3.1 report. The description of the Use Cases of the project follows the methodology prescribed by the IEC 62559-2 standard, which is a Microsoft Word format document that provides a way to dispatch each use case specified information into dedicated chapters and tables in a formatted manner. It compasses: the narrative of the use case (context and objectives), the diagrams of the use case, the technical details, including the extensive description of all the actors: actors name, actor type, actor description, the step-by-step analysis of the use case, the information exchanged, and the requirements.

More information of the services provided in OMEGA-X for these use cases are depicted in OMEGA-X_D3.4 report. For each service, the input and output data, granularity, description, units, volume, owners, and if its required or optional are defined in the annex of the report.

These 2 reports are used as reference while choosing the pilot use cases. This choice is made by cooperating with use case pilots to investigate the level of maturity of the use case description in order to manage a prioritized backlog of use cases to focus on.

This step ensures the Bottom-Up Business Driven approach required in OMEGA-X, and helps in designing iteratively the CSDM.

Methodological principles: principle 1 and principle 4.

Input: Report OMEGA-X_D3.1, Report OMEGA-X_D3.4, use case pilots' feedback about the level of maturity of the use case description.

Outcomes: Prioritized backlog of use cases.

4.2.3 Step 2: Select an Interaction Model (IM) of the UC to focus on

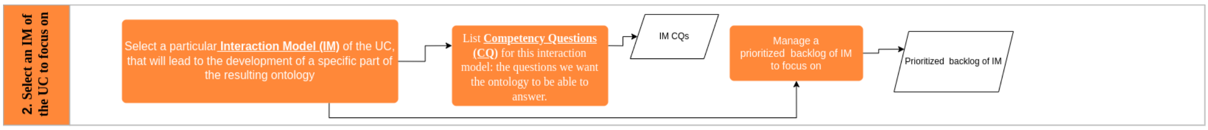


Figure 16 Step 2 of AIME workflow for the development of CSDM

The main aim of OMEGA-X CSDM is to model exchanged data between different actors within OMEGA-X data space. To be agile, we introduced the concept of **Interaction Model** which is a model that covers the data exchanged between 2 actors to reach certain goal. It is a partial view of a scenario of a specific use case described by several steps involving these 2 actors. The IM can be expressed using UML sequence diagram.

Thus, in this step, we select a particular IM of the UC, that will lead to the development of a specific part of the resulting ontology, either if they are not complete. Afterwards, we generate a prioritized backlog of IMs that can be updated all along the project.

For each IM, competency question CQs are defined. The CQs are questions written in formalized natural language. CQs permit to understand the goal of the ontology (ontology requirement in the ontology life cycle) and what questions the use case pilots want the ontology to answer once it is implemented and in production.

Methodological principles: principle 1 and principle 3.

Inputs: Report OMEGA-X_D3.1, *Report* OMEGA-X_*D3.4, workshops for ontology development*

Outcomes: Prioritized backlog of IM, CQs.

4.2.4 Step 3: For selected reference resource and the selected UC IM

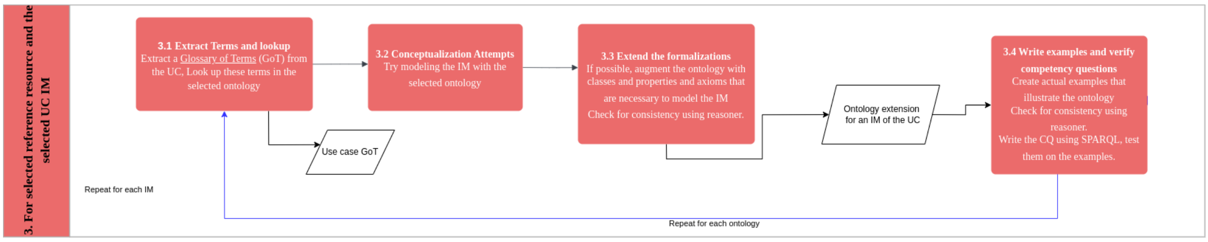


Figure 17 Step 3 of AIME workflow for the development of CSDM

In this step, we try to model the IM using the selected reference data model. It represents the “ontology implementation” phase in the ontology development life cycle. The following steps are followed:

- **Extract Terms and lookup:** The ontology engineer, with the cooperation of the business analysts and use case leader, extract the glossary of terms (GoT) for each IM, and define each terms based on existing well known standards in the energy domain, such as electropedia [10].These definitions should be validated by business analysts who know exactly how these terms are used in the pilot use cases. After that, we try to **classify** the term based on general well known upper domain term such as property, measurement, unit of measure, time series, etc. This classification is inspired from the reference model we are using. The GoT is created in an excel sheet and contains in each row, the term, the IMs that uses this term, its definitions, and its upper domain terms. It will be updated each time a new term is identified.
- This step is at the core of the conceptualization attempts and helps in creating a modular ontology where modules can be top-level, domain or application ontology. Afterwards, we look up these terms in the selected ontology.
- **Conceptualization Attempts:** The ontology engineer tries to model the IM with the selected ontology by relying on the GoT created in the previous step. The ontology engineer tries to match the term identified in the GoT with terms that are defined in the selected reference ontology, and can directly use concepts, relations, and instances from selected reference. The main idea is not to reinvent the wheel, however, try to model the IM using the already existing axioms. Moreover, terms that cannot be modelled should be indicated at the end of this step.

- **Extend the formalizations:** The ontology engineer, tries if possible, to augment the ontology with classes and properties and axioms that are necessary to model the IM. Moreover, it should check for consistency using reasoner. This check permits to verify if the data has any internal conflicts. If no conflict detected, an ontology extension or the IM is proposed.
- **Write examples and verify competency questions:** The ontology engineer creates actual examples that illustrate the ontology. It will help ontology users to understand the ontology and facilitates its usage. Moreover, the ontology engineer checks the consistency using the reasoner. In general, this step is important to validate the data formats when initiating the ontology. The CQs are written in form of SPARQL queries which is the standard query language and protocol to retrieve and manipulate semantic data in from of RDF triples. This step allows to verify that the representational model is complete with respect to the given set of CQs. Step 3 is repeated for all IMs and selected ontologies.

Methodological principles: principles 1, 2, 3, 4, 5 and 6.

Inputs: CQs, selected ontology, IM description.

Outcomes: GoT, part of the ontology, part of the instantiated ontology, identification of missed terms, proposition of extensions.

4.2.5 Step 4: Ontologies Comparison

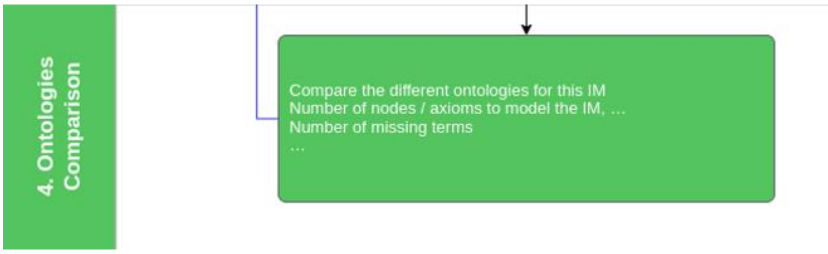


Figure 18 Step 4 of AIME workflow for the development of CSDM

For each IM, compare the different selected ontologies to determine the number of nodes and axioms reused from the selected ontology as well as the missing terms. This step helps to select the appropriate reference ontology to model each use case.

Methodological principles: principle 2

Inputs: IM modelled with selected ontologies

Outcomes: comparison analysis between selected ontologies based on conceptualization attempts.

4.2.6 Step 5: Ontologies Integration

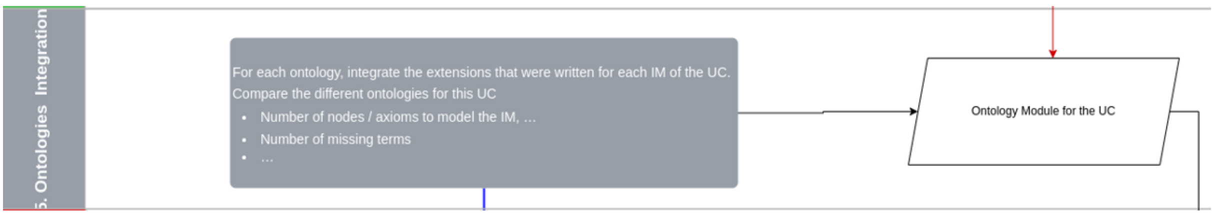


Figure 19 Step 5 of AIME workflow for the development of CSDM

The aim of this step is to integrate different part of the UC ontology in the CSDM. The classification of concepts in upper domain terms ease this step and help in grouping concepts and finding the relations between them. This step is repeated for each selected ontology.

Methodological principles: 2 and 3.

Inputs: Extension of each IM

Outcomes: Ontology based on reference model for all use cases.

4.2.7 Step 6: Publish/Maintain Ontology

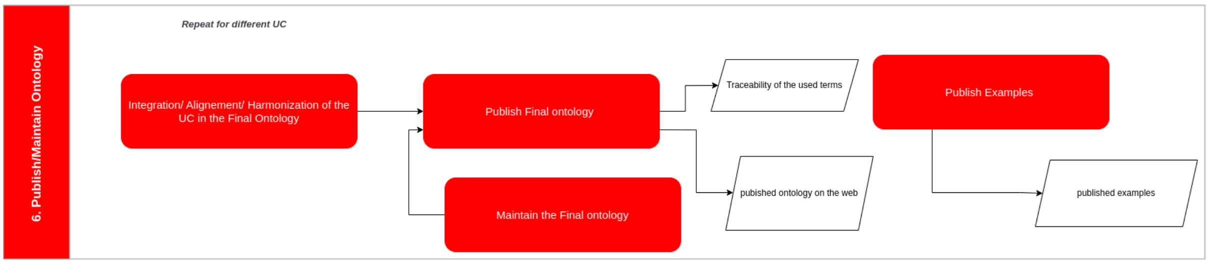


Figure 20 Step 6 of AIME workflow for the development of CSDM

In this last step, the ontology engineer selects the best reference model for each UC and try to integrate these models in a CSDM. At the level, an ontology of the CSDM should be published and maintained. Version platforms should be used. Moreover, the ontology should be:

- Findable: The ontology should have unique and persistent identifiers by defining URIs. Github can be used to publish the ontology and version it. Moreover, metadata that semantically describes the artefacts should be provided.
- Accessible: it can provide pointers to datasets, even without the actual data. Metadata about accessibility should be added.
- Interoperable: the data should be written in a formal, accessible, shared, and applicable language for knowledge representation. Thus, data should be written using semantic representation languages proposed by W3C such as RDF(S), OWL, JSON-LD. For (meta)data, ontologies already exist may be used, such as SKOS, dcterms, dcat.
- Re-usable: Human readable documentation it should be generated to describe best practices of the proposed ontology. Moreover, enough information about the permissions and conditions of the data usage should be provided using the Creative Commons vocabulary or ODRL. It is important to add meta-data associated with detailed provenance. Without meta-data to provide provenance, we have a dataset, we have a dataset without context. The W3C already provides the PROV-O ontology and standard specification that should be adopted for semantic annotation.

Methodological principles: 3,6 and 7

Inputs: Ontology modules for the Use Cases

Outcomes: published ontology; published examples.

To clarify the use of the methodology in OMEGA-X project, the instantiation of the methodology using 2 selected ontologies (INTERCONNECT and SEDMOON) on 14 IMs that cover the 4 OMEGA-X use case families is depicted in Section 4.3.

4.3 AIME Application in OMEGA-X Workshops

For demonstration purposes, the instantiation of the methodology has been applied on two selected reference ontology. In OMEGA-X WP2, the synchronization with sister projects is required, and since ENERSHARE project proposed to rely on SEDMOON ontology to define the Common Semantic Data Model (CSDM), we have chosen SEDMOON as reference ontology.

Moreover, INTERCONNECT ontology covers energy domains needed in OMEGA-X use cases (such as flexibility and LEC), and because INTERCONNECT extends the European standard SAREF core ontology and its extension, we have chosen INTERCONNECT as reference ontology too. More details about these ontologies can be found in Annex A.

4.3.1 Select pilot use cases

Four use case families are covered in OMEGA-X. For each use case family, workshops are organized to contribute to the CSDM. The use case leader, with the cooperation of the ontology expert, animated these workshops and invited participants from all interacting pilots. Table 3depicts the UC leader, UC participants and the selected BUC for each UC Family. Other BUC will be covered in the next version of this report.

Table 3 UC leader, UC participants and the selected BUC for each UC Family

UC Family	UC Leader	UC Participants	Selected Business use Case
Renewable (Ren)	Amélie Gyrard (EDF)	Marie Jubault (EDF) Cyril Effantin (EDF) Ricardo Alonso (Tecnalia) Erik Maqueda (Tecnalia) Lluis Canaves Navarro (EYPESA) Marc Jene (UPC) Ibon Salbidegoitia (METEO) Pablo Gonzalez (SENER ING)	PV Operation and Maintenance Optimisation (BUC Ren 1.0) Operating PV Smart Grid Integration (BUC Ren 2.0)

UC Family	UC Leader	UC Participants	Selected Business use Case
Flexibility (Flex)	Olivier Genest (EDF)	Maria Ines Marques (EDP) Mikel Fernandez (Tecnalia) Joseba Jimeno (Tecnalia) Pedro Pimenta (MAIA) Tanguy Chone (Odit-e)	Flexibility for internal optimization (BUC Flex 1.0) Flexibility for congestion management with bilateral contracts (BUC Flex 2.0)
Local Energy Community (LEC)	Valentina Janev (PUPIN)	Enrico Marchegiani (REVOLT) Alberto Rando (RINA) Mikel Fernandez (Tecnalia) Marc Jené (UPC) Martina Galluccio (RINA-C)	LEC O&M Optimization (BUC LEC 1.0) LEC Energy Consumption Optimisation Through Prosumer Engagement (BUC LEC 2.0)
Electromobility (EM)	Helder Oliveira (AWG)	Florian Mancel (EDF) Marion Arlès (GIREVE) Sarra Ben Abbès (Gireve) Sebastiaan Coppenholle (ELIA) Michiel Verbeeck (ELIA)	Roaming of Booking Services (BUC EM 1.0)

4.3.2 Select Interaction Models

To define the IMs, workshops have been conducted for each use case family. The workshops combine use case leader, use case participants, ontology specialist, and business analysts. UC leader with the coordination of the UC participants discussed the messages exchanged between the actors of each UC, and with the assistance of the ontology expert, defined interaction models for each UC. Sequence diagrams using Enterprise Architect have been used to illustrate each IM by defining 2 actors and the messages exchanged between them. We focused on messages that will be exchanged between business actors within OMEGA-X data space. For each BUC, a scenario can be divided into different IMs. Each IM's name reflects its aim Table 4. depicts the prioritized backlog of IMs. The sequence diagrams are depicted in Annex D. Afterwards, CQs are defined for each IM. The list of CQs is fully described in Section 4.5.

Table 4 Prioritized backlog of use cases

	UC	IM	IM Code
1	BUC Flex 1.0	Passive consumption Base Training	Flex-PCBT
2	BUC Flex 1.0	Passive consumption Baseline Prediction	Flex-BCBP
3	BUC Flex 1.0	Renewable Generator Base Training	Flex-RGBT
4	BUC Flex 1.0	Renewable Generator Baseline Prediction	Flex-RGBP
5	BUC Flex 1.0	Controllable Resources Base Training	Flex-CRBT
6	BUC Flex 1.1	Controllable Resources Baseline Prediction	Flex-CRBP
7	BUC Flex 2.0	Grid Observability and Network Analysis	Flex-GONA
8	BUC LEC 1.0	Water Losses detection at LEC level	LEC-WLD
9	BUC LEC 1.0	Thermal losses detection at LEC level	LEC-TLD
10	BUC LEC 2.0	Optimizing self-consumption for renewable energy at LEC level	LEC-OSC
11	BUC REN 1.0	Comparison of real production versus expected	REN-CRE
12	BUC REN 1.0	Failure detection and diagnosis	REN-FDD
13	BUC REN 2.0	Operating PV Smart Grid Integration	REN-OPV
14	BUC EM 1.0	Search of Available Charging Pool	EM-SACP

4.3.3 For selected reference resource and the selected UC IM

In this step, the GoT of each IM is defined, and the conceptualization attempts are done for IM using INTERCONNECT ontology and SEDMOON ontology. If some concepts are missed, extensions are proposed. We applied this step on the 14 IMs defined earlier. The resulting GoT is depicted in Section 4.4. Moreover, the conceptualisation attempts for all IMs grouped by use case family using INTERCONNECT and SEDMOON Ontology, in addition to the gap analysis are explained in Section 4.3.3.

For illustration purposes, we detail step 3 for FLEX-PCBT IM using INTERCONNECT ontology.

Flex-PCBT

In this interaction model, the portfolio manager service provider (PMSP) requests the passive load historical data by defining the start date, end date and the time step. The portfolio manager

(PM) will reply by sending, for each contracted non controllable load, a time series containing the active energy consumption and a time series containing the ambient temperature. The PMSP will accordingly train the passive load model.

Flex-PCBT with INTERCONNECT ontology

Conceptualisation attempts:

Table 5 depicts the extracted terms and the matching of this term using INTECONNECT ontology.

Table 5 Matching attempts for Flex-PCBT IM with INTERCONNECT

OMEGA-X term	Matching axiom	Axiom's type	Comments
Time Series	ic-data:TimeSeries	Class	Ic-data:TimeSeries can contain one or more ic-data:DataPoint
Time Step	time:TemporalDuration	Class	
Interval of Time	time:TemporalEntity	Class	
Non-Controllable or passive Load	saref:FeatureOfInterest	Class	In Interconnect, the feature of interest is neither related to a Time Series nor to a data point.
Active energy consumption	saref:property	Class	An individual of saref:property
kwh	om:kilowattHour		
value	saref:hasValue	Data Property	A data property for saref:Measurement
Qom	X	X	Missing concept
Ambient temperature	saref:property		
Degree Celsius	om:degreeCelsius		

Figure 21 depicts an example of how we can model the Flex-PCBT exchanged messages using Interconnect ontology. However, the unit of measure is associated to the data points instead.

of the time series, which causes redundancy since all data points in a time series will have the same unit of measure. Moreover, the quality of measurement is missing. In INTERCONNECT, a data point can be produced by a “foaf:Agent” or “saref:Device” which will make the measurements. However, in our IM, the time series is associated to a non-controllable load who cannot be considered as “saref:Device” because it is not doing the measurements. The non controllable load can be a feature of interest associated to the time series.

Extends the formalization:

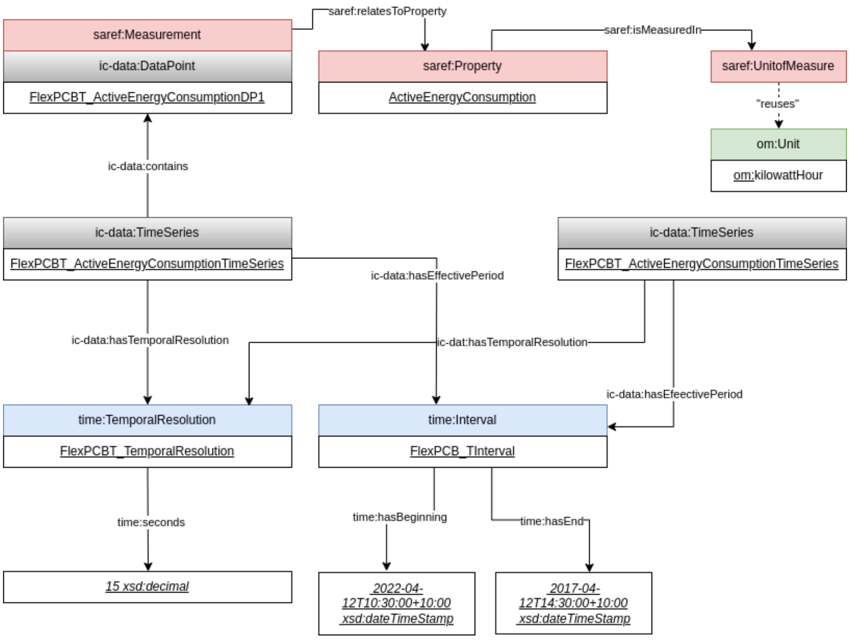


Figure 21 Conceptualization attempts of IM Flex_PCBT using Interconnect Ontology

In order to model Flex-PCBT with Interconnect, and since Interconnect uses the saref ontology, we can reuse “saref:FeatureofInterest” to represent the non-controllable loads. In addition, we can add the qom as data attributes to saref:Measurement class. An object property “:isRelatedTo” that has “ic-data:TimeSeries” and range “saref:FeatureofInterest” can be added. To avoid redundancy, an association can be created between the time series and the property, and another association can be added between the time series and the unit of measure.

After applying step 3, step 4 and step 5 of the methodology described in 4.1.2 on the list of IMs in table 3, three basic outcomes are obtained: the GoT that defines all the need terms, the competency questions to define goal of the ontology, and the conceptualisation attempts with the gap analysis of each selected ontology.

4.4 AIME Application Outcomes

4.4.1 Glossary of Terms

For each IM, the terms (Table 6) are extracted from the exchanged messages and defined as used in OMEGA-X project. UC leader and participants relied on existing energy standards to define the terms. For example, the following references have been used:

- Electropedia by the IEC which contains all the terms and definitions in the International Electrotechnical Vocabulary or IEV which is published also as a set of publications in the IEC 60050 series that can be ordered separately from the IEC webstore;
- IEC TS 61836:2016 [10], Solar photovoltaic energy systems - Terms, definitions and symbols). It provides terms, definitions and symbols from national and international solar photovoltaic standards and relevant documents used within the field of solar photovoltaic (PV) energy systems.

- eMI3 standards for Electric Vehicle ICT Interface Specifications [11][1] which defines terms used in electromobility use cases.

Table 6 Glossary of terms

IM Codes	Term	Definition	Reference
REN-FDD; REN-CRE	AC Voltage	Alternating voltage; alternating tension, voltage that is a periodic function of time with a zero direct component or, by extension, a negligible direct component	IEV ref 131-11-25
EM-SACP	Access details	Additional information e.g., the size of the vehicle	
REN-CRE; LEC-OSC; REN-OPV; FLEX-PCBT; FLEX-PCBP	Active Energy	Active energy integral of the instantaneous power p over a time interval [t1, t2]	IEV ref 131-11-57
REN-CRE; REN-OPV	Active Power	Under periodic conditions, mean value, taken over one period T of the instantaneous power p	IEV ref 131-11-42
REN-FDD	Alarm	An event triggered in the case performance parameters present a significant deviation. For each case, the specific failure modes related to this underperformance will be reported and the potential causes will be exposed.	
REN-FDD; REN-CRE; FLEX-PCBT; FLEX-RGBT; FLEX-RGBP	Ambient temperature	The air temperature outside the building	IEV ref 131-11-57
REN-CRE; REN-FDD; Flex-GONA	Ampere	SI unit of electric current, equal to the electric current corresponding to the flow of (1/1,602 176 634) × 1019 elementary electric charges per second	IEV ref 112-02-07
EM-SACP	Authentication Mean	The means that an EV user can use for authentication at the charging point include RFID badges, plug & charge, a remote app, etc...	
EM-SACP	Authentication Token	Data linked to the means of authentication used to identify the EVU at the charging point	
LEC-OSC	Battery	Electric power storage systems	SEAS ontology

[1] EM-SACP* terms that are not included in the EM_SACP interaction model but identified as potentially needed terms for EM use case.

IM Codes	Term	Definition	Reference
EM-SACP*	Cancelation event	This event refers to the action of cancelling a previously made reservation for using an electric charging station. This event can be initiated by the Electric Vehicle User (EVU), Charging Point Operator (CPO), or eMobility Service Provider (eMSP) and is an essential part of the reservation management process.	
FLEX-GONA	Capacity Requirements	The maximum power at which a power station can be operated continuously under the prevailing conditions	IEV ref 602-03-12
FLEX-GONA	Capacity Utilisation Rate (percentage)	Current power over the system capacity, i.e., the maximum power at which a system can be operated continuously under the prevailing conditions	
EM-SACP	Charging Point or electric vehicle supply equipment (EVSE)	The charging point or electric vehicle supply equipment (EVSE) refers to a specific physical location where an electric vehicle (EV) can be connected to a charging station or for the purpose of recharging its battery. Charging points can vary in the number and types of connectors they offer to accommodate different EV models and charging standards.	
EM-SACP*	Charging Session Event	A Charging Session Event refers to load events transmitted periodically during a charging session, providing technical details about power consumption and other relevant data.	
EM-SACP	Charging Pool	A Charging Pool is a collection of charging points grouped together based on their location and managed by a specific Charging Point Operator (CPO), typically identified by its unique CPO identification.	eMI3_EVSPool
EM-SACP	Connector	A connector refers to a physical component that allows an EV to connect to a charging point (EVSE).	eMi3_Connector
EM-SACP	Connector kind	A Connector Kind refers to the specific physical component type used for connecting to the electric vehicle, such as Type2, CHAdeMO, Type3C, and others.	eMi3_type of plug

IM Codes	Term	Definition	Reference
EM-SACP	Connector power	A Connector Power refers to the maximum electrical power, measured in watts (W), that a specific connector can handle or accept. It defines the power capacity of that particular connector, and it is an important specification for determining the charging capabilities and compatibility of electric vehicle charging stations and connectors.	eMi3-rated power level
EM-SACP*	Connector availability State	The Connector availability State refers to the current working status of a charging. connector. It can be one of the following states: available (The connector is in duty), or unavailable (The connector is off duty)	
EM-SACP*	Connector occupancy State	The Connector occupancy State refers to the current status of occupation of a charging connector. It can be one of the following states: occupied, free or booked	
LEC-WLD	Consumed Water	The quantity of water consumed by LEC participants	
Flex-CRBT; Flex-CRBP	Controllable Load State	The state of a controllable HVAC which can be on or off	
Flex-CRBT; Flex-CRBP	Controllable resource	Controllable device intended to absorb power supplied by another device or an electric power system	IEV-Ref 151-15-15
LEC-WLD	cubic meter per hour	Unit of the volume of water per hour	
FLEX-GONA	Current Imbalance	The current imbalance between phases, which, in a polyphase system, is the current of one phase with respect to the overall current (average of the three phases) in a polyphase system, the current of one phase with respect to the overall current (average of the three phases)	
REN-CRE	DC Current	Electric current that is time-independent or, by extension, periodic current the direct component of which is of primary importance	
REN-FDD; REN-CRE	DC Voltage	Voltage that is time-independent or, by extension, periodic voltage the direct component of which is of primary importance	
REN-FDD; REN-CRE; FLEX-PCBT	Degree Celsius	Special name of the kelvin for use in stating values of Celsius temperature	IEV 113-04-17

IM Codes	Term	Definition	Reference
REN-CRE	Predicted Deviation	The predicted % of deviation between the simulation and the real energy generation	
REN-FDD; REN-CRE	Direct Irradiance	The radiant power incident on an element of a surface divided by the area of that element	
LEC-TLD	Elosses	The estimated amount of energy lost in the distribution grid	
All IMS	End Time	The end time of a time series	
FLEX-RGBT; FLEX-RGBP	Generator	Energy transducer that transforms non-electric energy into electric energy	
EM-SACP	geolocation	This is an address or the latitude/longitude used to identify the location of an object or an individual (for example: charging pool)	
REN-FDD; REN-CRE; FLEX-RGBT; FLEX-RGBP	Global irradiance	Global irradiance equals horizontal direct irradiance plus horizontal diffuse irradiance	
Flex-CRBT; Flex-CRBP	HVAC	Acronym that stands for Heating, Ventilation, and Air Conditioning.	
REN-FDD	Indoor temperature	The temperature inside a building	
LEC-OSC; REN-CRE; REN-FDD; FLEXPCBT; FLEX-PCBP	kilo Watt (kw)	Unit of power	
LEC-OSC; REN-CRE; REN-FDD; FLEXPCBT; FLEX-PCBP	Kilo Watt hour (kWh)	Unit for energy corresponding to 1000 Watt. Hours i.e., 3,6 ×106 joules	
REN-CRE; REN-FDD; FLEX-GONA; REN-OPV;	kilovolt-ampere (kvar)	Unit of reactive power	
FLEX-GONA	Load	Power absorbed by a load	IEV ref 151-15-16
FLEX-GONA	Maximum	The maximum of measurements over a period of time	
LEC-TLD; FLEX-GONA	Meter	Measurements Device	
FLEX-GONA	Minimum	The minimum of measurements over a period of time	

IM Codes	Term	Definition	Reference
EM-SACP*	No show Event	This event refers to an event that occurs when an EV user fails to arrive at the charging point within a time interval. This event is typically initiated by the CPO and may lead to a charge or penalty for the reserved charging session that was not used as scheduled.	
FLEX-PCBT; FLEX-PCB	Non controllable load	Device intended to absorb power supplied by another device or an electric power system	IEV-ref 151-15-15
FLEX-GONA	Occurrence of current Imbalance	Occurrence of current imbalance	
EM-SACP*	Parking session event	This event is a specific event within a reservation that pertains to the allocated parking time without the consumption of electric charge.	
REN-FDD	Phase	One of the phases of a polyphase system	
FLEX-GONA	Polyphase System	Set of m interrelated sinusoidal integral quantities of the same kind, where m is an integer greater than one, all quantities having the same period but usually different phases	IEV ref 141-01-03
FLEX-GONA	Power Factor	Under periodic conditions, ratio of the absolute value of the active power P to the apparent power S: λ = |P| ÷ S Note – Under sinusoidal conditions, the power factor is the absolute value of the active factor.	IEV-ref 131-11-46
REN-FDD	precipitation unit		
REN-FDD; REN-CRE; LEC-OSC	PV	Photovoltaic panel; PV modules mechanically integrated, pre-assembled and electrically interconnected	IEC TS 61836:2007
FLEX-GONA	Q1	The first quartile of measurements over a period of time	
FLEX-GONA	Q2	The second quartile of measurements over a period of time	
FLEX-GONA	Q3	The third quartile of measurements over a period of time	
LEC-WLD	Qlosses	The amount of water lost in the distribution grid	
All FLEX IMs	quality of measurement	The quality of a measurement	

IM Codes	Term	Definition	Reference
LEC-WLD	Quantity of water	Volume flow rate quantity equal to the volume dV of substance crossing a given surface during a time interval with infinitesimal duration dt, divided by this duration, thus qV = dV / dt	IEV-ref 113-03-72
REN-FDD	Rainfall	Precipitation	
EM-SACP	Range location	Used for searching composed of a geolocation or an address, and an approximated range (it can be a radian, a city or a road or any other approximation done with a location others)	https://w3id.org/italia/onto/CLV
REN-CRE	Reactive Energy	In an AC system, the captive electrical energy exchanged continuously between the different electric and magnetic fields associated with the operation of the electrical system and of all the connected apparatus	IEV-ref 601-01-20
REN-CRE	Reactive Power	Quantity equal to the mean value of the product of the instantaneous voltage u and the instantaneous current i′ which is equal to i but leading it by π/2:	IEV-ref 131-11-44
EM-SACP*	Reservation	It refers to a pre-arrangement agreement or booking made by an EVU to secure to access to a specific charging point at a specified time. The reservation implies several aspects such as the reservation time interval, load conditions, pricing terms, and conditions for cancellation or no-show scenarios	
EM-SACP*	Reservation closing event	It is a final event that marks the end of the reservation	
Em-SACP*	Reservation event	It is an event associated with a reservation that logs various actions related to that reservation, such as charging sessions, parking sessions, no-shows, and cancellations. These events serve as the basis for generating the reservation balance sheet for billing purposes.).	
Flex-CRBT;Flex-CRBP	Set point temperature	The set point temperature of a controllable resource	
All IMs	Start Time	The start time of a time series	
LEC-WLD	Supplied Water	The quantity of water supplied to LEC participants	

IM Codes	Term	Definition	Reference
EM-SACP	Tariff	It refers to the pricing rules between two business players that are applied to a service. Each service may have multiple tariffs that define the rules used to calculate the final price of a service.	
EM-SACP	Tariff condition	The tariff conditions are the terms and criteria specified within a service that determine how a tariff is applied.	
LEC-TLD	Thermal Energy	Thermal energy is a kind of energy and it is generated when the temperature rises.	
FLEX-CRBT;FLEX-CRBP	Thermal zone	A thermal zone is a space or collection of spaces having similar space-conditioning requirements, the same heating and cooling setpoint, and is the basic thermal unit (or zone) used in modelling the building.	https://energycodeace.com/site/custom/public/reference-ace-2016/index.html#!Documents/53thermalzones.htm
All IMs	Time Series	A set of regular time-ordered measurements or values of quantitative nature of an individual or collective phenomenon taken at successive, in most cases equidistant, periods / points of time.	http://www.iec.ch/TC57/CIM#TimeSeries
All IMs	time step	The duration between two value in a time series	
FLEX-GONA	Volt	Unit to measure the voltage	
LEC-WLD	Water Meter	Device used to measure the volume of water	
Flex-RGBT; Flex-RGBP;REN-CRE	Watt-hour per square meter (Wh/m2).	Unit of irradiation.	
REN-FDD	wd	Unit to measure wind direction	
REN-CRE	Weather Station		
REN-CRE	Wind direction		
REN-FDD; REN-CRE	Wind speed	Specified point in space, speed of motion of a minute amount of air surrounding the point.	
LEC-OSC	Planned Active Power	Planned active power after a greedy algorithm	
LEC-OSC	Schedule set point of active power	Set point of active power for each battery	
FLEX-PCBP	Predicted Active Energy	The predicted active energy made by using historical data and AI	

4.4.2 Competency Questions

Competency questions are defined in Table 7

Table 7 Competency questions

IMs	CQ	CQ
Flex-PCBT; Flex-PCBP	CQ1	What is the active energy consumed?
Flex-PCBT; Flex-PCBP	CQ2	What is the active energy consumed between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ3	What is the active energy consumed for a specific non controllable load between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ4	What are the non-controllable loads?
Flex-PCBT; Flex-PCBP	CQ5	What is the predicted active energy consumed between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ6	What is the predicted active energy consumed for a specific non controllable load between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ7	What is the global irradiance?
Flex-PCBT; Flex-PCBP	CQ8	What is the global irradiance between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ9	What is the global irradiance for a specific generator between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ10	What the generators?
Flex-PCBT; Flex-PCBP	CQ11	What is the predicted active energy produced?
Flex-PCBT; Flex-PCBP	CQ12	What is the predicted active energy produced between t1 and t2?
Flex-PCBT; Flex-PCBP	CQ13	What is the predicted active energy produced between t1 and t2 for a specific generator?
Flex-PCBT; Flex-PCBP	CQ14	What is the predicted active energy produced between t1 and t2 for a specific generator?
Flex-PCBT; Flex-PCBP	CQ15	What are the controllable loads?
Flex-PCBT; Flex-PCBP	CQ16	What are the HVAC devices?
Flex-PCBT; Flex-PCBP	CQ17	What is the state of controllable load?
Flex-PCBT; Flex-PCBP	CQ18	What is the thermal zone of a HVAC?
Flex-PCBT; Flex-PCBP	CQ19	What is the temperature set point?
Flex-PCBT; Flex-PCBP	CQ20	What is the temperature set point between t1 and t2?

IMs	CQ	CQ
Flex PCBP	CQ21	What is the predicted active energy consumption for a specific non controllable load for an interval of time having a specific time step?
Flex-RGBT, Flex-RGBP	CQ22	What is the historical active energy production for a specific generator for an interval of time having a specific time step?
Flex-RGBT, Flex-RGBP	CQ23	What is the historical ambient temperature for a specific generator for an interval of time having a specific time step?
Flex-RGBP	CQ24	What is the predicted active energy production for a specific generator for an interval of time having a specific time step?
Flex-RGBP	CQ25	What is the predicted global irradiance for a specific generator for an interval of time having a specific time step?
Flex-CRBT, Flex-CRBP	CQ26	What is the historical active energy consumption for a specific controllable resource for an interval of time having a specific time step?
Flex-CRBT, Flex-CRBP	CQ27	What is the historical on/off state for a specific controllable resource for an interval of time having a specific time step?
Flex-CRBT, Flex-CRBP	CQ28	For each thermal zone of a specific controllable HVAC, what is the historical set point temperature?
Flex-CRBT, Flex-CRBP	CQ29	For each thermal zone of a specific controllable HVAC, what is the historical internal (inside the thermal zone) temperature?
Flex-CRBT, Flex-CRBP	CQ30	For each thermal zone of a specific controllable HVAC, what is the historical ambient (outside the thermal zone) temperature?
Flex-CRBP	CQ31	For each thermal zone of a specific controllable HVAC, what is the predicted internal (inside the thermal zone) temperature?
Flex-CRBP	CQ32	What is the predicted active energy consumption for a specific controllable resource for an interval of time having a specific time step?
LEC-WLD	CQ33	What is the historical quantity of water [m3] consumed for an interval of time [hour] having a specific time step/period per water meter?
LEC-WLD	CQ34	What is the historical quantity of water [m3] supplied for an interval of time [hour] having a specific time step/period per water meter?

IMs	CQ	CQ
LEC-WLD	CQ35	What is the predicted quantity of water losses Qlosses [m3] for a specific time step/period?
LEC-TLD	CQ36	What is the historical Hourly/Daily thermal energy consumed by LEC [kWh]?
LEC-TLD	CQ37	What is the historical Hourly/Daily thermal energy supplied to LEC [kWh]?
LEC-TLD	CQ38	What is the Daily estimated thermal losses for a specific time step/period
LEC-OSC	CQ39	What is the forecasted PV production active energy in kWh
LEC-OSC	CQ40	What is the consumption profiles active energy in kWh
LEC-OSC	CQ41	What is the optimized schedule [set points for active power in kW] for the 1 battery?
REN-CRE	CQ42	What is the value of ambient temperature = external measurement which is measured in Unit Degree Celsius for each weather station?
EM-SACP	CQ43	What are the available charging pools for a location range for a specific instant?
EM-SACP	CQ44	What are the available connectors (connector kind and connector power) for a specific charging pool for a specific instant?
FLEX-GONA	CQ45	What is the maximum value of the load for a specific meter and a specific interval of time?
REN-FDD	CQ46	What is the global irradiance taken by a weather station for a specific period of time?
REN-FDD	CQ47	What are the alarms triggered when failure is detected in the grid?
REN-CRE	CQ48	What is the predicted deviation for a specific time interval and a specific PV?

4.4.3 Conceptualization Attempts and Extensions

This section depicts the conceptualisation attempts of the IMs grouped by UC family using INTERCONNECT ontology (Figure 22), and then, SEDMOON ontology (Figure 23). Some extensions have been proposed. These attempts helped us to analyse the gap in these two selected ontologies and paved the way to the CSDM that we are proposing in section 6.

4.4.3.1 Flexibility with Interconnect

In this version of the document, 6 IMs for flexibility use case family have been modelled. In the first 5 IMS, the PMSP will receive historical data related to contracted loads or renewable generators in order to predict the energy or the internal temperature. Thus, at the core of the model, we have time series described by energy or weather properties, having a time step and a time period and related to a feature of interest such as generator, controllable load, HVAC or other.

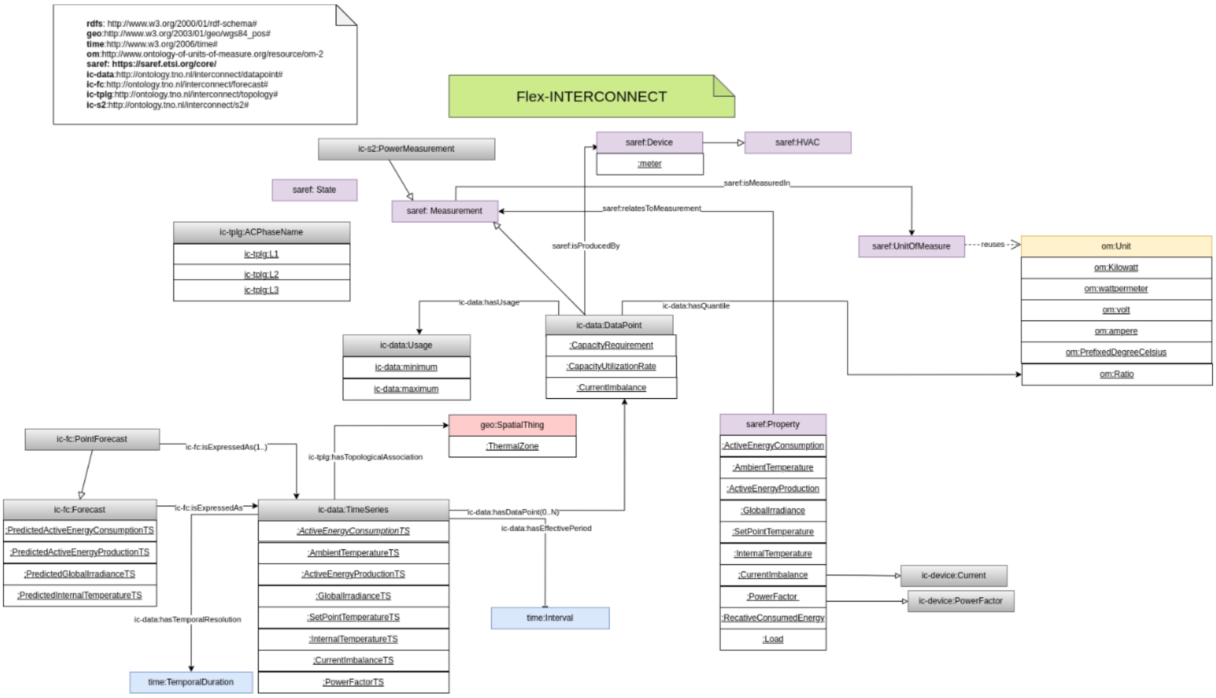


Figure 22 Conceptualisation attempts of flexibility IMs with Interconnect ontology

Gap analysis of the conceptualization attempts of Flexibility IMs with INTERCONNECT Ontology

The time series can contain measurements which have a quality of measurement QoM. This concept is not represented in INTERCONNECT. Moreover, the time series should be related to a feature of interest containing data about a specific property and measured in a unit of measurement. However, in INTERCONNECT, the feature of interest is missed, and the association between the time series and the property, and the time series and the unit of measures are not added. In Flex-CRBP, the state, of the controllable load is needed in order to make the prediction. This concept is missed in INTERCONNECT since a time series contains data point which is a measurement.

In Flex-GONA, the minimum, maximum, Q1, Q2 and Q3 voltage and load are needed to draw the visual data. In INTERCONNECT, the minimum and maximum can be expressed by using "ic-data:hasUsage" "ic-data:minimum" and "ic-data:maximum". This property provides the possibility to add some additional information about the usage of a data-point or time-series, such as a time series can be used as an upper limit, lower... However, in our IM, the minimum and maximum expresses that the time series contain an aggregated value. Thus, minimum and maximum are aggregation rather than expressing a specific usage of the time series.

Regarding the quantile values, Interconnect defines “ic-data:hasQuantile” to define on a data point of a quantile time series. The quantile must be a ratio, usually a percentage. In Flex-GONA, the current for each phase (L1, L2 and L3) should be sent. Although the phases can be modelled using the class of the names associated to electrical phases “ic-tplg:AcPhaseName”, but this class is not connected neither to the data point class, nor to the time series class.

Some extensions, can be proposed to model the flexibility IMs with INTERCONNECT:

- Reuse the saref:FeatureOfInterest and add the association between this class and the time series class. A load (Controllable and non-controllable), an AC phase (L1,L2,L3) and a renewable generator can be a feature of interest.
- Add the quality of measurement to the saref:Measurement class.
- Add a state class (saref:State) and add the association between the time series and the state class in order to express the state of a controllable load.
- Add an association “:usedAggregation” between the time series and “Aggregation” class. An aggregation can be minimum, maximum, Q1, Q2, etc. More details can be given to the aggregation to indicate if it’s a temporal or spatial aggregation
- Since all timeseries contain data related to the same property and had the same unit of measure, it will be more convenient to add on one hand, an association between the time series and the property, and, on other hand, an association between the time series and the unit of measure.

4.4.3.2 Flexibility with SEDMOON

Figure 23 depicts the conceptualisation attempts of Flexibility IMs using SEDMOON ontology. In SEDMOON, the data exchanged can be modelled as “seas:Evaluation” which is related to the “seas:Property” and is evaluated by a value and unit of measure. A “seas:Evaluation” can have a temporal context “time:TemporalEntity” in order to add the time stamp or the interval of time for an evaluation.

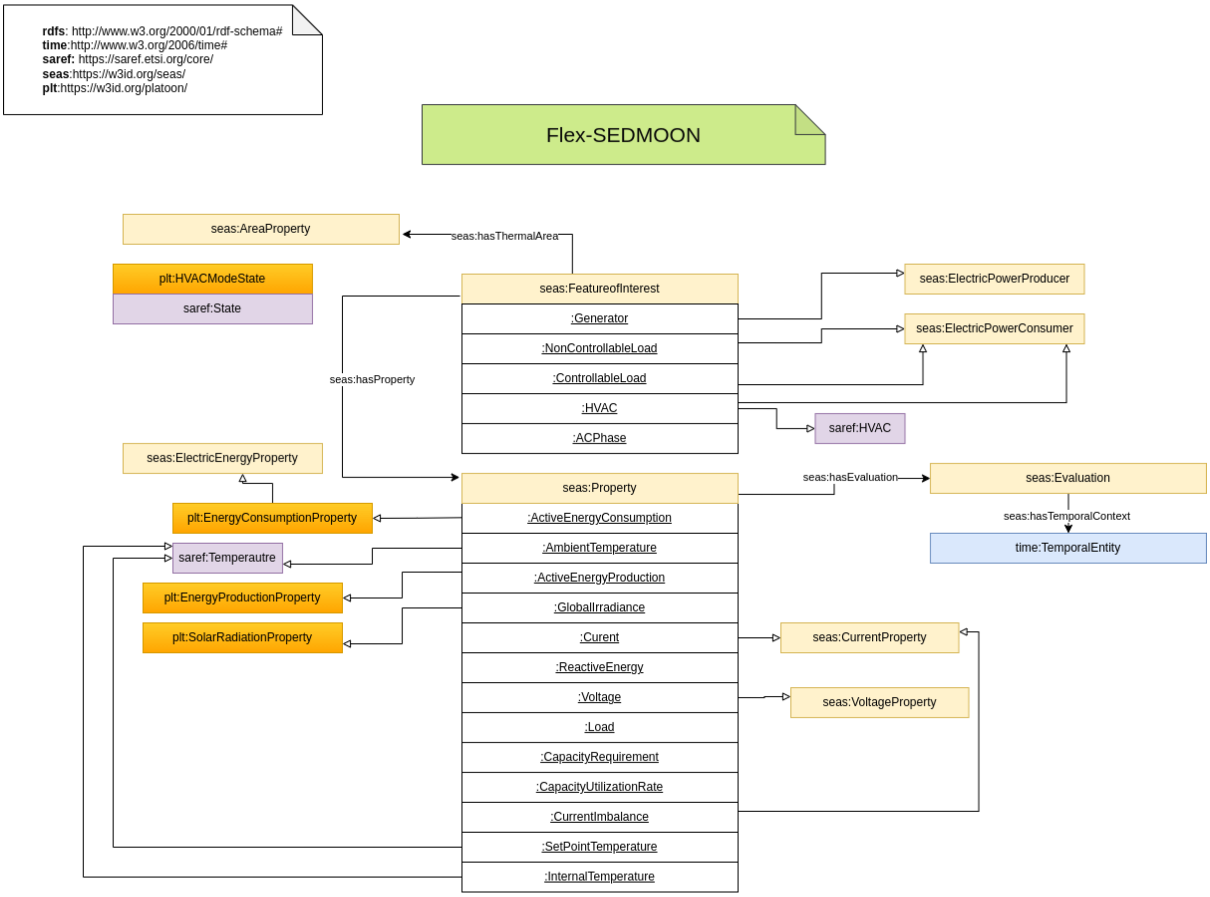


Figure 23 Conceptualisation attempts of Flexibility IMs using SEDMOON ontology

Gap analysis of the conceptualization attempts of Flexibility IMs with SEDMOON Ontology

SEDMOON does not use the concept of time series. Thus, time series will be modelled by creating evaluations. SEDMOON reuses the concept of “seas:FeatureOfInterest” which has a property. This is convenient to flexibility IMs where the feature of interest can be the controllable loads, the generator, etc. as mentioned previously.

To model the thermal zone, SEDMOON reuses “seas:hasThermalArea” to model the thermal zone for a feature of interest.

Although SEDMOON reuses “saref:State” and extended with “plt:HVACModeState” to model the state of a controllable load, however no association exists between the state and the feature of interest. The QoM is also missed in SEDMOON. Moreover, the minimum, maximum, and quantiles are not specified in the ontology.

Thus, we can extend SEDMOON by:

- Adding QoM to the evaluation class.
- Adding a Time Series class that contains one or more evaluation.
- Add “hasState” association between the feature of interest and saref:State classes.
- Add “hasAggregation” to the time series or the evaluation.

4.4.3.3 Renewable with INTERCONNECT

In this report, the IMs for the renewable use case family focuses on information exchanged between the service provider and asset manager. The renewable energy is the solar energy and the data exchanged is about energy data and the weather data. In REN-CRE IM, the service provider predicts the deviation between the simulation and the real energy generation. In REN-FDD, the service provider sends alarms he affected component or subsystem will be identified, the specific failure modes related to the underperformance and the potential causes. Figure 24 depicts the conceptualization attempts of the Renewable IMs using INTERCONNECT ontology. Basically, we have time series and ic-Forecast containing energy and weather information.

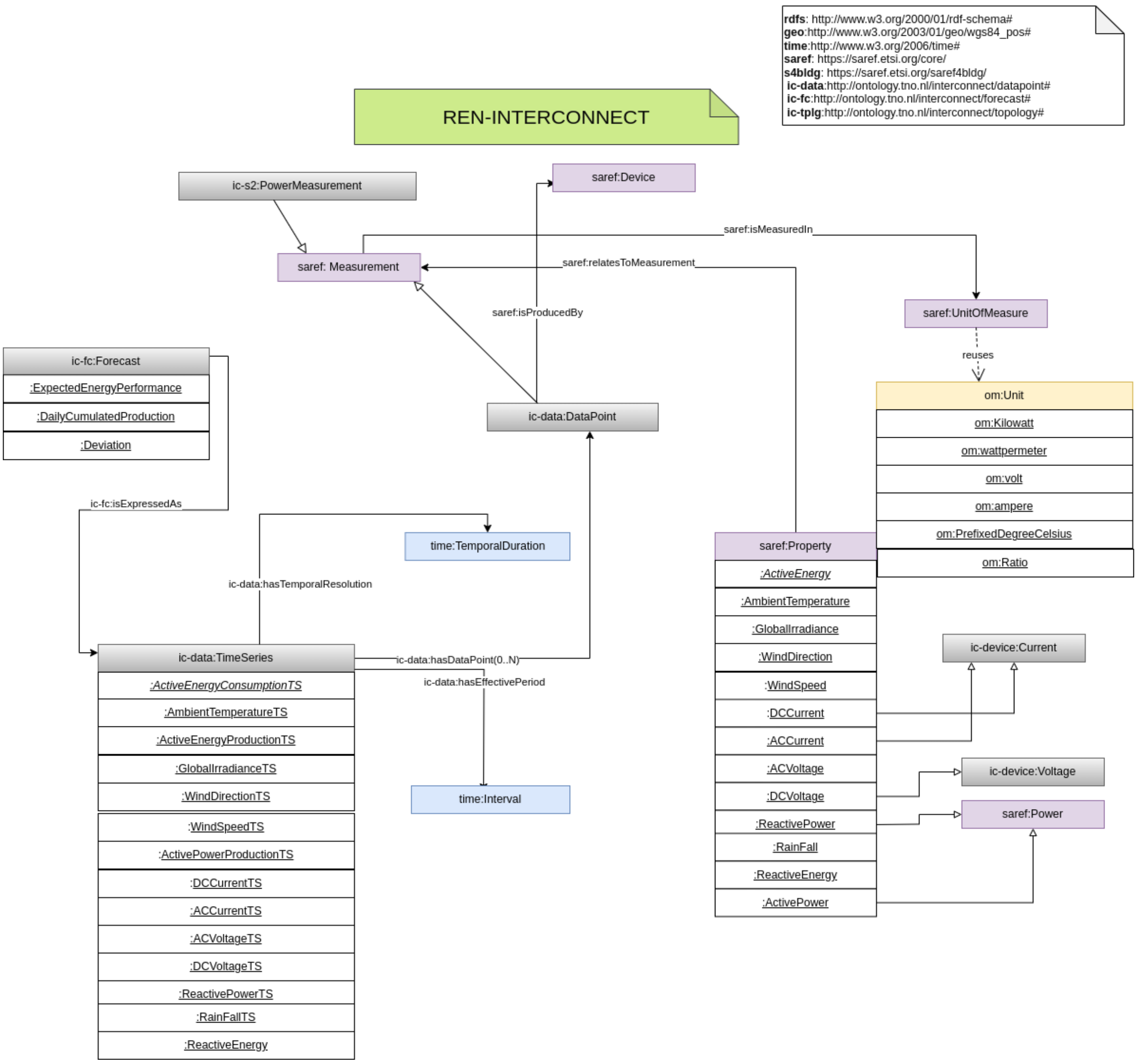


Figure 24 Conceptualization attempts of renewable IMs using Interconnect ontology

Gap analysis of Renewable IMs using INTERCONNECT Ontology

The Alarm concept is missed in this ontology. Moreover, the PV and the weather station are not modelled in INTERCONNECT. Thus, we propose to:

- Add the weather station and the PV as a feature of Interest
- Add a new class for Alarm and add the association between the time series and the alarm to indicate that a time series can contain a series of alarms.
- Add properties that describe an alarm such as the alarm code, the potential causes, and the affected components.

4.4.3.4 Renewable with SEDMOON

Although SEDMOON ontology covers renewable use cases, however it focuses on wind turbines rather than solar energy and PVs. SEDMOON defines the WeatherOntology module that model the weather station and the weather properties such as wind speed, precipitation, etc. Figure 25 depicts the conceptualization attempts of the renewable IMs using SEDMOON ontology.

Gap analysis of Renewable IMs using SEDMOON

The Alarm concept is missed. When a significant deviation is detected, a time series containing list of triggered alarms should be sent. Moreover, the PV feature of Interest should be added.

4.4.3.5 LEC Use Case with INTERCONNECT

In this report, 3 LEC IMs have been considered. In LEC-WLD, The LEC Operator will send data water profiles (consumed/ supplied) to the LEC Service provider who will predict the Qlosses. In LEC-TLD, the LEC Operator will send the thermal data profiles to the LEC service provider who will predict the ELosses. And in the LEC –OSC, the LEC Operator will send the predicted active energy produced and consumed related to contracted PVs to the LEC Service provider who will send a planned ed active power and a schedule set point of active power for each battery. Information exchanged are in form of Time series.

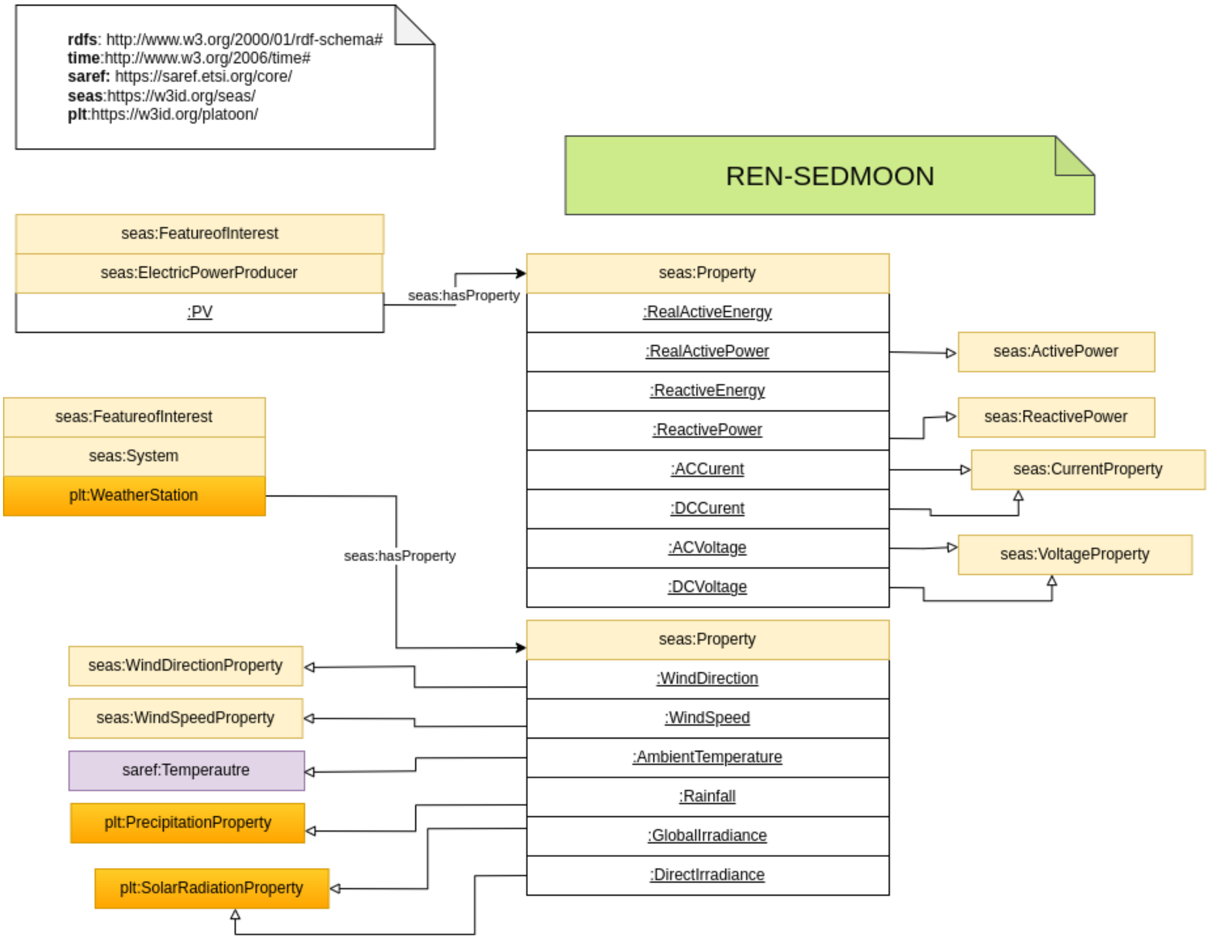


Figure 25 Conceptualization attempts of the renewable IMs using SEDMOON ontology

Figure 26 depicts the conceptualization attempts of the LEC IMs using INTERCONNECT ontology. The predicted values and be modelled as “ic-fc:Forecast” and the profiles data can be modelled as “ic-data:TimeSeries”. The unit of measure for the quantity of water cubic meter per hour and the PV concept are missed. The battery can be modelled as “ic-dev:Energy_Storage”.

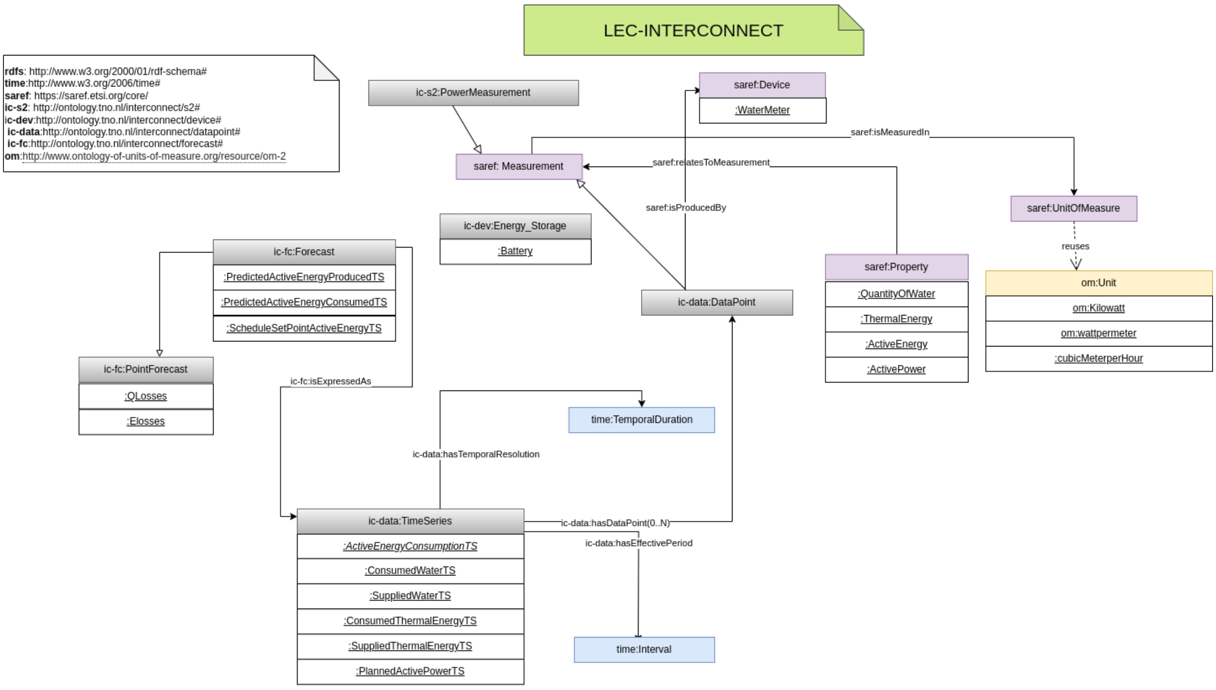


Figure 26 Conceptualization attempts of LEC IMs using Interconnect ontology

Gap Analysis of LEC IMS using INTERCONNECT ontology

The water meter, the battery, and the PV can be considered as feature of interest and an association between the time series and the feature of interest can be added.

4.4.3.6 LEC with SEDMOON

Figure 27 depicts the conceptualization attempts of the LEC IMs using SEDMOON ontology. The battery can be modelled as “seas:Battery” and the PV can be modelled as “seas:ElectricPowerProduced”. Each point of he predicted time series, the data profile time series, and the planned active power time series can be modelled as “seas:Evaluation”.

Gap Analysis of LEC IMS using SEDMOON ontology

As mentioned for the previously cited conceptualization attempts of the IMs using SEDMOON, the main missed concept is the Time Series.

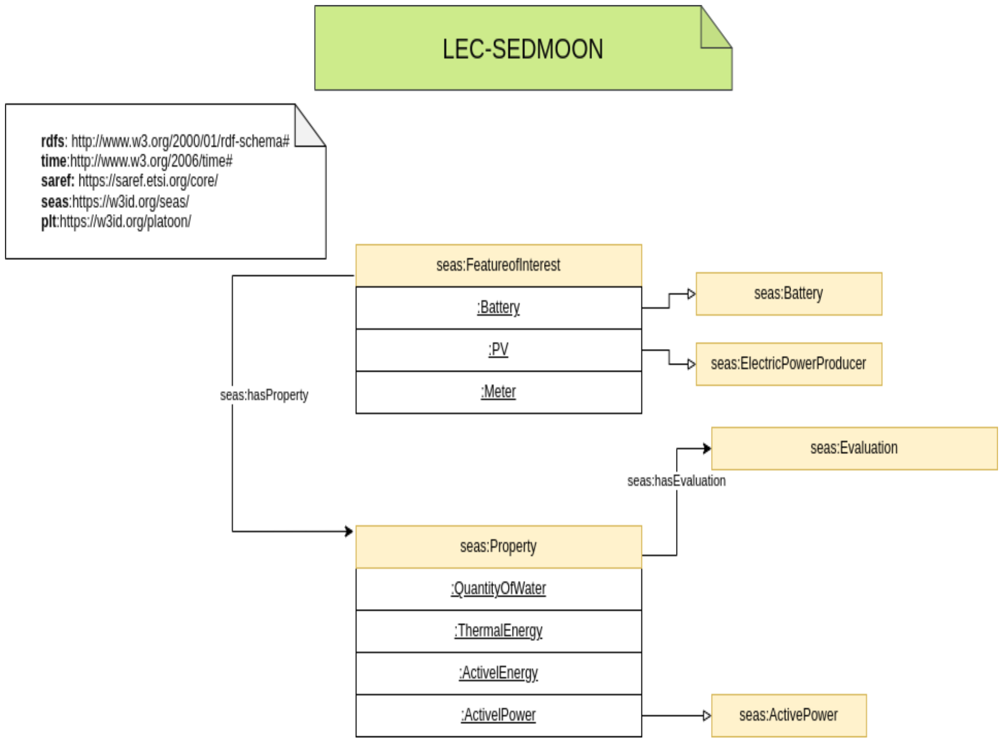


Figure 27 Conceptualization attempts of LEC IMs using SEDMOON ontology

4.4.3.7 Electromobility IMs with INTERCONNECT

In this report, the interaction models that we cover for electromobility is part of the booking service. First, the EMSP request to search for available charging pools for a specific location range and specific period of time. The EMRSP will than send the available charging pools, and for charging pool the location, the information of existing connectors (connector type and power), the associated tariff, the access details, and the accepted authentication means. Thus, a reservation contract can be made by defining the time interval of the reservation, the connector, the reservation power and the charging pool. The result of this contract can be a parking session, and/or a charging session, or a cancellation or a no show.

Figure 28 depicts the conceptualisation attempts of electromobility IMs using INTERCONNECT ontology.The charging pool, charging point and connectors can be modelled as “saref:FeatureOfInterest”. The tariff can be modelled as “ic-data:DataPoint” which is an “ic-uom:AmountMoneyPerEnergy”. It is defined as price pattern. Moreover, the location can be a “geo:SpatialLocation” or an “ic-tplg:TopologicalLocation”.

Gap analysis of the conceptualization attempts of Electromobility IMs with INTERCONNECT Ontology

The reservation contract and its resulting events such as charging session, and the authentication means are missed concepts. Moreover, we cannot model the relation between the charging pool, the charging point and the connectors.

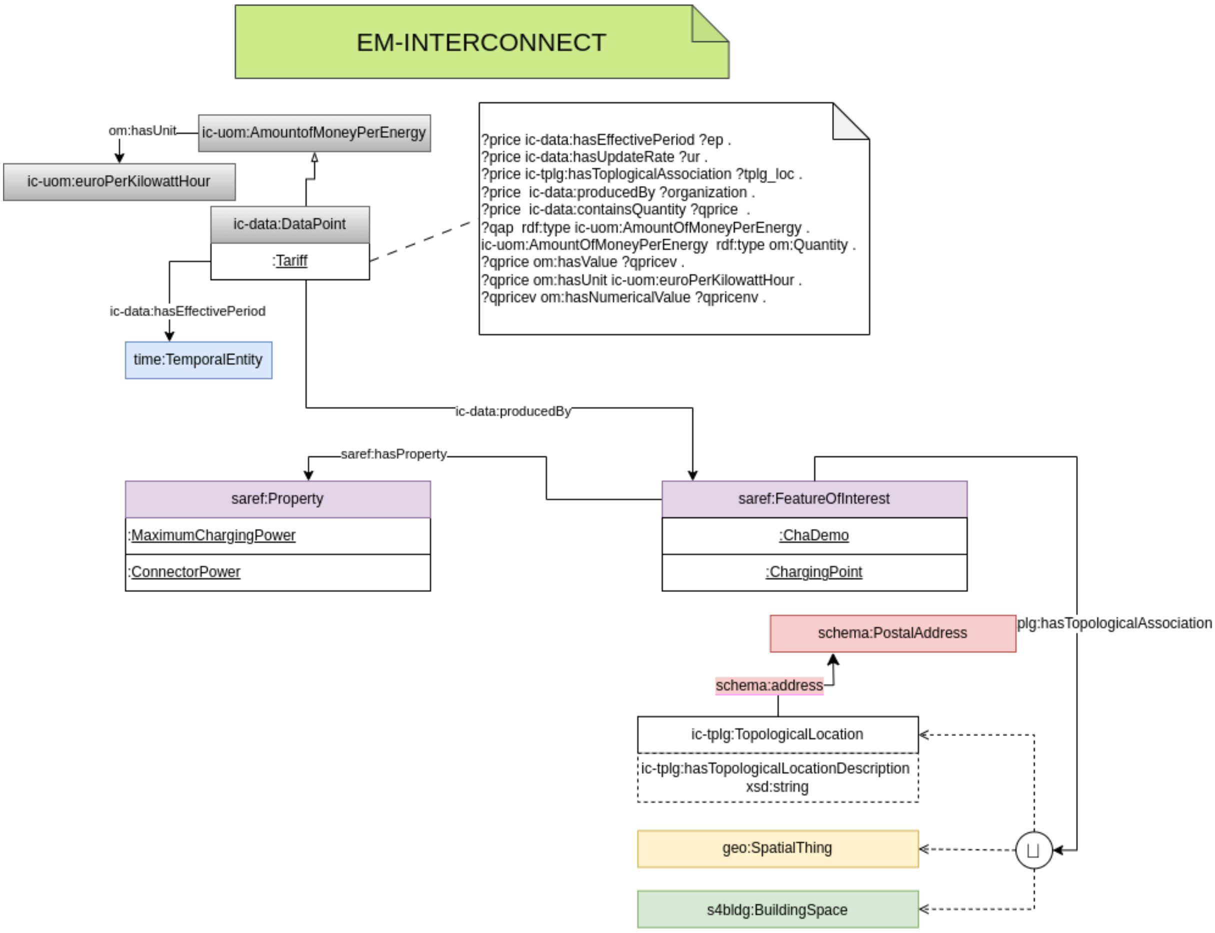


Figure 28 Conceptualization attempts of electromobility IMs with Interconnect ontology

4.4.3.8 Electromobility with SEDMOON

SEDMOON ontology does not cover the electromobility use case. However, it relies on SEAS ontology that describes some features of the electromobility use case. Thus, in our conceptualization attempts we tried to model the EM IMs relying on SEAS ontology. Figure 29 depicts the conceptualization attempts of EM using SEDMOON ontology.

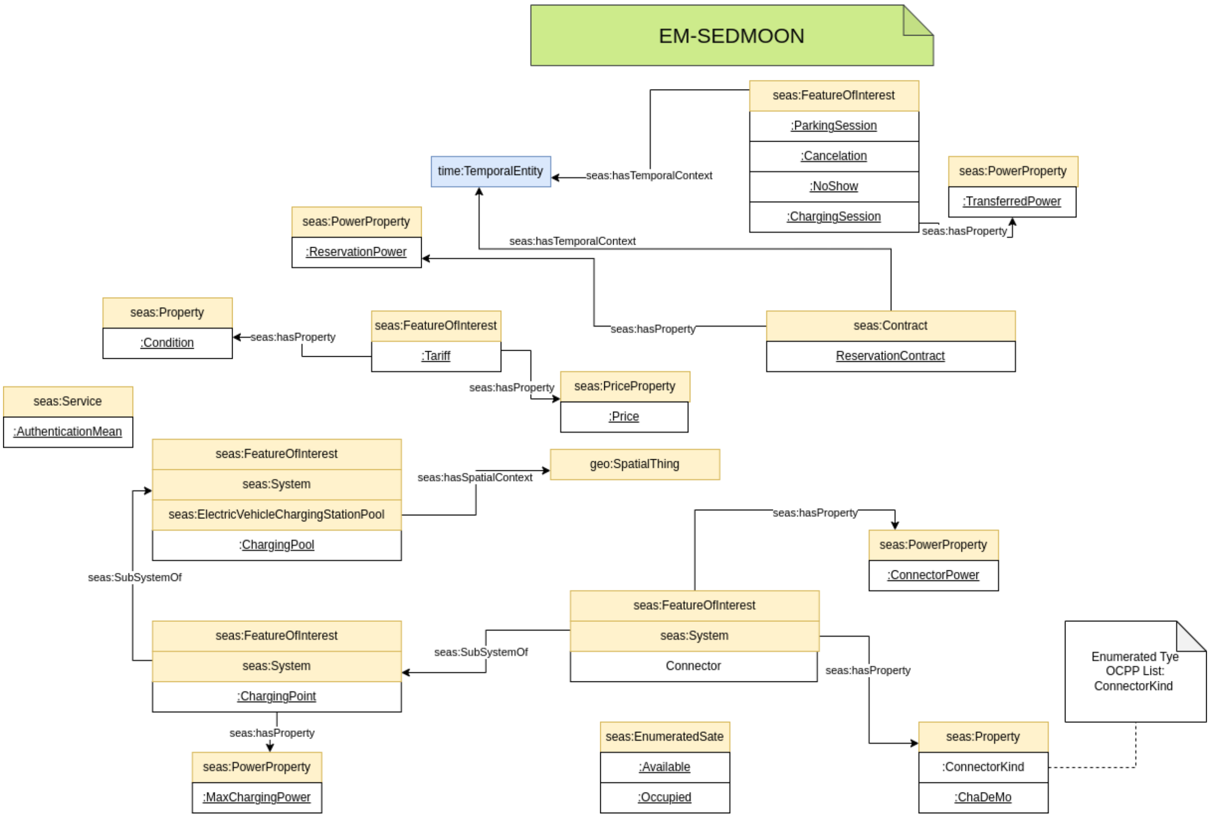


Figure 29 Conceptualization attempts of electromobility IMs with SEDMOON ontology

In SEAS, a feature of interest can be a seas system that is part of another seas system. The feature of interest has property a property such as power, price or other; has spatial context a "geo:SpatialThing" to describe the location; and has temporal context a temporal entity to define the temporal property such as the start date and end date. In our case, we can consider the charging pool, the charging point and the connector as seas:System. Thus, the charging point will be a subsystem of the charging pool and the connector will be a subsystem of the charging point. The state of the connector can be modelled as "seas:EnumeratedSate" which can be available, occupied, etc. Moreover, an event is a feature of event. Thus, in our use case, the parking session, the cancellation, the no show and the charging sessions can be modelled as a feature of interest. The tariff can be modelled as a feature of interest that has a property "seas:PriceProperty". The reservation contract can be modelled as "seas:Contract" and the authentication means can be modelled as seas:Service (is abstract entity, typically an activity described as capabilities and offered by a node).

Gap analysis of the conceptualization attempts of Electromobility IMs with SEDMOON Ontology

Although we can model the terms used in the electromobility IMs using SEAS ontology, however, some associations between concepts are missed. For example, the association between the contract and the event; the contract and the system; the service and the system. A proposition of extension of the SEAS ontology to cover the search of available charging points, the registration of the contact and the result of this contract is depicted in Figure 30 where the proposed modification are in RED. Each class or object can be extended with additional properties to fully describe it.

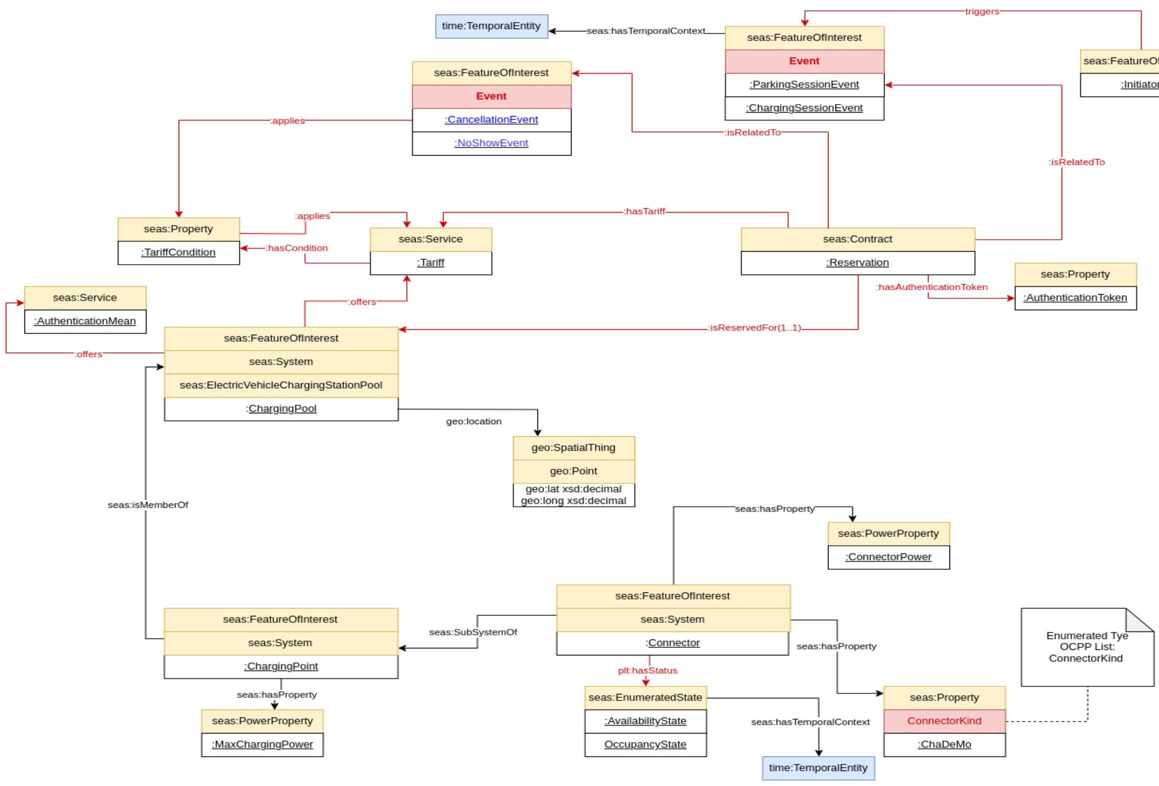


Figure 30 Extension of SEAS ontology to model EM IMs

4.4.3.9 Ontologies Comparison

As discussed previously, at the core of our IMs is the time series exchanged between actors. Thus, the comparison between existing ontologies should consider the way the time series are modelled. In SEDMOON ontology, the time series concept does not exist. We can express the measurement, estimation values, predicted values and the state as evaluations. Unfortunately, this model causes redundancy since all information related to the time series should be added for each evaluation. Moreover, we may need to describe a time series, its interval and step time, its unit of measurement, its property without adding all the time series points. It cannot be done using SEDMOON.

In INTERCONNECT the time series exist and can be described. However, the time series can include measurements or forecast values. In some cases, we have a time series of events, alarms, state or others which is missed in INTERCONNECT. Moreover, the property and the unit of measurement are associated to each data point instead to the time series itself.

Moreover, both ontologies do not model the quality of measurement and the aggregation that can be used when calculating the time series values.

The time series are related to a feature of interest. It is expressed as feature of interest in SEDMOON and it is associated to each evaluation instead to a time series. In INTERCONNECT, the time series are associated to the device using "ic-data:producedBy" association. These devices do not include PVs or generators since they do measurement. Thus, the use of feature of interest to describe devices, PVS, generators, CPO and others seem to be convenient.

In addition to time series, and especially for electromobility use case, a new concept should be modelled which is the event. The event is triggered by a feature of interest, has temporal context, and additional properties like the power or others. In addition, we should model the reservation contract, the tariff and the authentication mean.

Thus, for this first version of the report, we are proposing a first version of the CSDM which will be updated iteratively to include all concepts needed in OMEGA-X use cases.

4.5 Discussions

The use of the AIME methodology permits to explore existing standards and ontology in the energy domain and helps to identify missing concepts needed in OMEGA-X and other energy data space projects. The conceptualization attempts can be helpful for other projects to analyse which reference ontology can be used. One of the analysed reference ontology can be a starting point to create profiles and API.

Moreover, the GoT and CQs help in defining the knowledge that is needed for the semantic interoperability specification. This specification is needed to enable cross domain interoperability and to find a common semantic data model for the 4 use case families.

By analysing the terms, we can conclude that, in general, at the core of OMEGA-X data space, information is exchanged in form of time series and events. Since time series and events can be used not only in energy domain, it is convenient to propose an upper ontology model independent of a particular domain and describing efficiently time series.

In energy data spaces, context should be added to these time series and events such as the owner of the information, the related property, the location, the unit of measure, and others. Thus, domain ontology related to energy data spaces can be proposed. This upper domain ontology can be used across OMEGA-X use case families and other energy data spaces. These two ontologies pave the way to the convergence of the different European efforts in defining semantic models for energy data exchange. For each use case family, one or more application ontologies covering a particular specialization of the domain ontology can be created. Application ontologies can be created based on the use case requirement, or concepts used in more than one use case.

5 Common Semantic Data Model (CSDM)

CSDM (Common Semantic Data Model) is a semantic model that covers all the concepts manipulated in the OMEGA-X use cases. As the use cases presently focus on interactions handled by a data space between service users and service providers, the scope of CSDM is limited to dynamic data.

Two ontological modules are released in this version of CSDM. A first module, named DataValueOntology, is an upper-level ontology that describes time series and events. The second module is named EnergyDataSetOntology and is a domain ontology that describes datasets for Energy Data Spaces.

Updates of the CSDM will be released every month including extension of the scope in the form of additional modules and revision of existing modules taking into account partners' feedback.

This section is structured in three sub-sections. Section 5.1 introduces main concepts and properties of DataValueOntology module.

Section 5.2 introduces main concepts and properties of EnergyDataSetOntology module that is included in EnergyDataSetOntology. Section 5.3 illustrates the use of the two modules in representative datasets exchanged in OMEGA-X use cases.

5.1 DataValueOntology

The scope of this module of CSDM is the description of value sets as shown in the following figure.

A value set is a group of values semantically related. There are three kinds of value sets. The first kind is an event i.e., a value triggered for some reason – for instance, an alarm. The second kind is a record i.e., one or multiples values that are related and produced at an instant in time or during a certain period. The third kind of value set is a series that is a list of values that are related and produced sequentially in time.

The prefix for this module is 'ets' that stands for 'event and time series'.

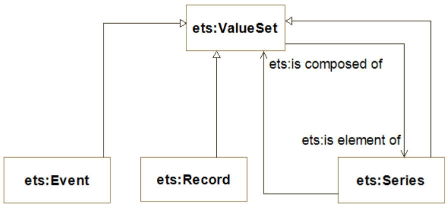


Figure 31 Overview of ValueSetOntology

A series is composed of elements, each element may be a value set. This means that a series may be composed of events or of records but also may be composed of embedded series in a hierarchical way.

Any value set - be it an event, a record or a series – is characterized by an identifier, a name and a quality. This later property indicates the quality of a value set. Possible values (but this list may be extended) are: adjusted, not available, estimated, as provided, incomplete, predicted, planned.

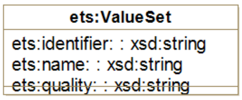


Figure 32 Detailed view of ValueSet

An event is a dedicated container for a value attached to something that happened. Apart the value itself, it is characterized by a cause (the reason for issuing the event), an instant (the time when the event occurred) and a state (the resulting state of the system that has issued the event). The value is serialized as a string but may have any datatype (integer, decimal, boolean …).

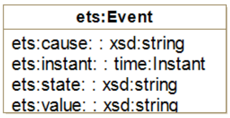


Figure 33 Detailed view of Event

A record is a dedicated container for a value or a set of values co-occurring. Apart the value(s), it is characterized by a rank (the position of the values if they are an element of a series), an instant (the time when the values were produced) and a period (the interval of time when the values were produced). The values are serialized as strings but may have any datatype (integer, decimal, boolean …).

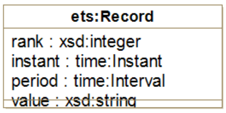


Figure 34 Detailed view of Record

A series is a dedicated container for a sequence of values. It is characterized by a step (the duration separating two elements of the series), a period (the interval of time between the first and the last element of the series) and several values (the number of elements in the series).

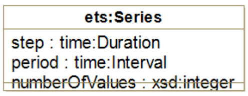


Figure 35 Detailed view of Series

5.2 EnergyDataSetOntology

The scope of this module of CSDM is the description of sets of energy-related data exchanged or shared in a Dataspace as shown in the following Figure 36.

An Energy data set contains a group of value sets (see previous section) gathered for a specific interaction across a Dataspace. There are three kinds of contextual information that can be added to the value sets in order to characterize this interaction. The first kind is an evaluation point i.e. an entity concerned by a value set. The second kind is a technical context that gives some details on the technical characteristics of a value set. The third kind of contextual information is a business context that adds some business-related information on a value set.

An energy value set is a specific case of a value set that is linked to these three categories of contextual information: evaluation point, technical context and business context.

The prefix for this module is ‘eds’ that stands for ‘energy data set’.

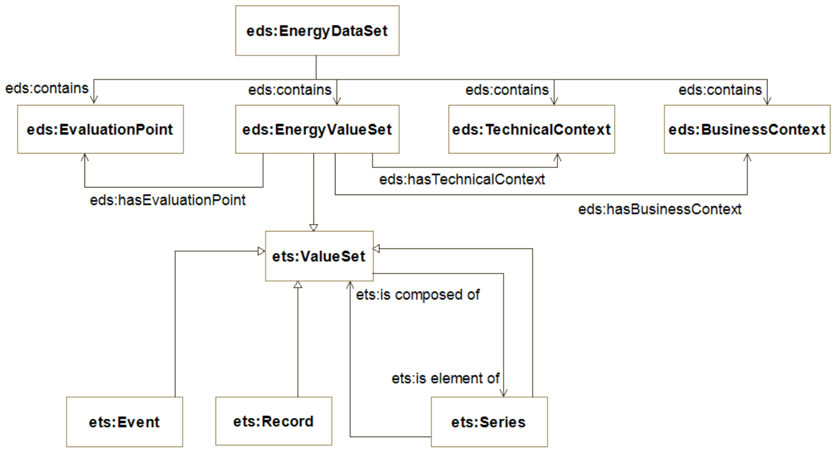


Figure 36 Overview of EnergyDataSetOntology

An evaluation point is an entity – either virtual or physical – that has served as an evaluation basis for a value set. It is characterized by three properties: an identifier, the location of the evaluation point in space and its category (any classification schema may be used).

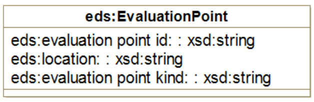


Figure 37 Detailed view of EvaluationPoint

A technical context is a set of properties that gives some technical details on a value set.

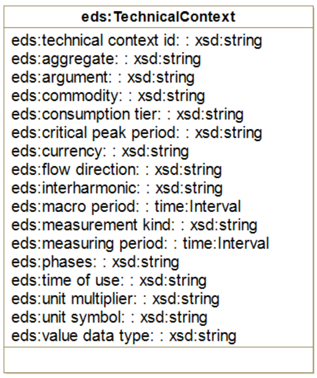


Figure 38 Detailed view of TechnicalContext

The signification and possible values of these properties are the following:

- technical context id: Identifier of the technical context.
- aggregate: Salient attribute of the reading data aggregated from individual endpoints. This is mainly used to define a mathematical operation carried out over 'macroPeriod', but may also be used to describe an attribute of the data when the 'macroPeriod' is not defined. Possible values are: none, average, axcess, highThreshold, lowThreshold, maximum, minimum, nominal, secondMaximum, secondMinimum, thirdMaximum, fourthMaximum, fifthdMaximum, sum, or other.
- argument: Argument used to introduce numbers into the unit of measure description where they are needed (e.g., 4 where the measure needs an argument such as CEMI(n=4)). Most

arguments used in practice however will be integers (i.e., 'denominator'=1). Value 0 in 'numerator' and 'denominator' means not applicable.

- commodity: Commodity being measured. Possible values are the following: none, electricitySecondaryMetered, electricityPrimaryMetered, communication, air, insulativeGas, insulativeOil, naturalGas, propane, potableWater, steam, wastewater, heatingFluid, coolingFluid, nonpotableWater, nox, so2, ch4, co2, carbon, hch, pfc, sf6, tvLicence, internet, refuse.
- consumption tier: In case of common flat-rate pricing for power, in which all purchases are at a given rate, 'consumptionTier'=0. Otherwise, the value indicates the consumption tier, which can be used in conjunction with TOU or CPP pricing. Consumption tier pricing refers to the method of billing in which a certain "block" of energy is purchased/sold at one price, after which the next block of energy is purchased at another price, and so on, all throughout a defined period. At the start of the defined period, consumption is initially zero, and any usage is measured against the first consumption tier ('consumptionTier'=1). If this block of energy is consumed before the end of the period, energy consumption moves to be reconed against the second consumption tier ('consumptionTier'=2), and so on. At the end of the defined period, the consumption accumulator is reset, and usage within the 'consumptionTier'=1 restarts.
- critical peak period: Critical peak period (CPP) bucket the reading value is attributed to. Value 0 means not applicable. Even though CPP is usually considered a specialised form of time of use 'tou', this attribute is defined explicitly for flexibility.
- currency: Metering-specific currency. Possible values are the following: AED, AFN, ALL, AMD, ANG, AOA, ARS, AUD, AWG, AZN …
- flow direction: Flow direction for a reading where the direction of flow of the commodity is important (for electricity measurements this includes current, energy, power, and demand). Possible values are the following: none, forward, lagging, leading, net, q1plusQ2, q1plusQ3, q1plusQ4, q1minusQ4, q2plusQ3, q2plusQ4, q2minusQ3, q3plusQ4, q3minusQ2, quadrant1, quadrant2, quadrant3, quadrant4, reverse, total, totalByPhase.
- interharmonic: Indication of a "harmonic" or "interharmonic" basis for the measurement. Value 0 in 'numerator' and 'denominator' means not applicable.
- macro period: Time period of interest that reflects how the reading is viewed or captured over a long period of time.
- measurement kind: Identifies "what" is being measured, as refinement of 'commodity'. When combined with 'unit', it provides detail to the unit of measure. For example, 'energy' with a unit of measure of 'kWh' indicates to the user that active energy is being measured, while with 'kVAh' or 'kVArh', it indicates apparent energy and reactive energy, respectively. 'power' can be combined in a similar way with various power units of measure: Distortion power ('distortionVoltAmperes') with 'kVA' is different from 'power' with 'kVA'. Possible values are the following: none, apparentPowerFactor, currency, current, currentAngle, currentImbalance, date, demand, distance, distortionVoltAmperes, energization, energy, energizationLoadSide, fanfrequency, fund, ieee1366ASAI, ieee1366ASIDI, ieee1366ASIFI, ieee1366CAIDI, ieee1366CAIFI, eee1366CEMIn, ieee1366CEMSMIn, ieee1366CTAIDI, ieee1366MAIFI, ieee1366MAIFIe, ieee1366SAIDI, ieee1366SAIFI, lineLoss, loss, negativeSequencephasorPowerFactor, phasorReactivePower, positiveSequence, power, powerFactor, quantityPower, sag, swell, switchPosition, tapPosition, tariffRate, temperature, totalHarmonicDistortion, transformerLoss, unipedeVoltageDip10to15,

unipedeVoltageDip15to30, unipedeVoltageDip30to60, unipedeVoltageDip60to90, unipedeVoltageDip90to100, voltage, voltageAngle, voltageExcursion, voltageImbalance, volume, zeroFlowDuration, zeroSequence, distortionPowerFactor, frequencyExcursion, applicationContext, apTitle, assetNumber, bandwidth, batteryVoltage, broadcastAddress, deviceAddressType1, deviceAddressType2, deviceAddressType3, deviceAddressType4, deviceClass, electronicSerialNumber, endDeviceID, groupAddressType1, groupAddressType2, groupAddressType3, groupAddressType4, ipAddress, macAddress, mfgAssignedConfigurationID, mfgAssignedPhysicalSerialNumber, mfgAssignedProductNumber, mfgAssignedUniqueCommunicationAddress, multiCastAddress, oneWayAddress, signalStrength, twoWayAddress, signaltoNoiseRatio, alarm, batteryCarryover, dataOverflowAlarm, demandLimit, demandReset, diagnostic, emergencyLimit, encoderTamper, ieee1366MomentaryInterruption, ieee1366MomentaryInterruptionEvent, ieee1366SustainedInterruption, interruptionBehaviour, inversionTamper, loadInterrupt, loadShed, maintenance, physicalTamper, powerLossTamper, powerOutage, powerQuality, powerRestoration, programmed, pushbutton, relayActivation, relayCycle, removalTamper, reprogrammingTamper, reverseRotationTamper, switchArmed, switchDisabled, tamper, watchdogTimeout, billLastPeriod, billToDate, billCarryover, connectionFee, audibleVolume, volumetricFlow.

- measuring period: Time attribute inherent or fundamental to the reading value (as opposed to 'macroPeriod' that supplies an "adjective" to describe aspects of a time period with regard to the measurement). It refers to the way the value was originally measured and not to the frequency at which it is reported or presented. For example, an hourly interval of consumption data would have value 'hourly' as an attribute. However, in the case of an hourly sampled voltage value, the meterReadings schema would carry the 'hourly' interval size information. It is common for meters to report demand in a form that is measured over the course of a portion of an hour, while enterprise applications however commonly assume the demand (in kW or kVAr) normalised to 1 hour. The system that receives readings directly from the meter therefore shall perform this transformation before publishing readings for use by the other enterprise systems. The scalar used is chosen based on the block size (not any sub-interval size).
- phases: Metering-specific phase code.
- time of use: Time of use (TOU) bucket the reading value is attributed to. Value 0 means not applicable.
- unit multiplier: Metering-specific multiplier. Possible values are the following: y, Z, A, F, P, n, micro, m, c, d, none, da, h, k, M, G, T, P, E, Z, Y.
- unit symbol: Metering-specific unit. Possible values are the following: none, m, kg, s, A, K, mol, d …
- value data type: Data type (integer, decimal, boolean, string...) of the values contained in the value set.
- A business context is a set of properties that gives some business details on a value set.

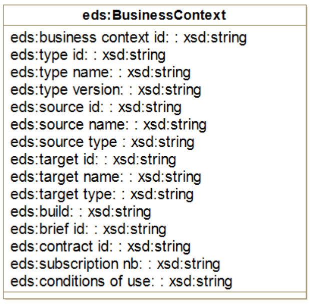


Figure 39 Detailed view of BusinessContext

The signification and possible values of these properties are the following.

business context id: Identifier of the business context.

type identifier: Identifier of the type of the business context.

type name: Name of the type of the business context.

type version: Version of the type of the business context

source identifier: Identifier of the source of the data exchanged.

source name: Name of the source of the data exchanged.

source type: Type of the source of the data exchanged.

target identifier: Identifier of the target of the data exchanged.

target name: Name of the target of the data exchanged.

target type: Type of the target of the data exchanged.

build: Time stamp of the data exchange.

brief identifier: Identifier of the brief associated to the business context.

contract identifier: Identifier of the contract associated to the business context.

subscription number : Number of the subscription associated to the business context.

conditions of use: Conditions of use associated to the business context.

5.3 Illustrations

5.3.1 Renewable

In this Renewable IM we created 2 energy data sets:

- « SendPVForecastData » that has as evaluation point the PV, and contains different time series such as « TS_ACVoltage », « TS_AmbientTemperature », etc.
- « SendAlarms » which contains a time series of alarms where each alarm is an event described by a name (alarm's code), a cause (potential cause) and a state (failure mode).

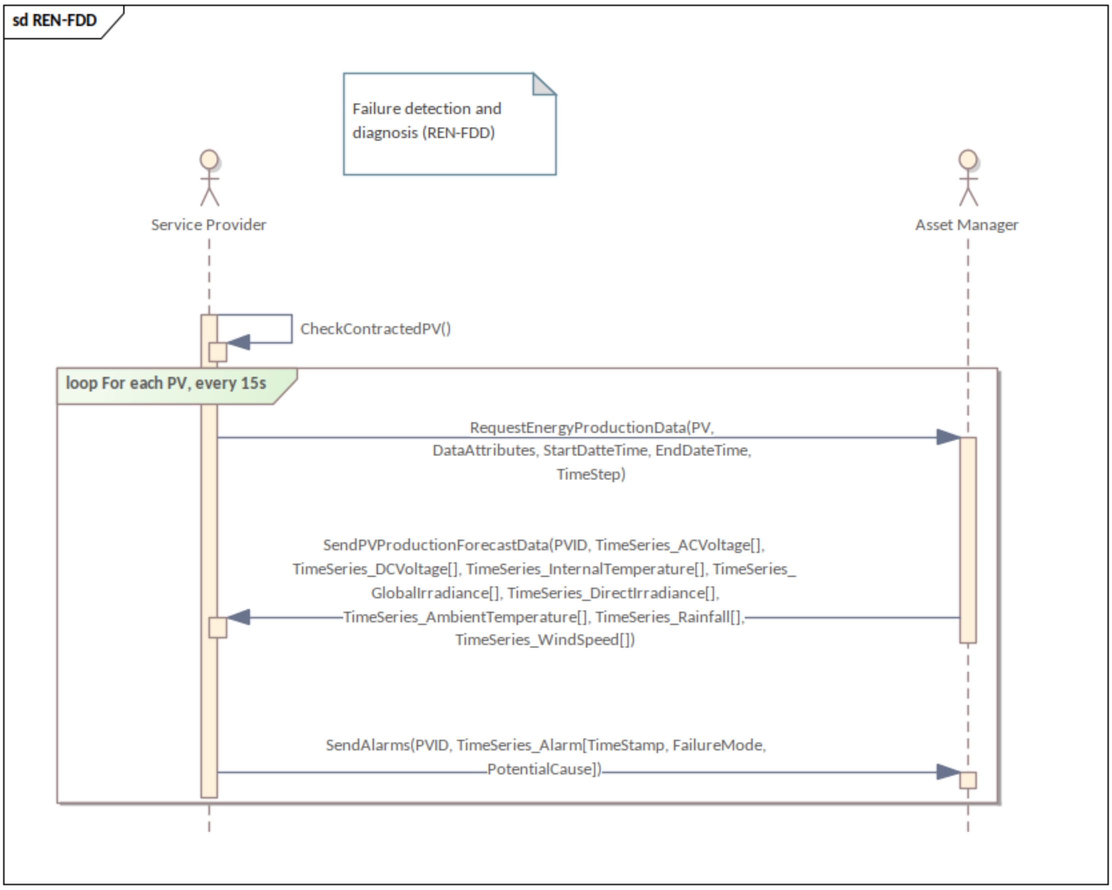


Figure 40 Renewable with alarms IM: REN-FDD

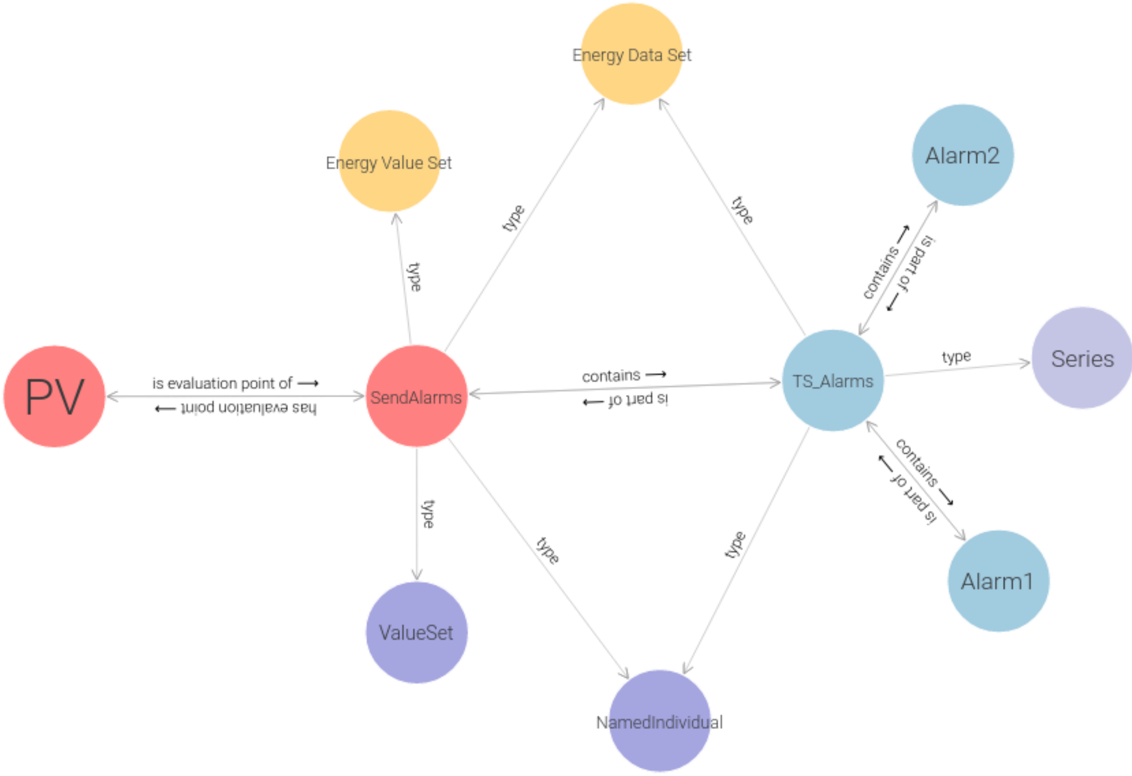


Figure 41 SendAlarm energy data set description

Figure 41 depicts the « SendAlarm » energy data set description.

5.3.2 Flexibility

In this Flexibility IM (Figure 42), we have two energy data sets : « SendMeterData » and « SendVisualData». Each data set has evaluation point the « Meter » which can be described by an id and a name. Each data set will contain time series. For example, « SendMeterData » will contain current time series for each phase (« TS_CurrentL1, TS_CurrentL2, TS_CurrentL3). The time series will have as step 15 seconds and is described by a corresponding technical context where the measurement kind, the phase and the unit symbol are added. « SendVisualData» contains time series that contain other time series. For example, the « TS_VoltageBoxPlotsL1 » time series used to draw the voltage box plot for each phase contains the time series for the minimum, maximum, Q1, Q2 and Q3 values. In these cases, an additional data property for technical context is used: « aggregate ». Figure 43 Description of « SendVisualData », depicts the description of « SendVisualData ».

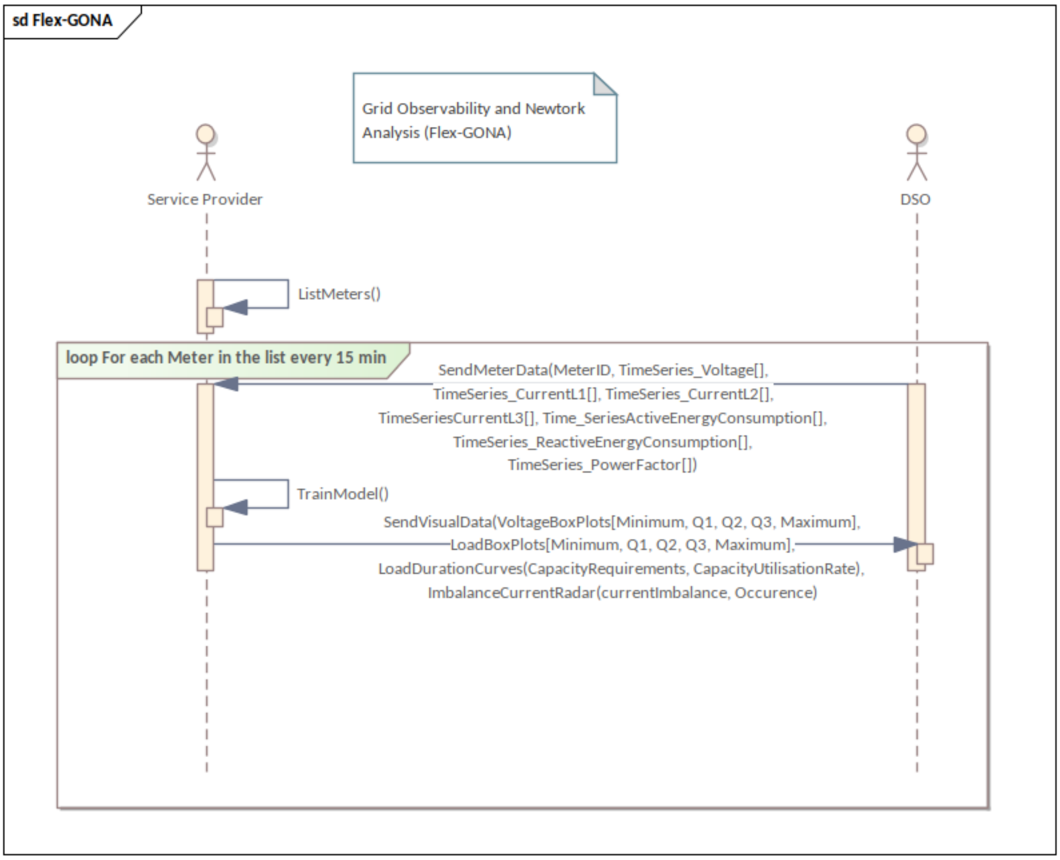


Figure 42 Flexibility IM: FLEX-GONA

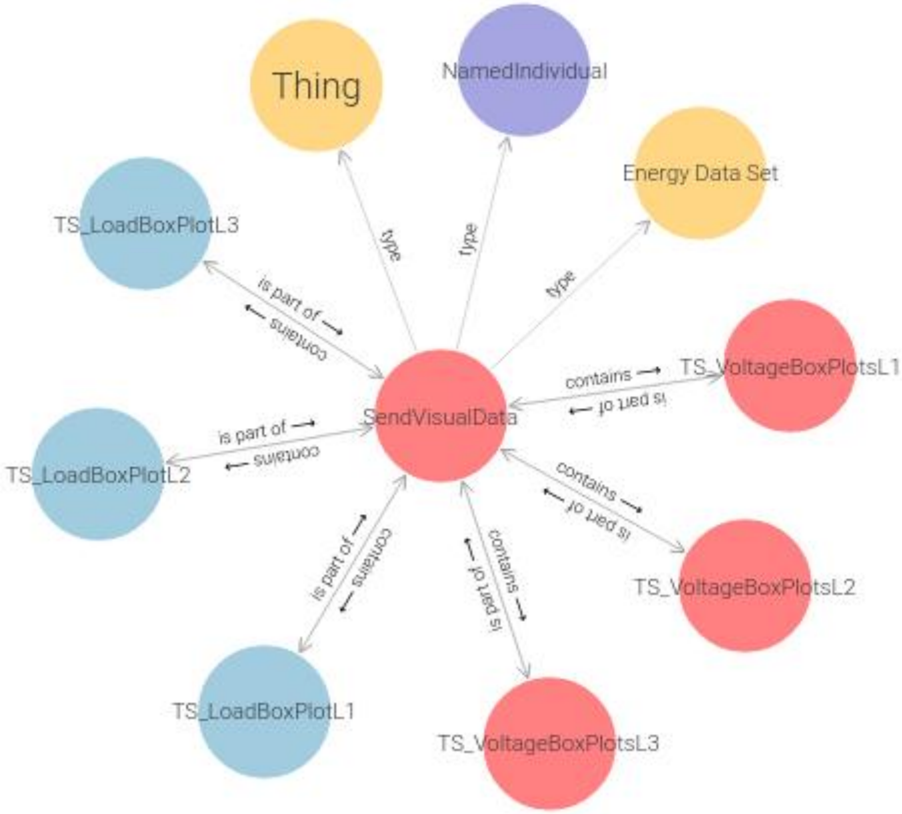


Figure 43 Description of « SendVisualData »

Figure 44 depicts an example of the description of a time series, in particular the Voltage box plot for L1.

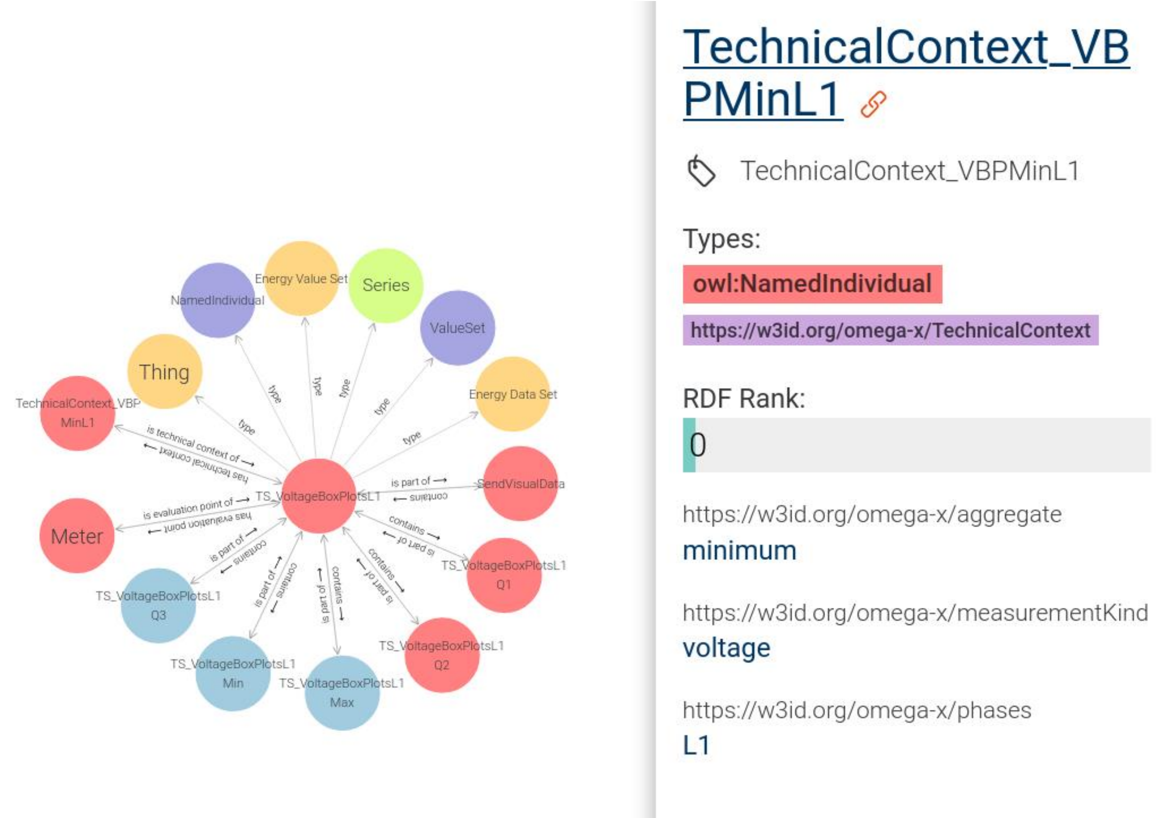


Figure 44 Example of the description of a time series (Voltage box plot for L1)

One of the CQs of this IM is to find the time series that contains energy data. This can be done by launching the following SPARQL query:

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX :  <https://w3id.org/omega-x/EnergyDataSetOntology/Flex/GONA#>
PREFIX omg: <https://w3id.org/omega-x/>
PREFIX om: <http://www.ontology-of-units-of-measure.org/resource/om-2/>
SELECT?x
         WHERE {
        ?x rdf:type omg:Series.
        ?x omg:hasTechnicalContext?y.
        ?y omg:measurementKind?z.
   FILTER (?z="energy"^^xsd:string)
   }
```

ANSWER

https://w3id.org/omega-x/Flex/GONA#TS_ActiveEnergyConsumption

https://w3id.org/omega-x/Flex/GONA#TS_ReactiveEnergyConsumption

6 Framework for Data Ingestion, Adapters & Alignment for Data Spaces

This section delves into essential aspects that form the foundation of the data ingestion and identification of resources to be used at OMEGA-X level.

Section 6.1 sets the stage by discussing the architecture profile based on ISO standards. It explores the context of data spaces, emphasizing their role in cross-domain interoperability. It provides insights into the integration of horizontal and vertical standards, including significant policy-level discussions. The concept of using profiles within data spaces is introduced, categorized into architecture profiles, interoperability profiles, and trustworthiness profiles. These profiles will form the backbone of OMEGA-X data space strategy, enabling achieving the project's objectives effectively.

Moving forward to **Section 6.2**, the report explores the critical building blocks setting up a Vocabulary hub that is able to provide the semantic context to all data sets that will be flowing into the Data Space, as a step previous to their indexing into the federated catalog.

Section 6.3 takes a deep dive into data ingestion principles and the outcomes of OMEGA-X pilot analysis. Understanding how data is generated at the source is crucial for data harmonization. This section discusses the information exchanged within the project use cases, offering insights into data formats, access types, and measurement frequencies. This section will pave the way for our data space's efficient data ingestion and harmonization process.

Continuing the journey, **Section 6.4** focuses on the IDSA Connector and Data Models. The section explores the International Data Spaces Association (IDSA), its open standard for data exchange, and the Reference Architecture Model (RAM). The Information Model defines the concepts regarding exchanged information, as well as its role in ensuring secure and trusted data exchange. This section will highlight the key components and models essential for the project's data ecosystem.

Finally, **Section 6.5** establishes the link between data ingestion, harmonization, and compliance within OMEGA-X. The importance of semantic activities performed by the Vocabulary Hub is emphasized as a prerequisite for data harmonization and compliance.

6.1 Architecture Profiles based on ISO Standards

Data space context

Data spaces will serve multiple domains (energy, transport, health) and enable cross-domain interoperability. But to make this happen there is a need to integrate properly standards, horizontal standards (common to all domains) and vertical standards (specific to a given application domain).

Integration of horizontal and vertical standards

This concern of integration has been discussed multiple times at the policy level:

- The annual workshop ISO/CASCO [12] (committee focusing on conformity assessment) that took place in April 2023, 28th, on digitalization in conformity assessment included a keynote speech [13] on the definition of profiles integrating horizontal and vertical standards.
- The European commission recently organised a workshop [14] on the interplay between horizontal and vertical standards addressing three domains (health, aeronautics and automotive) highlighting the need for profiles.

- ISO/IEC JTC1 [15] has started some specific groups that addresses the interplay i.e., AG19 on drones, AG21 on strategic directions.

Using profiles in data spaces

In order to address integration, a profile approach is proposed. Profiles is a mature concept that has been applied in many cases for decades. ISO 10000-1 (Framework and taxonomy of International Standardized Profiles) [16] , was published in 1998, and has been used in initiatives such as OSI, OSE, ISO/IEC 29110, or ISO/IEC 20944-5 to guide the creation of profiles. In a nutshell, a profile is *a set of one or more standards, subsets, options, parameters, necessary to accomplish a particular function.* Three profiles are identified:

- **Architecture profiles** to express common high-level requirements and solution requirements where high-level requirements focus on data space reference architecture, and solution requirements focus on implementation standards (e.g., published by IDSA, Gaia-X)
- **Interoperability profiles** to express common semantic interoperability requirements and data exchange solution requirements, where high-level requirements focus on semantic based interaction models and solution requirements focus on implementation solutions (e.g. common semantic data models repository, connectors specification, …). Interoperability profiles have been defined for IEC CIM Model. Refer to IEC 62361-103 (Standard Profiling), IEC 61970-401 (Profile Framework), IEC 62325-450 (Profile and context modelling rules). The following figure describe the general profiling methodology associated to IEC CIM and IEC 61850 as presented in IEC 62361-103:

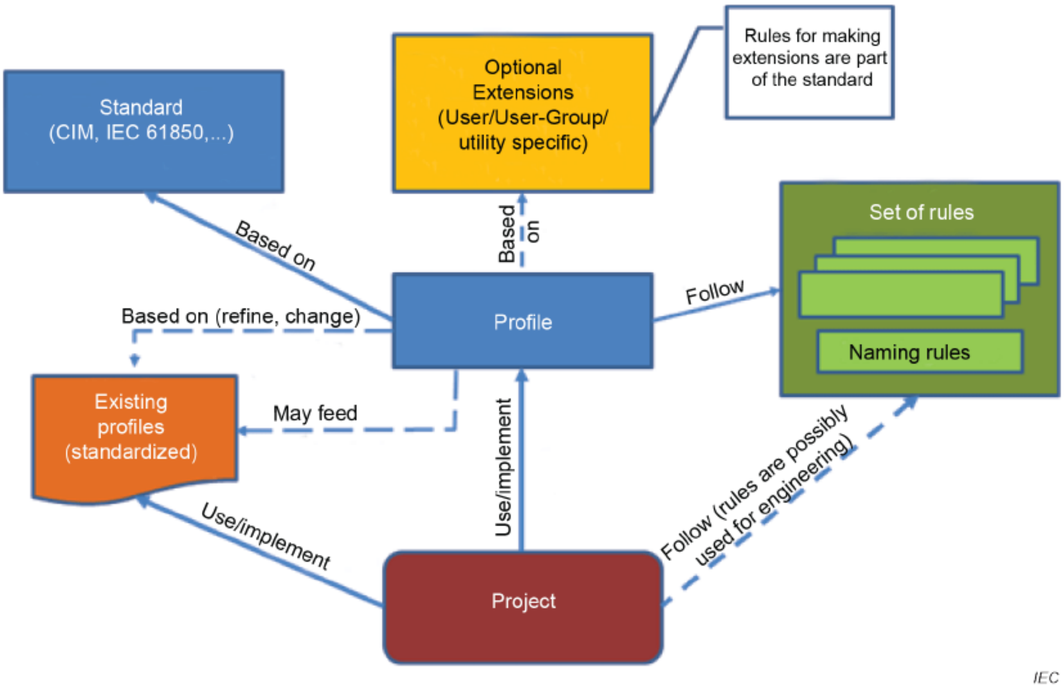


Figure 45 Framework for profile

The following figure described the main steps for profiling IEC CIM:

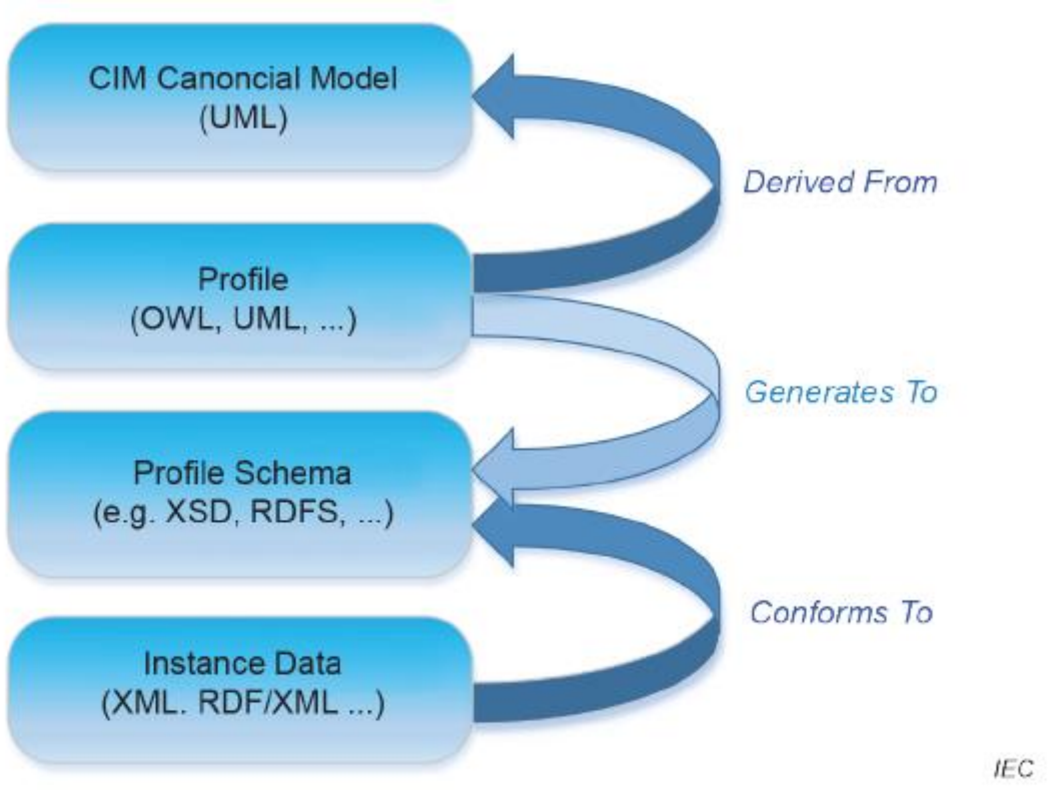


Figure 46 Main steps for profiling IEC CIM

- **Trustworthiness profiles** to express requirements on verifiable stakeholder expectations and solution requirements, where high-level requirements focus on behavior models and solution requirements focus on implementation solutions (e.g., trusted data transaction, digital twin validation and verification).

Figure 47 shows the relationship between the three types of profiles: interoperability and trustworthiness profiles extend architecture profiles. The combination of the three profiles allows for a complete ecosystem. Note the following:

- there might be several architecture profiles;
- there might be several interoperability profiles for the same architecture profile, and
- there might be several trustworthiness profiles for the same architecture profiles.

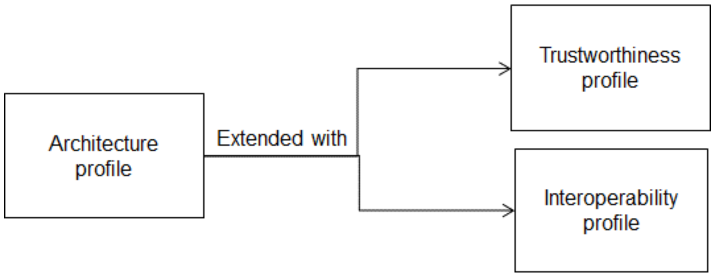


Figure 47 Relationship between profiles

Figure 48 shows the relation between organisations and profiles: profiles are standards which organisations use for compliance. Architecture profiles enable the use of common data space platforms. Interoperability profiles enable data sharing and trustworthiness profiles enable data access and usage enforcement.

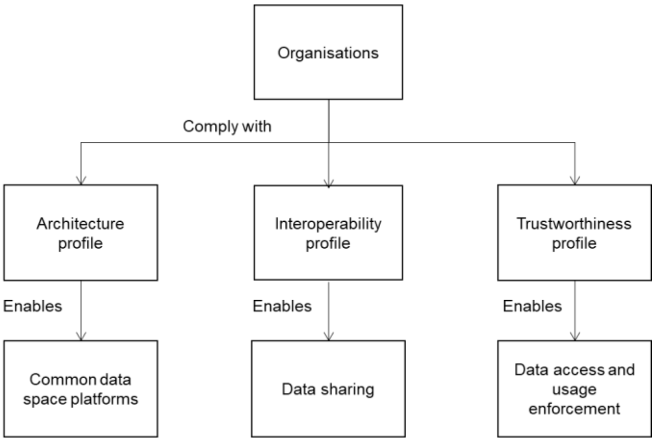


Figure 48 Relationship between organisations and profiles

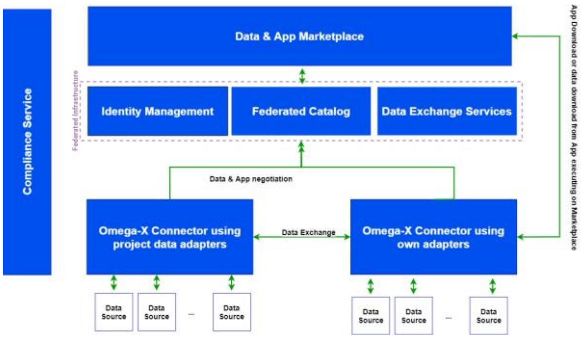
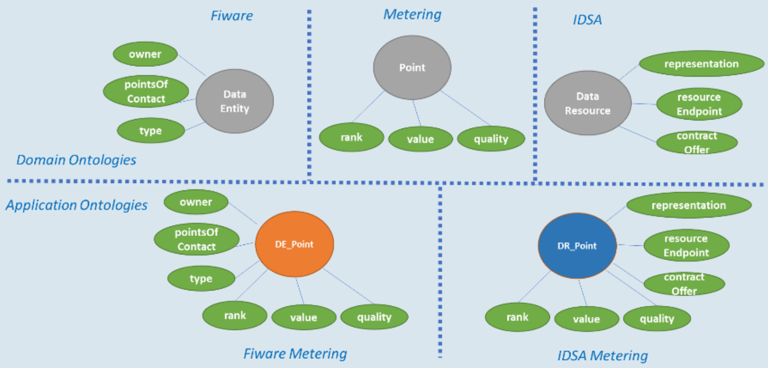
6.2 Principles for a Data Space Vocabulary Hub

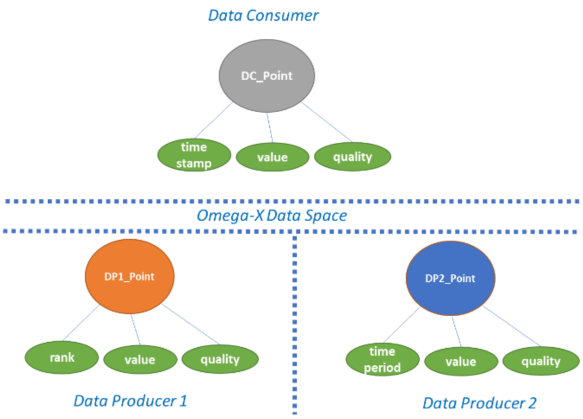
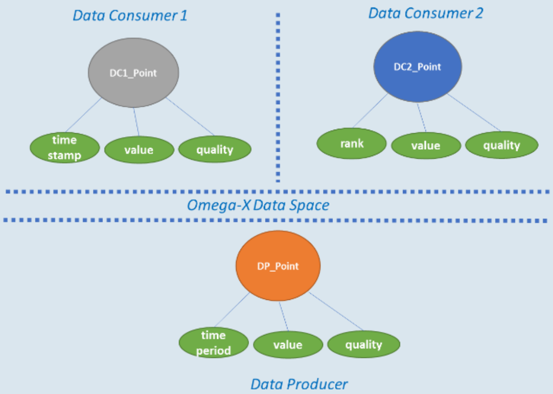
Ten architecture principles are underlining OMEGA-X ontology development. We first list some definitions of terms, and then describe and illustrate each architecture principle.

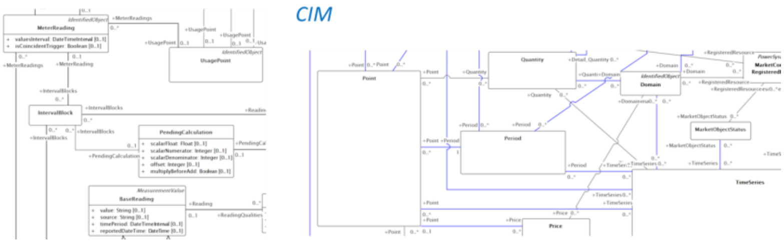
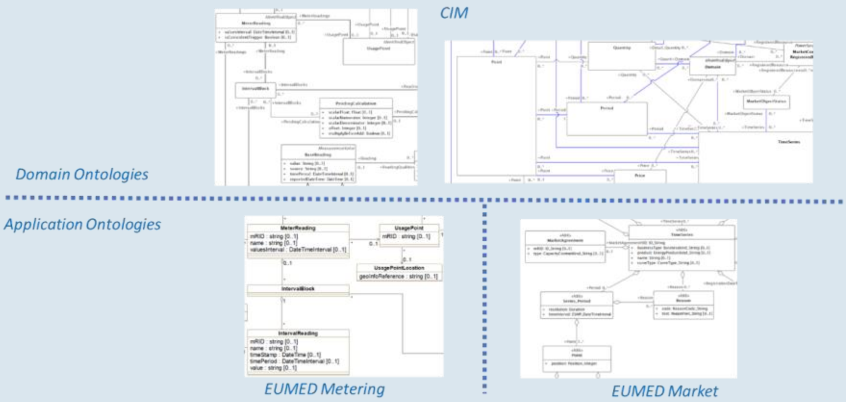
Table 8 Terms used

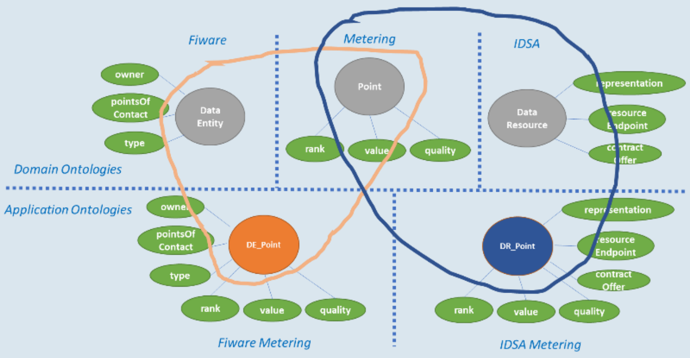
Terms Used	Definitions
Domain ontology	all the concepts known in a specific domain, e.g., electromobility
Application ontology	concepts used in the context of a specific application, e.g., booking of charging points for electrical vehicles.
Data sharing	communication of data based on a dataset accessible by data readers and data writers, e.g., charging sessions registered in a charging point
Data exchange	communication of data based on a dataflow produced by data producers and consumed by data consumers, e.g., state change notifications sent by a charging point.
Data distribution	fragmentation of a dataset on several sites, each fragment may be duplicated. This architecture may be applied to an ontology
Data federation	interconnection of several datasets, each dataset may have its own data model.

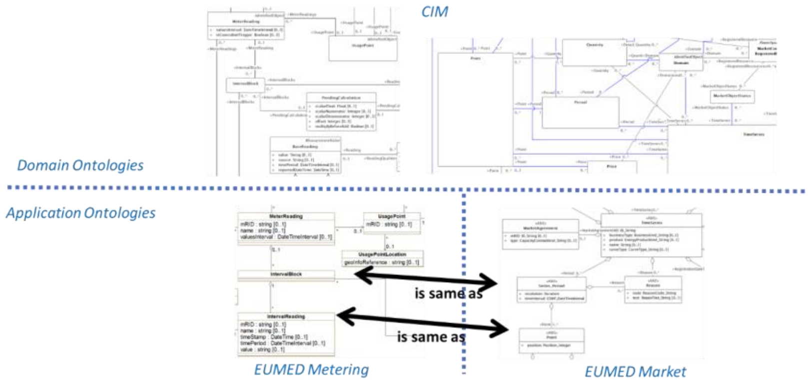
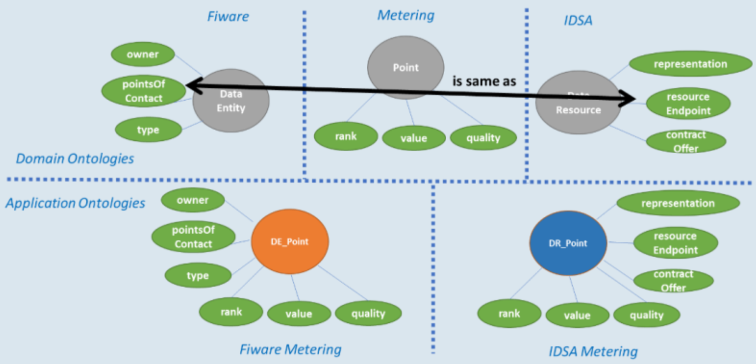
Table 9 Principles for a data space vocabulary hub

<table>
<tr><th>Principles</th><th>Definitions</th></tr>
<tr><td>Principle 1 – At the semantic level, the way data has been acquired is transparent</td><td>The current system architecture of OMEGA-X project is illustrated in the following figure. Data ingestion is performed by Data Source component and data is made available to Data Exchange Services component or Data&App Marketplace component through Connector component. This encapsulation of the data ingestion in Connectors offers abstraction with regards to acquisition technology to other components of the data space.

</td></tr>
<tr><td>Principle 2 – Conceptual model for a data space is described as a domain ontology</td><td>OMEGA-X_D2.2 “Data Space initiatives/projects in EU and BRIDGE alignment” concluded that “Harmonization of architectural frameworks and assets of the four data space initiatives assessed has not yet been achieved. This situation hinders global interoperability and will impose to OMEGA-X project to adopt an agile development strategy for both the definition of its own framework and the production of its software building blocks.” This principle will avoid tight coupling between a data set and the data space(s) where it is made available. For instance, a metering data may be published on two data spaces, one conformant to Fiware and the other to IDSA. In the first case, the published data will refer to Fiware and Metering ontologies. In the second case, the published data will refer to IDSA and Metering ontologies.

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

<table>
<tr><th>Principles</th><th>Definitions</th></tr>
<tr><td>Principle 3 – A conceptual model used by a data consumer is loosely-coupled to conceptual models used by data producers</td><td>This principle ensures that, in case of model disparities among several data sources, semantic alignment is handled at the level of the semantic data model. For instance, a metering data may be published by two data producers, one using a rank in a timeseries and the other a time period to localize the measurement in time. The data consumer may wish to use a timestamp for this purpose.

</td></tr>
<tr><td>Principle 4 – A conceptual model used by a data producer is loosely-coupled to conceptual models used by data consumers</td><td>This principle ensures that, in case of model disparities among several data requests, semantic alignment is handled at the level of the semantic data model. For instance, a metering data may be published by a data producer, using a time period to localize the measurement in time. One data consumer may wish to use a timestamp for this purpose while another data consumer may use a rank in a timeseries.

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

Principles	Definitions
Principle 5 – Conceptual models for data sharing are described as domain ontologies	This principle guarantees that IEC CIM models for instance can be used directly for data sharing interactions. For instance, left part of the figure below illustrates some entities and their relationships that can be used for metering operations and right part of the figure illustrates some entities and their relationships that can be used for market operations. These models can be directly instantiated to share business entities in these two operations. 
Principle 6 – Conceptual models for data exchange are described as application ontologies	This principle guarantees that data exchange models are derived from one or several domain ontologies. For instance, bottom left part of the figure below illustrates a standard exchange model derived from the IEC CIM used to exchange metering data and bottom right part of the figure illustrates another standard exchange model used to exchange market data. These exchange models can be instantiated to exchange data in these two different contexts. 

Principles	Definitions
Principle 7 – A domain ontology has a unique reference composed of its name, version number, publication date and site location	This principle eliminates any ontology where one of these information is unknown. It also fosters configuration management (version), freshness (publication date) and accessibility (location). For instance, in the IoT domain, SAREF exists in three different versions. Name: SAREF Version number: 1.1.1 Publication date: Nov. 2015 Site location: https://www.etsi.org/deliver/etsi_ts/103600_103699/103673/01.01.01_60/ts_103673v010101p.pdf (pdf) Name: SAREF Version number: 2.1.1 Publication date: March 2017 Site location: https://w3id.org/saref ou https://ontology.tno.nl/saref/ (html) Name: SAREF Version number: 3.1.1 Publication date: Feb. 2020 Site location: https://labs.etsi.org/rep/saref/saref-core/-/tree/release-v3.1.1/ontology (ttl)
Principle 8 – An application ontology refers to one or several domain ontologies	This principle can be implemented by reference (only pointers to the concepts of the referenced ontology are used in the application ontology) or by value (a copy of the referenced ontology is used in the application ontology). In case of the approach by value, the local copy will be linked to the referenced ontology. For instance, in the example illustrating principle 2, 'FIWARE Metering' application ontology refers to two domain ontologies 'FIWARE' and 'Metering' ontologies while 'IDSA Metering' application ontology refers to two domain ontologies 'IDSA' and 'Metering' ontologies. 

Principles	Definitions
Principle 9 – Intra-domain interoperability is supported by similarity links among application ontologies	This principle ensures that semantic alignment is possible among data models sharing the same domain ontology. For instance, in the example illustrating principle 6, some concepts defined in 'EUMED Metering' application ontology may be found similar as concepts defined in 'EUMED Market' application ontology. 
Principle 10 – Inter-domain interoperability is supported by similarity links among domain ontologies	This principle ensures that semantic alignment is possible among several domain ontologies. This term should be preferred to horizontal interoperability. For instance, in the example illustrating principle 2, some concepts defined in 'FIWARE domain ontology may be found similar as concepts defined in 'IDSA' domain ontology. 

6.3 Applying the Principles and Results of the Pilot Analysis

One of the initial steps towards both data harmonization and data ingestions consists of understanding how the data is generated at the source. The initial analysis of the data that is being used and, more importantly, indexed in the data space, was started at OMEGA-X_D3.1

[6]. This deliverable contains a section analysing OMEGA-X Business Use Cases, using the IEC 62559-2 standard [7] [8].

On the template for the use case description, the IEC 62559-2 standard defines a section for "Information Exchanged" which is a table describing the nature of the data and why is it flowing through the use case. Nevertheless, this is not enough to produce a thorough analysis for the data ingestion and harmonization. This is why OMEGA-X partners decided to extend the information exchanged table with the extra fields detailed below. The complete responses of the different use case families are included in the Annexes of this report, while in the following a summary of the conclusions are included.

The Data Exchange Information Table (DEIT) collects and summarises most the different data communication needs for each use-case family. The extra fields included in the table are aiming at:

- **Data Format.** This will allow determining the format used for the data being exchanged at use case level (JSON, CSV, XML…)
- **Data access type.** This field indicates whether the use case will consider real time exchange (streaming) so that the data will be sent periodically or by request grouping several measurements together (batch).
- **Measurement Frequency Rate.** This indicates how often the value for each data attribute is collected. For batch files, this is the frequency of sampling, although the batch might send the aggregated data less often.
- **Measurement Range.** These are the expectable limits on the measurement. This will ease the process of quality checks.
- **Personal data (GDPR).** Use case families are asked to indicate whether the information could be considered as personal information or not. Personal Data which is fully anonymized is not considered Personal Data. The goal of the data space is to index just non-personal data.
- **Transmission Frequency.** This is to report the frequency used to send the data. In streaming cases, this coincides with the measurement frequency rate.
- **Transmission Protocol.** This important field includes information about the protocol used in the data exchange (inside or outside the connector).
- **Data exchange inside the Data Space.** "Yes" indicated if this data is flowing inside the data space (connector or internal modules), whereas "No" is when data is exchanged outside (service APIs).

Table 10 Additional information included in the DEIT.

Additional Information to be included	
Data Format	[JSON/CSV/XML...]
Data Ontology/ Information Model	[NGSI-LD/SAREF/Other standards]
Data access type	[Streaming/batch]
Measurement Frequency Rate	1 measurement every 10s/10min/1h…

Additional Information to be included	
Measurement Range	Minimum Maximum and typical values expected (e.g., min:10W max: 300W typical: 80W)
Personal data (GDPR)	Yes/No
Transmission Frequency	1 message every 10min/1h/1day…
Transmission Protocol	[MQTT/AMQP/Rest API/S3...]
Data exchange inside the Data Space	[INSIDE the Data Space/OUTSIDE the Data Space]
If REST API: Documentation/Specification	Link to REST API documentation or postman collection

During a first iteration of the DEIT, and after a preliminary analysis conducted on its outcomes, some interesting insights have been identified.

One of the firsts remarkable results is the great alignment between most of the data providers. Having such a diverse variety of data providers sharing same technologies vastly simplifies the communication challenges. Moreover, the reached consensus evidences why these technologies and protocols are the de facto standard for their use cases. Another relevant result is the agreement on the use of open-source technologies which add yet another layer of robustness and security to the proposed solution.

Following these results, and thanks to the general unanimity, project-wide decisions can now be made regarding certain requirements. One such decision is the adoption of **JSON-LD (JavaScript Object Notation for Linked Data)** as the optimal data format solution for this project."

JSON-LD is a powerful and flexible data format that has quickly gained importance in modern web development and data integration projects. It builds upon the widely adopted JSON format, adding key capabilities to enable the seamless exchange and integration of structured data on the web. JSON-LD is designed with a strong focus on semantic meaning, making it particularly well-suited for representing linked data and facilitating interoperability between different systems and platforms. Its versatility and adherence to web standards have made it a preferred choice for structuring data in a manner that is both machine-readable and human-friendly, making it an ideal fit for data space’s data format requirements.

Regarding data communication protocols a similar consensus has been reached. Despite the immense variety of available solutions either for real-time or batch communications such as MQTT, AMQP, S3 or FTP; the paradigm selected is **REST-APIs (REpresentational State Transfer Application Programming Interface).**

Although REST-APIs was originally designed to be a web-based architecture, their use-cases have been growing since the first conception and nowadays it’s a valid protocol for transmitting information both in batch and in real-time or near real-time. The list of benefits offered by REST-APIs is huge and some of them are extremely relevant. In terms of security, for instance, the encryption protocols used in the modern web (HTTPS and TLSv1.2/1.3) grants the safest and fastest cypher suites standards and ensures the integrity and privacy of the data shared against all means of attacks. On the other hand, the flexibility and the comprehensible documentation eases a fast and seamless development of new solutions to integrate the data sources.

Finally, the DEIT also showed a clear preference about transmitting the **data in batches** instead of in real-time. As stated above, REST-APIs support both types of communications so the decision of using batch transfers does not imply any changes in the previous decisions. Although batch size might also differ from one use-case to another, these changes should be handled by the APIs without impacting the performance.

These outcomes and agreements will be fed to the development team in OMEGA-X for the Data Space components. In the following iterations of this report, and also in the reports related to the Data Space releases (OMEGA-X_D4.2 [17] and subsequent deliverables), the analysis will be extended.

6.4 IDSA Connector and Data Models

The International Data Spaces Association (IDSA) is a non-for-profit association of more than 140 partners that aims to stablish an international open standard for sovereign data exchange allowing the generation of data spaces that can foster the data economy [18].

IDSA has defined an open-source Reference Architecture Model (RAM) [19] which defines the reference architecture and the necessary building blocks for secure and trusted data exchange in business ecosystems. The IDS Reference architecture pursues the idea of a federated data ecosystem which requires a comprehensive description of each data source and the value and usability of data for other companies, combined with the ability to integrate domain-specific data vocabularies. In addition, Metadata Brokers in the ecosystem provide services for real-time data search. The IDS connector is a central component of the architecture, is implemented in different variants and can be acquired from different vendors. Nevertheless, each Connector is able to communicate with any other Connector (or other technical component) in the ecosystem of the International Data Space following the IDS Information Model.

The IDS Information Model is an RDFS/OWL-ontology which defines the fundamental concepts regarding the information that is exchanged by participants by means of the IDS components. The ontology is open-source and it is publicly available in https://w3id.org/idsa/core. The IDS Information Model is a generic model which aims at describing, publishing and detecting data assets and data apps (services). Domain specific data models are delegated to shared vocabularies provided by domain-specific communities (e.g. SAREF, OntoWind, etc.). The Information Model does not provide a meta-model for defining custom structured datatypes comparable to the OData or OPC-UA standards. Considerations beyond the scope of modelling digital assets and their interchange are considered out-of-scope. The Information Model does not deal with the side effects of data exchange (on Data Consumer's side), for example in scenarios where data is used for real-time machine control. RPC (remote procedure call) semantics of data messages is also not covered by the Information Model. The IDS information model leverages other well-known ontologies such as ODRL for data usage control as shown in Figure 49.

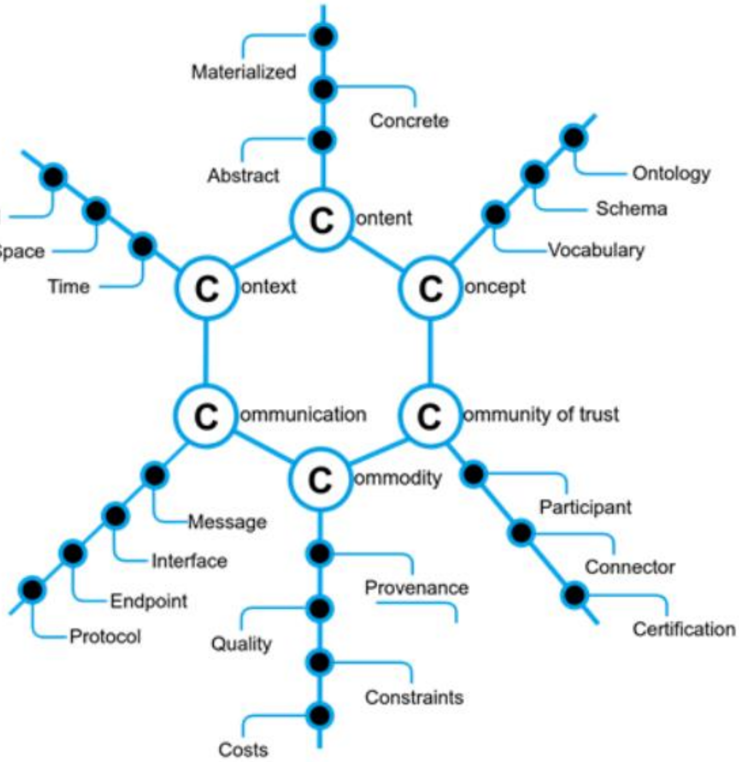


Figure 49. IDS information model. usage control language [5]

6.5 Data Ingestion and Harmonization Link with the Compliance Modules

The activities for data ingestion and harmonization are very much linked to the compliance activities OMEGA-X Data Space should enforce so that if follows the principles and recommendations of the references identified as primary both at proposal level and also as described when introducing the high level architecture at OMEGA-X_D3.1 [6].

OMEGA-X compliance goals are set for both IDSA and Gaia-X. In the former case, the compliance is obtained by using certified Data Space Connectors and following the principles of the rulebook [18]. In the latter case, the compliance is given by the ability of a given data space to obtain signed compliance verifiable credentials from a Gaia-X Digital Clearing House.

The details on both the connector selection and implementation together with the Digital Clearing House deployment (including the underlying modules for compliance, registry, catalog, etc.) in OMEGA-X will be documented in OMEGA-X_D4.2 [17],which covers the description, analysis and implementation of the horizontal Data Space modules.

For harmonization purposes, the important message on this would be to stress the importance of the semantic activities conducted by the Vocabulary Hub (as described in section 6.2) as step to be performed before indexing metadata in the OMEGA-X catalog, compliant with Gaia-X.

7 Conclusions

At this stage of the project, we have focused on the production of a Common Semantic Data Model (CDSM) V1 to cover the needs of the OMEGA-X MVP (Section 5). Four use case family workshops (flexibility, renewable, local energy community, and electromobility) were carried out, where the project focused on data exchanged within the use cases from data providers to data consumers, more precisely the content of the data itself. As a result, we focused on the modelling of timeseries, units and measurement type.

In order to ensure extensions and improvement of CSDM, we have defined

- AIME (Agile Interaction model-based Methodology for Energy dataspaces) to develop extensions to the CDSM (Section 4)
- A CSDM framework for the management of a vocabulary hub in data spaces (Section 6)

The OMEGA-X CSDM, the AIME methodology and the CSDM framework

- will be used and improved during the pilots of OMEGA-X,
- will be proposed to sister projects of OMEGA-X such as Enershare, Data Cellar, Eddie, and Synergies and IntNet (the hub of sister projects).
- will be proposed as enablers to data space support actions projects such as Int:net (energy data space support), DSSC (Data Space Support Center), and

will be proposed as contributions to ongoing standards such as ETSI SAREF4Grid, ETSI Interconnect ontologies supported by ETSI SAREF, and standards on interoperability2 in ISO/IEC JTC 1/SC41 (IoT and digital twin).

[2] PWI Behavioural and policy interoperability that will be proposed in the ISO/IEC 21823 series

8 References

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[14] Key note speech by Antonio Kung from Trialog. See first 15 mn of video (https://web.cvent.com/event/224b7c02-f757-46e2-b75a-413228b80196/websitePage:f859d15c-7f53-424f-8246-bc9c99aaf48f?locale=en-US&tm=-H1rU8lztthusI-rnJ4Ap1u6mIxWKIgrQK6V3dFwmWE).

[15] https://futurium.ec.europa.eu/en/european-ai-alliance/events/exploring-interplay-between-horizontal-and-vertical-standardisation-deliverables.

[16] *ISO/IEC JTC 1 Information technology https://www.iso.org/committee/45020.html.*

[17] ISO/IEC TR 10000-1:1998 Information technology Framework and taxonomy of International Standardized Profiles Part 1: General principles and documentation framework https://www.iso.org/standard/30726.html. This standard is freely available, ISO, 1998.

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[23]“International Data Spaces Association (IDSA),” [Online]. Available: https://internationaldataspaces.org/. [Accessed 23 August 2023].

Annex AOntology Templates

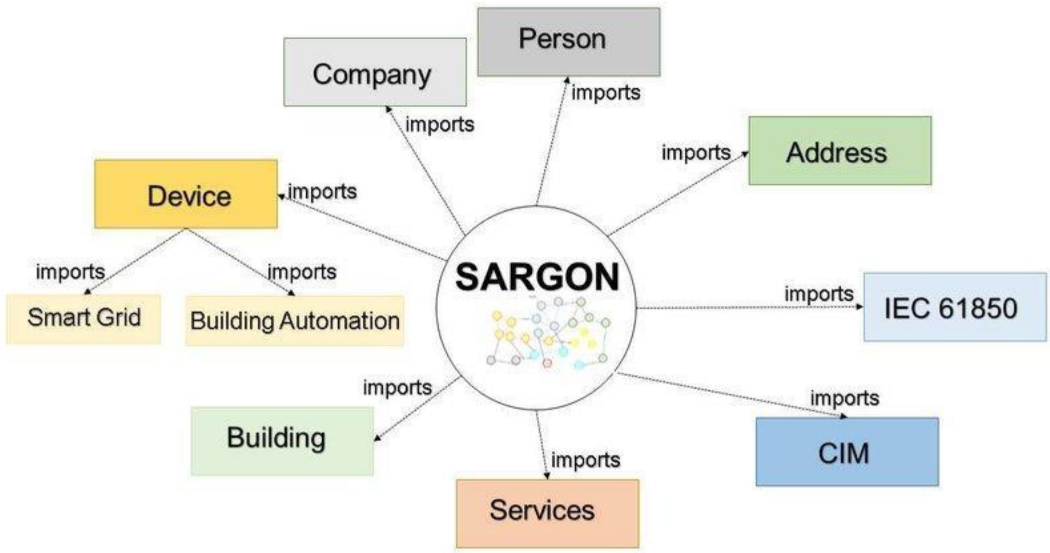
This section provides templates describing SARGON, Interconnect using ETSI SAREF, PLATOON/SEDMOON, BD4OPEM, SEAS, IEC CIM, and DLSM-COSEM, IEC 61850).

A.1 Ontology Template – SARGON

Ontology Overview
• Define the ontology full name: SmArt eneRGy dOmain oNtology • Define the ontology acronym: Example: SARGON • Creator of the ontology and organization: Maliheh Haghgoo & Antonello Monti (Institute for Automation of Complex Power Systems, E.ON Energy Research Center, RWTH Aachen University, Germany), Ilya Sychev & Frank H.P. Fitzek (Deutsche Telekom Chair of Communication Networks, Technische Universität Dresden, Germany) • Ontology version number: 1.0? • Ontology date of publication?

Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL): https://sargon-n5geh.netlify.app/ontology/1.0 • Persistent URI of Ontology File: https://sargon-n5geh.netlify.app/Resources • Research Papers Describing Ontology: SARGON–Smart energy domain ontology [Haghgoo et al. *IET Smart Cities* 2020] https://ietresearch.onlinelibrary.wiley.com/doi/pdf/10.1049/iet-smc.2020.0049

Ontology Domain & Description & Usage
• Define the domain of interest/ Topic/ Scope: Energy: Local energy, Renewable, IoT/ Smart Appliances, Smart Home/Building, Smart Grid Describe the ontology: It is an open-source effort to define semantic descriptions of the smart assets in building automation and smart grid and the relationships between them. SARGON consists of an extensible dictionary of terms and concepts in and around building and smart grid, a set of relationships for linking and composing concepts together, and a flexible data model permitting seamless integration of SARGON with existing tools and databases. Through the use of powerful Semantic Web technology, SARGON can describe the broad set of Devices and custom features, assets and subsystems found across the building stock in a consistent matter.
• Usage of the ontology: In which context and projects has the ontology been developed? N5GEH, a German funding research project which looked into the usage of fifth generation (5G) mobile standard for applications in smart energy technology, with special reference to building energy technology.

Ontology Domain & Description & Usage
• What are the use cases? ○ Automation of medium voltage distribution grids ○ Phasor measurement units (PMU) interaction and data visualization ○ Building automation and monitoring: The control of energy demand in buildings such as gas, electricity, hot ○ Energy management with residential/non-residential involvement: ○ Energy management in building/districts level: It targets the interaction between the energy management of building/districts and their electrical automation. • What are the competency questions? Not available • What are the main ontology concepts? Or provide the figure overview See figure below.  https://www.researchgate.net/publication/357812863/figure/fig1/AS:1111945939816449@1642119979370/SARGON-Ontology-Network-Structure-24_W640.jpg

Ontology Modelling, Reusability and Availability
• Ontology implementation language: In what language the ontology is implemented? Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? TTL and OWL JSON • Does the ontology have a usage license? Which one? No • Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? • Referenced on ontology catalogs: No • PURL URL: https://sargon-n5geh.netlify.app/ontologies/ • Reuse of ontologies: SAREF, W3C time • Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? No • Ontology Catalog: In what ontology catalogs is registered the ontology? No

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL4. Justify the choice of this TRL: Validated in the N5GEH test case • Ontology Adoption: Is the ontology adopted by the industry and used in practice? Are there relevant communities behind it (industry, standardization, research)? Is it supported by standards, which? Currently adopted in MATRYCS, I-NERGY, EnerShare • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Have upper ontologies been extended? Have ontology design patterns been used? • Has this ontology been used by other ontologies? SARGON ontology aligned with ontologies such as SAREF, and IEC CIM, IEC 61850 data models. The requirements specification of SARGON is carried out according to the CIM and IEC standard. These two standards are taken as a pattern to identify terms, relations, and to extract the domain model. In particular, CIM and IEC 61850 data model have been considered to describe the basic components and data model, terms, and relations used to transmit electricity and manage the building energy domain besides monitoring and protection of smart grids. • Sustainability & Maintainability: Is there a community maintaining the ontology? Is there a sustainability plan? Is there a plan for the medium and long-term maintenance of the ontology? Yes, ACS is the main community for now. There are sustainability plan and maintenance plan. Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 2 - an organization

Reasoning
• Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose) Yes, Pellet reasoning

IoT/Sensor
• What are the sensors used? Add Sensor measurement name and unit. Home and buildings sensors (temperature, humidity, energy-plugs, energy clams, energy meters, water-flow, water quality, presence, occupancy, air monitors, environmental sensors, CO2 sensors, weather stations, etc.) and actuators (windows, doors, stores). Sensors belonging to appliances are treated individually, White goods, as classified by CECED, Rinsing and Cleaning, Cooking and Baking, Refrigerating and Freezing, Vacuum Cleaning , Washing and Drying, HVAC; heating, ventilation, and air conditioning, plumbing, security and electrical systems, as classified by Eu.bac, Lighting, with use cases as defined by Lighting Europe (f.k.a. ELC), Micro renewable home solutions (solar panels, solar heaters, wind, etc.) • Did you used IoT ontologies? Unit Ontologies? SAREF

References

Haghgoo, M., Sychev, I., Monti, A., & Fitzek, F. H. (2020). SARGON–Smart energy domain ontology. IET Smart Cities, 2(4), 191-198.

A.2 Ontology Template – Interconnect

Ontology Overview
• Define the ontology full name: Interconnect (Interoperable solutions connecting smart homes, buildings and grids) • Define the ontology acronym: Interconnect • Creator of the ontology and organization: Interconnect Consortium, Laura Daniele, Dena Tahvildari, Cornelia Bouter, Giulia Biagoni, Georg Jung, et al. https://gitlab.inesctec.pt/interconnect-public/ontology/-/graphs/master?ref_type=heads No creator name within the ontology metadata • Ontology version number: No versioning number? https://gitlab.inesctec.pt/interconnect-public/ontology/-/blob/master/ontology/Interconnect/ic-device.ttl • Ontology date of publication: No date of publication within the code https://gitlab.inesctec.pt/interconnect-public/ontology/-/blob/master/ontology/Interconnect/ic-device.ttl Otherwise, deliverable D2.3: Interoperable and secure standards and ontologies [Interconnect 2022]

Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL). https://gitlab.inesctec.pt/interconnect-public/ontology/-/tree/master/ontology/Interconnect D2.3: Interoperable and secure standards and ontologies [Interconnect 2022] • Persistent URI of Ontology File: https://gitlab.inesctec.pt/interconnect-public/ontology/-/tree/master/ontology/Interconnect • Research Papers Describing Ontology: Not a research paper but deliverable. D2.3: Interoperable and secure standards and ontologies [Interconnect 2022]

Ontology Domain & Description & Usage
• Define the domain of interest/ Topic/ Scope: Energy: -> YES Flexibility -> YES Smart Home/Building -> YES • Describe the ontology: Interconnect (Interoperable solutions connecting smart homes, buildings and grids) • Usage of the ontology: In which context and projects has the ontology been developed? Within Interconnect pilots Interconnect D1.1 Services and use cases for smart buildings and grids • What are the use cases? Interconnect pilots and use cases. Interconnect D1.1 Services and use cases for smart buildings and grids • What are the competency questions? Interconnect pilots and use cases • What are the main ontology concepts? Or provide the figure overview. See figure. • Figure URL: https://gitlab.inesctec.pt/interconnect-public/ontology/-/blob/master/diagrams/ontologies%20overview/Ontologies_overview.png

Ontology Modeling, Reusability and Availability
• Ontology implementation language: In what language the ontology is implemented? Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? TTL • Does the ontology have a usage license? Which one? Copyright EU H2020 Interconnect • Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? Reuse of ontologies: SAREF, SAREF4ENER • Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? Yes Example: http://ontology.tno.nl/interconnect/device# return the code But not HTML documentation (only GitHub documentation) https://gitlab.inesctec.pt/interconnect-public/ontology

Ontology Modeling, Reusability and Availability
• Ontology Catalog: In what ontology catalogs is registered the ontology? Not Yet May 2023 LOV4IoT, AIOTI Ontology Landscape, LOV

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL 6 • Justify the choice of this TRL: TRL 6 Designed for the Interconnect Project. Interconnect IA Project perhaps higher TRL • Ontology Adoption: Is the ontology adopted by the industry and used in practice? Are there relevant communities behind it (industry, standardization, research)? Is it supported by standards, which? Industrial partners from the Interconnect project • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Have upper ontologies been extended? Have ontology design patterns been used? Has this ontology been used by other ontologies? SAREF, SAREF4ENER • Sustainability & Maintainability: Is there a community maintaining the ontology? Is there a sustainability plan? Is there a plan for the medium and long-term maintenance of the ontology? Interconnect project sustainability plan. ETSI Smart M2M via Specific Task Force Example: https://portal.etsi.org/ngppapp/ContributionPortlet.aspx?tbid=726&SubTB=726&Param=&Alone=1 Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 4 - a standardization body (member-based organization) Interconnect project, ETSI Smart M2M?

Reasoning
• Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose). Interconnect Knowledge Engine https://gitlab.inesctec.pt/interconnect-public/knowledge-engine Jena inference engine - see paper: SAREF-Compliant Knowledge Discovery for Semantic Energy and Grid Interoperability IEEE World Forum on Internet of Things (WF-IoT) 2021. Amelie Gyrard, Antonio Kung, Olivier Genest, Alain Moreau https://hal.archives-ouvertes.fr/hal-03336052

IoT/Sensor

- What are the sensors used? Add Sensor measurement name and unit. See paper: SAREF-Compliant Knowledge Discovery for Semantic Energy and Grid Interoperability IEEE World Forum on Internet of Things (WF-IoT) 2021. Amelie Gyrard, Antonio Kung, Olivier Genest, Alain Moreau https://hal.archives-ouvertes.fr/hal-03336052

Sensor, Measurement Name and Unit	M3 Scenarios	SAREF-Core, SAREF4ENER, SAREF4BLDG	Other Names and Standards E.g., IEC 61360 Common Data Dictionary
m3:Sensor	✓M3-Generic	✓saref-core:Sensor	Device? IEC 61360 AAA103 - sensor
m3:LightSensor (Sensor) m3:Illuminance m3:Lux	✓M3-Home	✓saref-core:LightSwitch saref-core:illuminanceunit	IEC 61360 AAA105 - light sensor Light switch, Luminosity Sensor, Lamp Illuminance Sensor, Lighting
m3:Lamp (Actuator)	✓M3-Home	✓saref4bldg:Lamp	IEC 61360 AAA075 - lamp
m3:OccupancyDetector m3:Presence xsd:boolean	✓M3-Home	✓saref-core:Motion, saref-core:Occupancy,	IEC 61360 AAA109 - proximity sensor Pyroelectric IR (PIR) Occupancy Detector, Intrusion Detector, Trespassing, presence detector, motion sensor
m3:SoundSensor m3:Sound, m3:Decibel	✓M3-Home	✓saref4bldg:audiovolume	IEC 61360 AAA159 - microphone Microphone, Noise level, Volume
m3:HumiditySensor m3:Humidity m3:Percent	✓M3-Weather	✓saref-core Humidity (property) no HumiditySensor, no HumidityUnit no percent	IEC 61360 AAA104 - humidity sensor Hygrometer, Humidifier
m3:Thermometer m3:Temperature m3:DegreeCelsius	✓M3-Energy	✓saref-core:TemperatureSensor saref-core:Temperature saref-core:TemperatureUnit	IEC 61360 AAA110 - temperature sensor Thermostat
m3:LuminousEfficacySensor m3:LuminousEfficacy m3:LumenPerWatt	✓M3-Energy	Not found	- - -
m3:Ventilation (Actuator)	✓M3-Energy	✓saref-core:HVAC	HVAC, Fan -
m3:Heating (Actuator)	✓M3-Energy	✓saref-core:HVAC	HVAC
m3:AirConditioner (Actuator)	✓M3-Energy	✓saref-core:HVAC	HVAC, Cooling, AC
m3:ElectricalCurrentSensor m3:ElectricCurrent m3:Ampere	✓M3-Energy	Not found saref4bldg:primaryCurrent (owl:objectProperty) CurrentUnit not found, Ampere not found	Intensity
m3:ElectricalPotentialSensor m3:ElectricalPotential, m3:Volt	✓M3-Energy	Not found saref4bldg:primaryVoltage (owl:ObjectProperty)	Electric potential difference (Voltage)
m3:ElectricalResistanceSensor m3:ElectricalResistance, m3:Ohm	✓M3-Energy	Not found saref4bldg:initialResistance (owl:ObjectProperty)	-
m3:FrequencySensor m3:Frequency m3:Hertz	✓M3-Energy	Not found saref4bldg:nominalFrequency (owl:ObjectProperty) saref4bldg:primaryFrequency (owl:ObjectProperty)	-
m3:ThermalConductivitySensor m3:ThermalConductivity m3:WattPerMeterKelvin	✓M3-Energy	Not found saref4bldg;thermalConductivity (owl:ObjectProperty)	-
m3:PowerMeter m3:Power, m3:Watt	✓M3-Energy	✓saref-core:Power, saref-core:PowerUnit but no PowerMeter	-

TABLE I: Subset of the SAREF-compliant sensor dictionary, applied to energy (similar sensor tables for building, weather, and air quality can be provided). We focused on sensors employed within the Interconnect project.

- Did you used IoT ontologies? Unit Ontologies? SAREF, SAREF4ENER

References

SAREF-Compliant Knowledge Discovery for Semantic Energy and Grid Interoperability IEEE World Forum on Internet of Things (WF-IoT) 2021. Amelie Gyrard, Antonio Kung, Olivier Genest, Alain Moreau https://hal.archives-ouvertes.fr/hal-03336052

Linked Open Vocabularies for Internet of Things (LOV4IoT): https://lov4iot.appspot.com/, https://lov4iot.appspot.com/?p=updateCatalogueForm

LOV4IoT: A second life for ontology-based domain knowledge to build Semantic Web of Things applications. International Conference on Future Internet of Things and Cloud (FiCloud 2016). Amelie Gyrard, Christian Bonnet, Karima Boudaoud and Martin Serrano

Ontology Catalog for Energy: http://lov4iot.appspot.com/?p=lov4iot-energy

Building IoT based applications for Smart Cities: How can ontology catalogs help? IEEE Internet of Things Journal 2018. Amelie Gyrard, Antoine Zimmermann, Amit Sheth

Reusing and Unifying Background Knowledge for Internet of Things with LOV4IoT. International Conference on Future Internet of Things and Cloud (FiCloud 2016). Amelie Gyrard, Ghislain Atemezing, Christian Bonnet, Karima Boudaoud and Martin Serrano

AIOTI Ontology Landscape Report (Bauer, … Gyrard et al. 2021) https://aioti.eu/wp-content/uploads/2022/02/AIOTI-Ontology-Landscape-Report-R1-Published-1.0.1.pdf

AIOTI: https://ec.europa.eu/eusurvey/runner/OntologyLandscapeTemplate

AIOTI ontology catalog: https://aiotieu.github.io/ontologylandscape/

Linked Open Vocabularies (LOV): https://lov.linkeddata.es/dataset/lov/

A.3 Ontology Template – Platoon – SEDMOON Ontology

Ontology Overview
• Define the ontology full name: SEmantic Data MOdels Of Energy • Define the ontology acronym: SEDMOON • Creator of the ontology and organization: PLATOON H2020 project (GA No 872592) • Ontology version number: V2.0 • Ontology date of publication: 2023/01/13

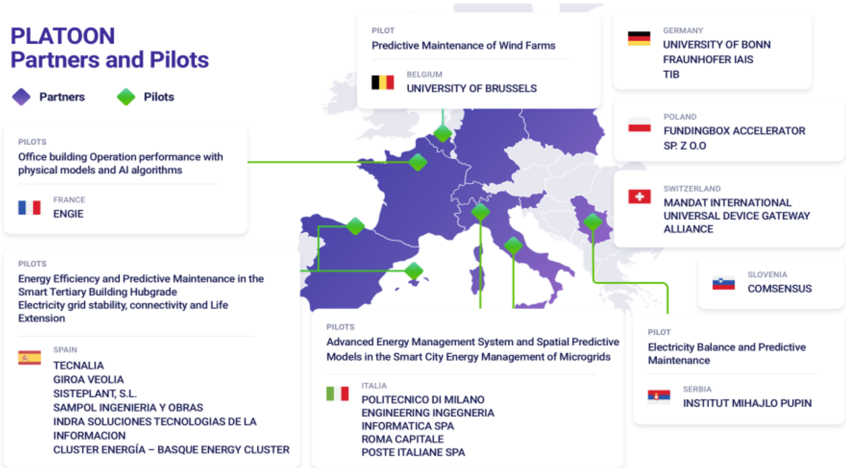
Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL): PLATOON D2.7- D2.3-V2-Common data models for energy (H2020- PLATOON Project, March 2022) (public document) (https://cordis.europa.eu/project/id/872592/results) • Persistent URI of Ontology File: https://w3id.org/platoon/ • Research Papers Describing Ontology ○ PLATOON D2.7- D2.3-V2-Common data models for energy (H2020- PLATOON Project, March 2022) (public document) (https://cordis.europa.eu/project/id/872592/results) ○ Reuse of Semantic Models for Emerging Smart Grids Applications **,** Janev, V.; Popadic, D.; Pujic D.; Vidal, M.; Endris, K.; ISOS Conference Proceedings Series, 1, 2021, Page(s) 119-123, ISBN 978-86-85525-24-7, Information Society of Serbia – ISOS, 10.48550/arxiv.2107.06999 ○ Managing Knowledge in Energy Data Spaces , Valentina Janev, Maria Esther Vidal, Kemele Endris, Dea Pujic, Companion Proceedings of the Web Conference 2021, 19 April 2021, 2021, Page(s) 7-15, ISBN 9781450383134, ACM, DOI: 10.1145/3442442.3453541 ○ Data Spaces for Energy, Home and Mobility, Position Paper, Alberto Dognini (RWTH Aachen University) Lynda Temal (ENGIE), Chandra Challagonda (FIWARE Foundation), Olivier Genest (Trialog), Erik Maqueda Moro (Tecnalia), Philippe Calvez (ENGIE), Kristian Helmholt (TNO), Razgar Ebrahimy (DTU) , Henrik Madsen (DTU), Rolf Riemenschneider (EC - DG CNECT), Laura Daniele (TNO), Robert Böhm (EEBUS), Laurent Schmitt (Digital4Grids), Sarra Ben-Abbes (ENGIE),OPENDEI, DOI: 10.5281/zenodo.7113452

- [Responsible Knowledge Management in Energy Data Ecosystems](#) ,Valentina Janev, Maria-Esther Vidal, Dea Pujic, Dusan Popadic, Enrique Iglesias, Ahmad Sakor, Andrej Campa, Energies, 15,11, 2022, ISSN 1996-1073, Multidisciplinary Digital Publishing Institute (MDPI), DOI: 10.3390/en15113973.
- Towards a Solution for an Energy Knowledge Graph, Dušan Popadić, Enrique Iglesias, Ahmad Sakor, Valentina Janev, Maria-Esther Vidal, Semantic-Intelligence Conference ISIC 2022, Semantic Intelligence- Springer Nature (in print), 2023, ISBN 978-981-19-7125-9, Springer

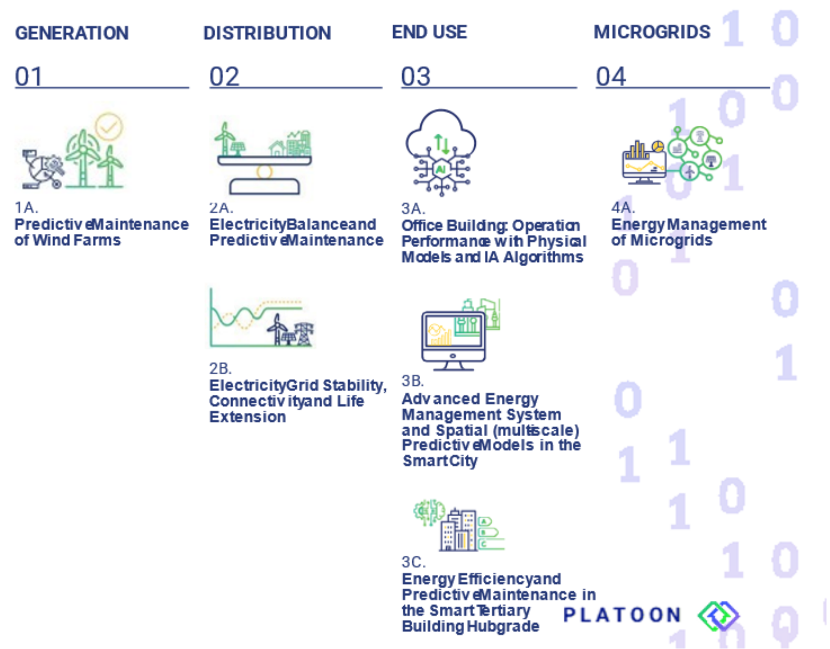
- Select the domain of interest/ Topic/ Scope: Energy: Renewable (solar and wind). Smart Grids (concepts regarding TSO/DSO that apply to Electromobility UCF). End use of energy – energy efficiency for smart buildings (concepts that apply to LEC and Flexibility UCF). Generic IoT (Horizontal). Smart Home/Building. Cities
- Describe the ontology: SEDMOON ontology is a combination of other existing standard ontologies (SAREF, SEAS, OntoWind, etc.) adapted to the requirements of the different pilots and use cases inside the project. Also, SEDMOON extends some concepts and properties for the usecases that are not covered in existing technologies.
- Usage of the ontology: In which context and projects has the ontology been developed? PLATOON EU H2020 project (2020-2022)

Ontology Domain & Description & Usage

- What are the use cases? 7 different pilots within PLATOON:



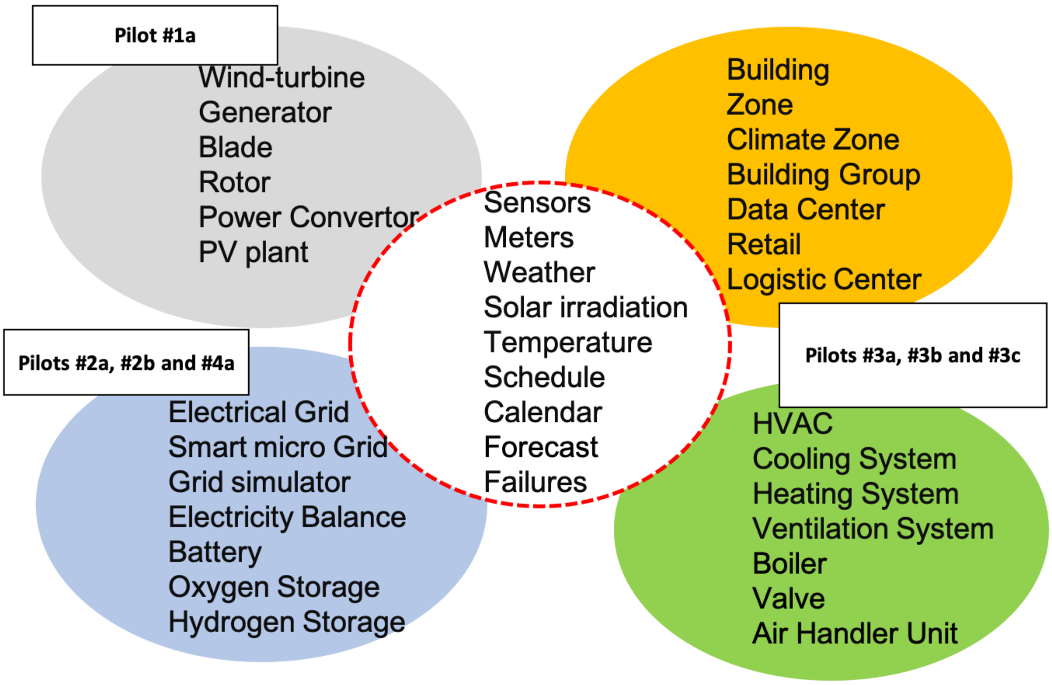
Ontology Domain & Description & Usage



Ontology Domain & Description & Usage

- What are the competency questions? Due the number of entities inside the ontology and the relationships between those, the variety of competency questions and the combinations of the queries to obtain information is huge. So, some examples that illustrate the ontology are listed:
  - What is the 24h ahead comfort temperature schedule?
  - What is the 24h ahead weather forecast?
  - What is the 24hahead forecast of the energy demands of the building?
  - What is the 24h ahead forecast of the solar radiation?
  - What is the 24h ahead forecast of the RES (PV panels) energy production?
  - What is the 24h ahead forecast of the energy prices?
  - What is the 24h ahead schedule of the PV energy management system?
  - What is the schedule for HVAC on/off command and set point?
  - What are the components of the HVAC system?
  - What are the sensors and actuators (set point) of the HVAC system?
  - What is the current value of the sensors and actuators (set point) of the HVAC system?
  - What is the current value of the ambient temperature?
  - What is the current value of the solar radiation?
  - What is the current energy production of the local RES (PV panels)?

Ontology Domain & Description & Usage
○ What is the current energy price? ○ What is the difference between the real and forecasted values ? ○ What are the different constraints of the local installed renewable energy sources?

Ontology Domain & Description & Usage
• What are the main ontology concepts? Or provide the figure overview

• All the details about specific ontology modules are publicly available in: PLATOON D2.7- D2.3-V2-Common data models for energy (H2020- PLATOON Project, March 2022) (public document) (https://cordis.europa.eu/project/id/872592/results) https://w3id.org/platoon/

Ontology Modelling, Reusability and Availability
• Ontology implementation language: In what language the ontology is implemented? Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? OWL • Does the ontology have a usage license? Which one? Yes. Apache-2.0. • Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? Yes. https://w3id.org/platoon/ • Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? Yes, in the context of ontology publication, the user enable to request the ontology in different formats such as RDF/XML, Turtle, OWL, etc. • Ontology Catalog: In what ontology catalogs is registered the ontology? https://w3id.org/platoon/ Also published in TNO´s Vocabulary Hub: https://energy.vocabulary-hub.eu/#/Projects

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies). Justify the choice of this TRL: TRL 6 Ontology validated in 8 large scale pilots within PLATOON project • Ontology Adoption: Is the ontology adopted by the industry and used in practice? Are there relevant communities behind it (industry, standardization, research)? Presented in International Conference Knowledge Graph and Semantic Web Conference KGSWC 2022. Industrial partners involved in the project: ENGIE, PUPIN, SAMPOL, GIROA-VEOLIA, POSTE ITALIANE • Is it supported by standards, which? Reused existing standard ontologies SAREF, SEAS, OntoWind, etc. • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Have upper ontologies been extended? Have ontology design patterns been used? Has this ontology been used by other ontologies? PLATOON ontology has reused parts of well-known standards such as SAREF, SEAS, OntoWind. Please see table below with the considered standard ontologies:

Ontology Maturity, Maintenance, Adoption, Sustainability

Domain	Format	Link	Semantic Data Models	Renewable Generation	Smart grids		End Use of Energy			Generation, Distribution and End Use of Energy
				Predictive Maintenance of Wind Farms	Electricity Balance and Predictive Maintenance	Electricity grid stability, connectivity and Life Extension	Office building: Operation performance thanks to physical models and IA algorithms	Advanced Energy Management System and Spatial (multi-scale) Predictive Models in the Smart City	Advanced Energy Management System and Energy Efficiency and Predictive Maintenance in the Smart Tertiary Building Hubgrade	Energy Management in microgrids
Home appliances	TTL	https://forge.etsi.org/	Saref*	✓	✓	✓	✓	✓	✓	✓
Energy	TTL	https://ontology.tno.	Saref4Ener*	✓	✓	✓	✓	✓	✓	✓
Environment	Ntriple, RDF/XML, TTL	https://w3id.org/def/	Saref4Envi*	✓						
Building	Ntriple, RDF/XML, TTL	https://w3id.org/def/	saref4Bldg*				✓	✓	✓	
Smart city	Ntriple, RDF/XML, TTL, JSON-LD	https://w3id.org/def/	Saref4City*			✓		✓		
Industry	Ntriple, RDF/XML, TTL, JSON-LD	https://w3id.org/def/	Saref4INMA*							
Agriculture	Ntriple, RDF/XML, TTL, JSON-LD	https://w3id.org/def/	Saref4Agri*							
Building, device,	JSON-LD	https://fiware-datamo	FIREWARE*	✓			✓	✓	✓	
IOT	JSON-LD	https://www.gsma.co	GSMA*	✓	✓	✓	✓	✓	✓	✓
Electricity	UML, RDF	https://ontology.tno.	CIM*		✓	✓				✓
Sensor device Iot	TTL	http://www.w3.org/r	SSN	✓	✓	✓	✓	✓	✓	✓
SSN and spatial data	TTL	http://www.w3.org/r	SOSA	✓	✓	✓	✓	✓	✓	✓
Energy system	TTL	https://w3id.org/seas	SEAS	✓	✓	✓	✓	✓	✓	✓
Energy heating	TTL, TAG	https://brickschema.o	Brick schema				✓	✓	✓	
Building topology	TTL	http://www.w3id.org	BOT				✓	✓	✓	
Energy efficiency in Future Smart Homes	OWL	https://www.auto.tu	ThinkHome				✓	✓	✓	
Prosumer-Oriented Smart Grid	OWL, TTL	http://data-satin.tele	ProSGV3							✓
OEMA (Ontology for Energy Management Applications); Infrastructure, Energy, Equipment, Geographical data, Smart Grid Stakeholders, Units of Measure	RDF/XML, Ntriples, TTL	https://innoweb.mon	OEMA (reutilise ThinkHome, Saref, Energyuse, ProSGV3)	✓	✓	✓	✓	✓	✓	✓
Energy flexibility for a specific device	TTL	https://sites.google.c	Mirabel	✓	✓	✓	✓	✓	✓	✓
Smart city	RDF	http://wlode.disit.org	KM4city					✓		
Energy domain: Building energy consumption	OWL	http://semanco-tools	SEMANCO				✓	✓	✓	
LCC (Leeds City Council): Energy Consumption	TTL	http://smartcity.linke	LCC	✓	✓	✓	✓	✓	✓	✓
Smart Building	OWL	http://lpis.csd.auth.g	BOnSAI				✓	✓	✓	
Intelligent Domotic Environments	JSON LD, RDF/XML, Ntriples, TTL	http://iot-ontologies.	DogOnt	✓	✓	✓	✓	✓	✓	✓
Wind farms/turbines	OWL	https://raw.githubuse	OntoWind	✓						

- Sustainability & Maintainability: Is there a community maintaining the ontology? Is there a sustainability plan? Is there a plan for the medium and long-term maintenance of the ontology? PLATOON project has ended in December 2022, However, the ontology will be reused, extended and maintained as part of Horizon Europe ENERSHARE project (2022-2025). Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 1 - a single maintainer (an individual and/or a project)

Reasoning

- Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose). In PLATOON project, we locally tested the reasoner of GraphDB for several queries in pilots 1a, 3a and 4a. In Engie's portal, the triplestore Apache Fuseki and its reasoner are integrated.

IoT/Sensor

- What are the sensors used? Add Sensor measurement name and unit.

activeEnergy	kWh
activePower	kW
current	A
frequency	Hz
reactiveEnergy	kVArh
reactivePower	kVAr
setPointTemperature	ºC
temperature	ºC
voltage	V
Humidity	%
Solar radiation	W/m2
Wind Speed	m/s
Wind direction	Degrees
Rotational Speed	RPM
Torque	Nm
Gas flow	m3/h

- Did you used IoT ontologies? Unit Ontologies? GSMA, SAREF

Ontology Template – BD4OPEM

Due to confidential reasons, the BD4OPEM ontology template analysis is not shared here.

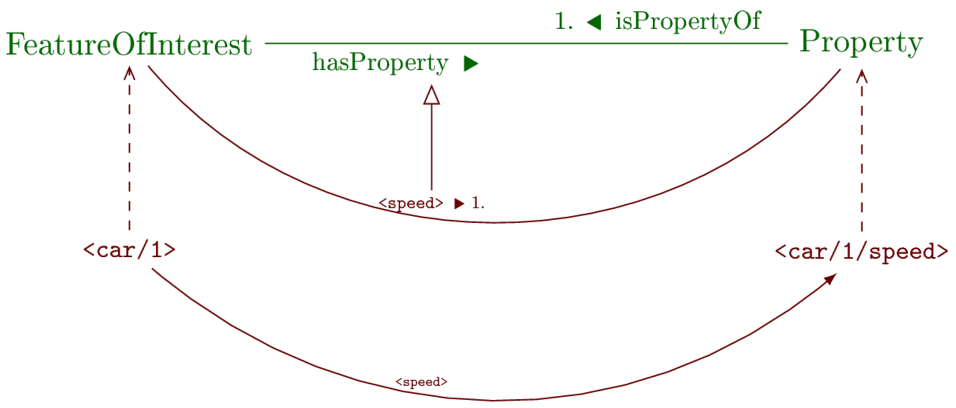
A.4 Ontology Template – SEAS

Ontology Overview
• Define the ontology full name: Smart Energy Aware Systems • Define the ontology acronym: SEAS • Creator of the ontology and organization: ITEA 12004 SEAS Project • Ontology version number: V1.1 • Ontology date of publication: 2017-08-29

Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL): https://w3id.org/seas/ • Persistent URI of Ontology File: https://w3id.org/seas/seas-1.1.ttl • Research Papers Describing Ontology : ○ Maxime Lefrançois, Planned ETSI SAREF Extensions based on the W3C&OGC SOSA/SSN-compatible SEAS Ontology Patterns. In Proceedings of Workshop on Semantic Interoperability and Standardization in the IoT, SIS-IoT, Amsterdam, Netherlands, July 2017 (https://www.maxime-lefrancois.info/docs/Lefrancois-SIS-IoT2017-Planned.pdf) ○ Maxime Lefrançois, Jarmo Kalaoja, Takoua Ghariani, Antoine Zimmermann, The SEAS Knowledge Model, ITEA2 12004 Smart Energy Aware Systems Deliverable 2.2, Jan 2017 (https://www.maxime-lefrancois.info/docs/SEAS-D2_2-SEAS-Knowledge-Model.pdf)

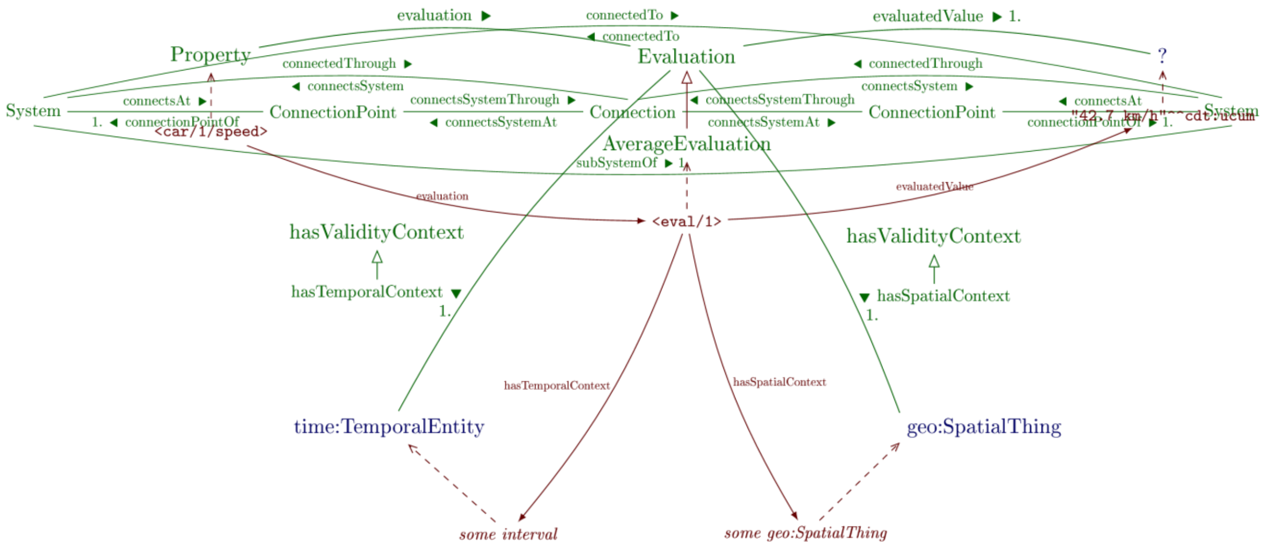
Ontology Domain & Description & Usage
• Select the domain of interest/ Topic/ Scope: Energy: Renewable (solar and wind). Smart Grids (concepts regarding TSO/DSO that apply to Electromobility UCF). End use of energy – energy efficiency for smart buildings (concepts that apply to LEC and Flexibility UCF). Generic IoT (Horizontal). Smart Home/Building. Smart Cities • Describe the ontology: The SEAS Electric Power System Vocabulary defines: Electric power systems that consume, produce, or store electricity, electrical connections between electric power systems, where electricity is exchanged, and electrical connection Points of electric power systems, through which electricity flows in/out the power systems. SEAS ontology modules are organized on top of a core of three main modules: the seas:FeatureOfInterestOntology describes feature of interests and their properties;

Ontology Domain & Description & Usage



seas:EvaluationOntology describes evaluations of these properties;

Ontology Domain & Description & Usage



the seas:SystemOntology describes virtually isolated systems that share connections with other systems;

On top of the seas:SystemOntology module, various vertical domain ontologies are defined for specific sub classes of systems and why they may be connected:

the seas:AreaOntology describes Zone systems:

a zone may be linked by a crossable connection with another zone;

a zone may be a sub-zone of another zone;

zones are quantified in terms of area, population, and humidity.

Ontology Domain & Description & Usage
Moreover, the ontology encompasses energy domain ontologies: BatteryOntology-1.0, ElectricLightSourceOntology-1.0 , ElectricPowerSystemOntology-1.0 , ElectricVehicleOntology-1.0 , EnergyFormOntology-1.0 , FlexibilityOntology-1.0 , ForecastingOntology-1.1 , PhotovoltaicOntology-1.0 , PlayerOntology-1.1 , PricingOntology-1.0 , SmartMeterOntology-1.1. • Usage of the ontology: In which context and projects has the ontology been developed? The ontology has developed in the context of the ITEA2 12004 SEAS project. SEAS defines generic ontology patterns that can be instantiated in different domains.

Ontology Modeling, Reusability and Availability
• Ontology implementation language: In what language the ontology is implemented? • Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? OWL, Turtle, RDF/XML. • Does the ontology have a usage license? Which one? Yes. Apache-2.0. • Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? Yes. https://w3id.org/seas/ Modular and versioned ontology, slash-based URIs, deferencable term URIs • Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? Yes, HTML, Turtle, RDF/XML. • Ontology Catalog: In what ontology catalogs is registered the ontology? The Linked Open Vocabularies (http://lov.okfn.org/dataset/ lov/vocabs/seas)

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies). Justify the choice of this TRL The SEAS, PLATOON, and RESPOND projects that use SEAS address TRL 6-7. • Ontology Adoption: Is the ontology adopted by the industry and used in practice? The ontology is used in large scale Research and Development projects, especially in the smart building and energy domain. For example: RESPOND (integrated demand REsponse Solution towards energy POsitive NeighbourhooDs). PLATOON (Digital PLAtform and analytic TOOls for eNergy) The following ontologies are closely aligned to SEAS: SSN (Semantic Sensor Networks), EEPSA (Energy Efficiency Prediction Semantic Assistant), The SEAS System module has been adopted by ETSI in the SAREF4SYST ontology • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Have upper ontologies been extended? Have ontology design patterns been used? Has this ontology been used by other ontologies? The imported ontologies are: Goodrelations - http://www.heppnetz.de/ontologies/goodrelations/v1.html, foaf – http://xmlns.com/foaf/spec/ , vcard for RDF - http://www.w3.org/TR/vcard-rdf/, org - http://www.w3.org/TR/vocab-org/, time - http://www.w3.org/2006/time, The following ontologies use SEAS: BPO (Building Product Ontology), SBEO (Smart Building Evacuation Ontology), SEDMOON ontology by Platoon (Digital PLAtform and analytic TOOls for eNergy) • Sustainability & Maintainability: Is there a community maintaining the ontology? Is there a sustainability plan? Is there a plan for the medium and long-term maintenance of the ontology? The ontology project is archived and its development discontinued. Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 1 - a single maintainer (an individual and/or a project)

Reasoning
• Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose) SEAS is a OWL 2 DL ontology

IoT/Sensor
• What are the sensors used? Add Sensor measurement name and unit. • Did you used IoT ontologies? Unit Ontologies? SEAS promotes the use of the cdt:ucum datatype for representing quantity values as literals. Alternatively, the OM or QUDT ontologies can be used

References

Maxime Lefrançois, Planned ETSI SAREF Extensions based on the W3C&OGC SOSA/SSN-compatible SEAS Ontology Patterns. In Proceedings of Workshop on Semantic Interoperability and Standardization in the IoT, SIS-IoT, Amsterdam, Netherlands, July 2017 (https://www.maxime-lefrancois.info/docs/Lefrancois-SIS-IoT2017-Planned.pdf)

Maxime Lefrançois, Jarmo Kalaoja, Takoua Ghariani, Antoine Zimmermann, The SEAS Knowledge Model, ITEA2 12004 Smart Energy Aware Systems Deliverable 2.2, Jan 2017 (https://www.maxime-lefrancois.info/docs/SEAS-D2_2-SEAS-Knowledge-Model.pdf

A.5 Ontology Template – DLMS-COSEM

Ontology Overview

• Define the ontology full name: Companion Specification for Energy Metering
• Define the ontology acronym: COSEM (often referred to as DLMS/COSEM™)
• Creator of the ontology and organization:
  ○ The DLMS User Association developed the ontology initially known as the coloured books and more recently as the Core specifications:
  ○ Blue book – part 1: OBIS codes
  ○ Blue book – part 2: COSEM interface classes
  ○ Green book: DLMS/COSEM Architecture and Protocols
  ○ These specifications were brought to international standardization through IEC TC13, where the ontology is comprised of 3 standards:
  ○ IEC 62056-5-3: DLMS/COSEM application layer
  ○ IEC 62056-6-1: Object Identification System (OBIS)
  ○ IEC 62056-6-2: COSEM interface classes
  ○ These standards are maintained by IEC TC13 with the support of DLMS User Association (DLMS UA).
• Ontology version number:
  ○ The current versions of the DLMS UA Core specifications are:
  ○ Blue book – part 1: Edition 15 from December 2021
  ○ Blue book – part 2: Edition 15 from December 2021
  ○ Green book: Edition 11 from December 2021
  ○ The current versions of the IEC standards are:
  ○ IEC 62056-5-3:2017 Edition 3.0
  ○ IEC 62056-6-1:2017 Edition 3.0
  ○ IEC 62056-6-2:2017 Edition 3.0
  ○ The next version planned is Edition 4.0, which is expected before end of 2023 (see IEC website)
• Ontology date of publication: See above.

Ontology Documentation & References

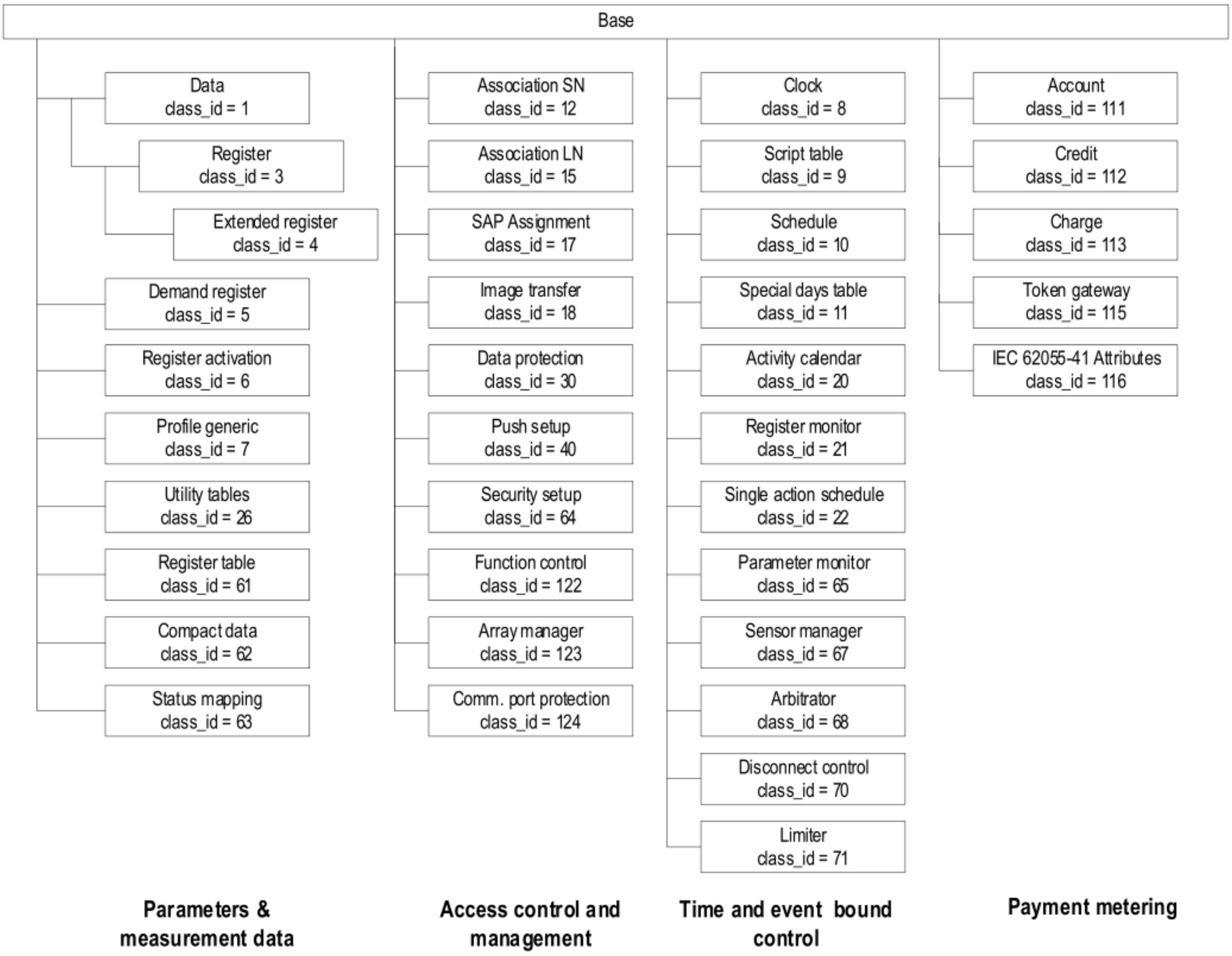
- Ontology Documentation: Technical Specification / Documentation of Ontology (URL): Blue and Green Books are not public and available only to DLMS UA members: see DLMS UA website The IEC standards are available through the IEC webstore (see below).
- Persistent URI of Ontology File: https://webstore.iec.ch/publication/27065 https://webstore.iec.ch/publication/32782 https://webstore.iec.ch/publication/34317
- Research Papers Describing Ontology: Many papers about DLMS/COSEM™ but not specifically about COSEM interface classes

Ontology Domain & Description & Usage

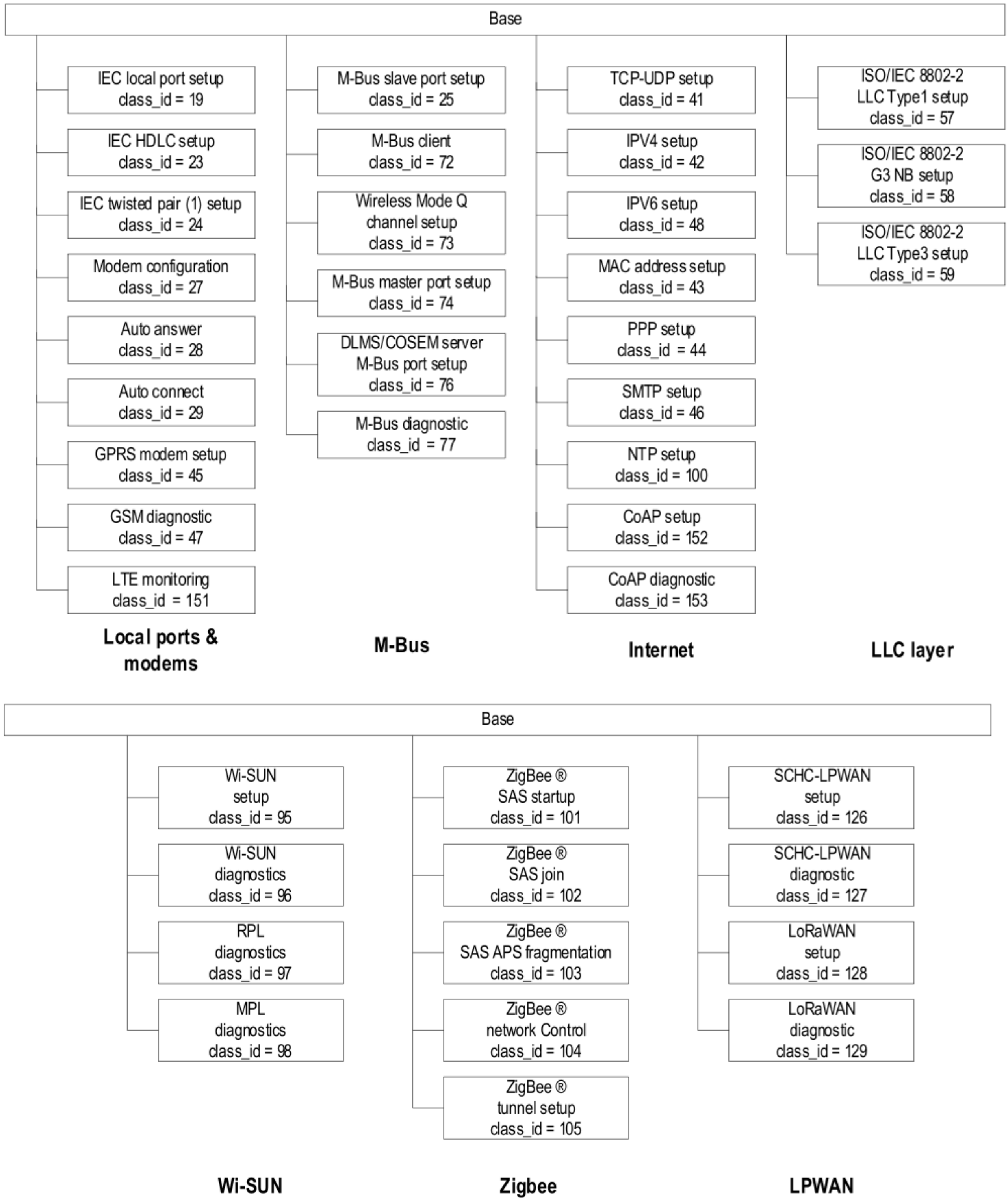
- Select the domain of interest/ Topic/ Scope: Main scope: Energy metering and load control. Other relevant topics: Renewables Local energy production/management Electromobility Flexibility/Demand-Response
- Usage of the ontology: In which context and projects has the ontology been developed? COSEM is the dominant ontology worldwide for Advanced Metering Infrastructures (AMI) and other Smart Metering systems. It evolved over time to include various interface classes to support new usages and country requirements. COSEM is used in metering devices deployed throughout Europe, Africa, Asia and North America. The ontology is in line with Functional reference Architecture for communication in smart metering system developed under EU mandate M/441.
- What are the use cases? The main use-case is smart metering: recording of energy consumption/generation in registers, providing measurements over time intervals, supply control and other switches, apply tariffs etc. It also includes sub-metering and pre-payment metering. During the last years, the use-cases have been extended to support smart grid, e-mobility, … A list of relevant use-cases is presented below: Meter registration, Remote tariff programming, Meter reading on demand, Meter reading for billing, Meter disconnection and reconnection (supply control), Meter clock synchronisation, Quality of supply reporting, Load management by relay, Firmware update, Meter supervision, Consumer Information Push (CIP) using PUSH operation, Communication supervision, Consumer information (via local port or meter display), Function opt-in/opt-out control
- What are the competency questions? What are the meters and submeters? What are the measured data over time? What actuators can be controlled in the meter? What are the parameters for the communication channels?
- Describe the ontology: COSEM defines 104 interface classes to describe: Energy-metering-related data, including registers, tariff calendar, peak period, supply control, load management, voltage/current/power measurements, load profile, … It covers metering of several energy carriers: electricity, gas, heat, water. Management of the communication interfaces (such as PLC, cellular, radio mesh, …). Years after years, the 2nd part (communication interfaces) has been growing and now represents ~60% of the defined interface classes.

Ontology Domain & Description & Usage

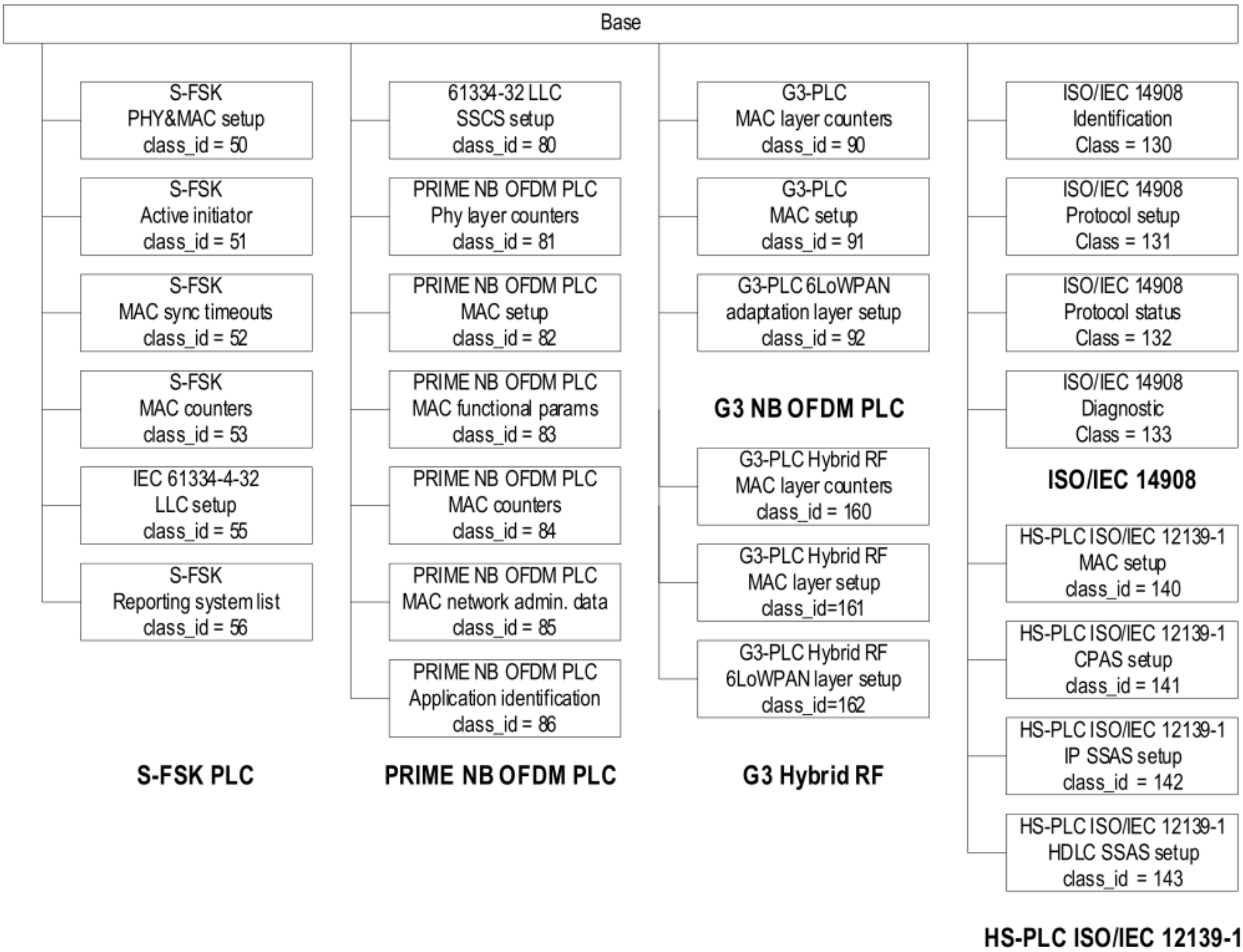
- What are the main ontology concepts? Or provide the figure overview Interface classes as defined in Blue Book v15 are illustrated below:



Ontology Domain & Description & Usage



Ontology Domain & Description & Usage



Currently, there is no digital model available detailing each of the interface classes, but this is being considered by DLMS UA and IEC TC13.

Ontology Modeling, Reusability and Availability
• Ontology implementation language: N/A In what language the ontology is implemented? N/A (only specification document in text format) Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? N/A • Does the ontology have a usage license? Which one? No, but access is not free: either through DLMS UA membership or via the IEC TC13 webstore. • Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? No • Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? No • Ontology Catalog: In what ontology catalogs is registered the ontology? None (to our knowledge)

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space). Justify the choice of this TRL: COSEM has been used and deployed in Smart Metering system (as described below) for over 20 years • Ontology Adoption: Is the ontology adopted by the industry and used in practice? Yes. DLMS/COSEM is integrated in over 300 million smart meters worldwide and OBIS parts of the specifications in over 700 million devices, with a continued deployment of over 40 million devices per year. Are there relevant communities behind it (industry, standardization, research)? DLMS User Association. Is it supported by standards, which? IEC 62056 series developed by IEC TC13 (DLMS UA has a liaison category A with IEC TC13) • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Mapping of DLMS/COSEM to IEC CIM (common information model, see IEC 61968-9) has been performed in IEC 62056-6-9:2016 Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? N/A Have upper ontologies been extended? Have ontology design patterns been used? N/A Has this ontology been used by other ontologies? Implementation examples of the Data model are from the Gulf region, in Russia via SPODES, and some national specific implementations at SWISS Metas and Austrian BEW. DLMS/COSEM has also been adopted by ANSI C12 Suite in the USA and partially by India BIS and in China. • Sustainability & Maintainability: Is there a community maintaining the ontology? Yes: DLMS UA • Is there a sustainability plan? The DLMS UA has a longterm engagement for the maintainance of the specifications and continous improvement of the data model and carry out yearly reviews in order to make evolutions needed in order to adopt to market requirements. Is there a plan for the medium and long-term maintenance of the ontology? Yes under the responsability of DLMS UA Sustainability & Maintainability Level: There can be different levels, starting from an individual

Ontology Maturity, Maintenance, Adoption, Sustainability
person committed to the maintenance, to a professional organization such as a standardization body. Level 4 - a standardization body (member-based organization)

Reasoning
• Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose) No

IoT/Sensor
• What are the sensors used? Add Sensor measurement name and unit. Current sensors (A), Voltage sensors (V) • Did you used IoT ontologies? Unit Ontologies? No

References

DLMS User Association: https://www.dlms.com/

IEC 62056-6-2: https://webstore.iec.ch/publication/34317

IEC 62056-5-3: https://webstore.iec.ch/publication/27065

IEC 62056-6-1: https://webstore.iec.ch/publication/32782

A.6 Data Model Ontology Template – IEC 61850

Ontology Overview
• Define the ontology full name: IEC 61850 Communication networks and systems for power utility automation • Define the ontology acronym: IEC 61850 • Creator of the ontology and organization: IEC TC57: Power systems management and associated information exchange • Ontology version number: IEC 61850:2023 SER Series. Communication networks and systems for power utility automation - ALL PARTS. • Ontology date of publication: 2023/01/16 Edition 1.0

Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL): The series includes, the following IEC documents IEC TR 61850-1:2013 IEC TS 61850-1-2:2020+AMD1:2022 CSV IEC TS 61850-2:2019 IEC 61850-3:2013 IEC 61850-4:2011+AMD1:2020 CSV IEC 61850-5:2013+AMD1:2022 CSV IEC 61850-6:2009+AMD1:2018 CSV IEC 61850-7-1:2011+AMD1:2020 CSV IEC 61850-7-2:2010+AMD1:2020 CSV IEC 61850-7-3:2010+AMD1:2020 CSV IEC 61850-7-4:2010+AMD1:2020 CSV IEC TR 61850-7-5:2021 IEC TR 61850-7-6:2019 IEC TS 61850-7-7:2018+AMD1:2023 CSV IEC 61850-7-410:2012+AMD1:2015 CSV IEC 61850-7-420:2021 IEC TR 61850-7-500:2017 IEC TR 61850-7-510:2021 IEC 61850-8-1:2011+AMD1:2020 CSV IEC 61850-8-2:2018 IEC 61850-9-2:2011+AMD1:2020 CSV IEC/IEEE 61850-9-3:2016 IEC 61850-10:2012 IEC TR 61850-10-3:2022 IEC TS 61850-80-1:2016

IEC TR 61850-80-3:2015
IEC TS 61850-80-4:2016
IEC TR 61850-90-1:2010
IEC TR 61850-90-2:2016
IEC TR 61850-90-3:2016
IEC TR 61850-90-4:2020
IEC TR 61850-90-5:2012
IEC TR 61850-90-6:2018
IEC TR 61850-90-7:2013
IEC TR 61850-90-8:2016
IEC TR 61850-90-9:2020
IEC TR 61850-90-10:2017
IEC TR 61850-90-11:202IEC TR 61850-90-12:2020
IEC TR 61850-90-13:2021
IEC TR 61850-90-14:2021
IEC TR 61850-90-16:2021
IEC TR 61850-90-17:20170

IEC Map associated: https://mapping.iec.ch/#/maps/21

- Persistent URI of Ontology File: iec61850uml02v06-iec61850_7_410uml01v01-iec61850_7_420uml01v01-iec61400_25_2uml01v01.eap. This fie is accessible by IEC TC57 members. The version is changed on a regular basis.
- Research Papers Describing Ontology: See PACWorld reference

Ontology Domain & Description & Usage

- Select the domain of interest/ Topic/ Scope: Energy: Electricity. Substation Automation. DER Data model. Hydro power plant data model. Wind plant data model. Product data model: HV switchgear and controlgear. Product data model: Digital interface for instrument tranformers. Feeder Automation. Inverter-based DER. EV. Electric storage systems. Power Quality. Scheduling. Communication to control center. Network Enginneering. WAN communications
- Describe the ontology (extract from Wikipedia): IEC 61850 is an international standard defining communication protocols for intelligent electronic devices at electrical substations. It is a part of the International Electrotechnical Commission's (IEC) Technical Committee 57 reference architecture for electric power systems. The abstract data models defined in IEC 61850 can be mapped to a number of protocols. Current mappings in the standard are to Manufacturing Message Specification (MMS), GOOSE (Generic Object Oriented System Event), SV (Sampled Values) or SMV (Sampled Measure Values), and soon[to web services. In the previous version of the standard, GOOSE stood for "Generic Object-Oriented Substation Event, but this old definition is still very common in IEC 61850 documentation. These protocols can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying.
- Usage of the ontology: In which context and projects has the ontology been developed? Substation and Distribution automation systems What are the use cases?

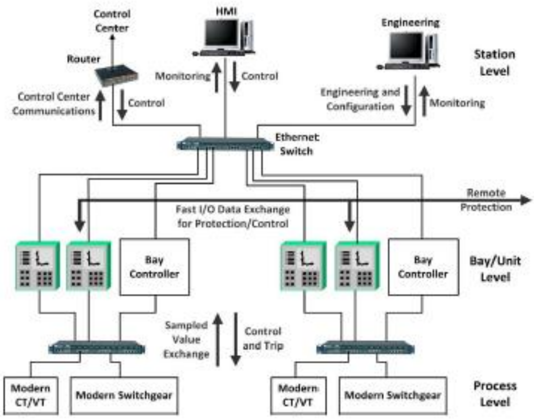
Ontology Domain & Description & Usage

- https://www.researchgate.net/publication/252000959_Applications_of_IEC_61850_in_distribution_automation Fault detection, Fault isolation Service restoration, Voltage regulation, Volt/var control, Protection Coordination, Load Forecast and Modelling, DER Integration to the Grid … Important document: Content of BAP Technical Report (IEC 61850-7-6 ED1)

  From a user point of view, the system specification might be realized by aggregating different BAPs (Basic Application profiles) to answer to his requirements. From an engineering process, the selected BAPs will have to be machine processable to be easily merged. The purpose of the future edition of the IEC TR 61850-7-6 is to describe a new kind of SCL file, supporting additional rules to adapt the BAP to a real system needs. The concept of BAP comes from the need to standardize applications in the context of specific kind of users to simplify the implementation and reusability of well tested components of systems. This is the notion of profile applied to IEC 61850 to express a subset of data from the standard, integrated together to create a functional application. The IEC 61850-7-6 ED1 has defined a development process and implementation requirements to express such a standardized IEC 61850 application profile by means of BAP, independent of any users. This TR also gives advice for user groups to manage these profiles in a central repository. But the document does not define itself standardized BAPs. See : https://www.pacw.org/basic-application-profiles for more information

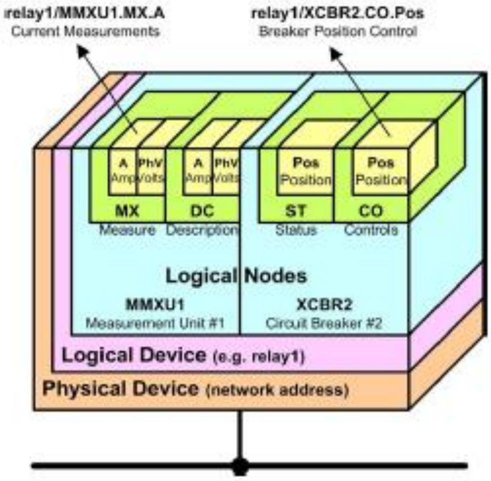
- What are the competency questions? How to design a substation automation system? How to transmit substation data to a SCADA control centre? How to control and monitor a substation automation system form a control centre and Scada system? What are the protocols used in a substation automation system? How to manage Voltage, active Power Reactive Power in a Substation? How to model protections in a substation? How to model distribution automation functions?

- What are the main ontology concepts? Or provide the figure overview. CIM and 61850 SGAM Plane



Substation Automation topology based on IEC 61850
Data Structure in IEC 61850

Ontology Domain & Description & Usage



Ontology Modeling, Reusability and Availability

- Ontology implementation language: 61850 is using UML from which it can be exported/transformed in different formats. In what language the ontology is implemented? XML Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)?: XML/XSD
- Does the ontology have a usage license? Which one? Yes. The purchase of this IEC standard carries a copyright license for the purchaser to sell software containing Code Components from this standard directly to end users and to end users via distributors, subject to IEC software licensing conditions, which can be found at: http://www.iec.ch/CCv1 (Code Components End-user licence agreement)
- Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? No.
- Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? The ontology is managed using Entreprise Architect from Sparx Systems. Several exports of the model can be done (html, XMI, …). The Model is not open source.
- Ontology Catalog: In what ontology catalogs is registered the ontology? Not registered yet as such or to be investigated

Ontology Maturity, Maintenance, Adoption, Sustainability
• Define the TRL: TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space). Justify the choice of this TRL: Vendors (Siemens, Hitachi, GE, …) and Utilities are implementing/using IEC 61850 • Ontology Adoption: Is the ontology adopted by the industry and used in practice? • Are there relevant communities behind it (industry, standardization, research)? Is it supported by standards, which? IEC UCA : Test certificates https://www.ucaiug.org/org/TechnicalO/Testing/Lists/IEC61850Ed1ClientCertificates/AllItems.aspx Conferences Smart Grid Forum PACWorld: https://www.pacw.org/iec-61850 IEEE PES • Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Harmonisation with 61850 and COSEM Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Have upper ontologies been extended? Have ontology design patterns been used? Has this ontology been used by other ontologies? IEC CIM, IEC COSEM, IEC 61400 wind data model • Sustainability & Maintainability: Is there a community maintaining the ontology? YES Is there a sustainability plan? YES, Is there a plan for the medium and long-term maintenance of the ontology? YES. Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 4 - a standardization body (member-based organization)

Reasoning
• Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose) OCL, IEC 61131 : programmable logic controllers

IoT/Sensor
• What are the sensors used? Add Sensor measurement name and unit. Intelligent Electronic Devices are used (IED). • Did you used IoT ontologies? Unit Ontologies? No

References:

IEC TC57 :
https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1273,25

Detailed Introduction to IEC 61850

IEC 61850 Technical Issues website

UCA International Users Group

IEC61850: A Protocol with Powerful Potential

Smart High Voltage Substation Based on IEC 61850 Process Bus and IEEE 1588 Time Synchronization

A.7 Ontology Template – IEC CIM

Ontology Overview

- Define the ontology full name: IEC Common Information Model
- Define the ontology acronym: CIM
- Creator of the ontology and organization:
  - EPRI through CCAPI project.
    Brought to IEC mid- 90.
  - CIM UML model is made by UCA. https://cimug.ucaiug.org/
  - The CIM Users Group (CIMUG) was formed in 2005, as a subgroup of the UCA International Users Group, to provide a forum in which users, consultants, and suppliers could cooperate and leverage the IEC CIM international standards to advance interoperability across the utility enterprise.
- Ontology version number:
  - We need to distinguish the CIM version associated to IEC standard publications (IEC 61970-301, IEC 61968-11, IEC 62325-301) from CIM draft version
    The official CIM version (associated to IEC publications) is available here:
    https://cimug.ucaiug.org/Current%20Official%20CIM%20Model%20Releases/Forms/Custom%20All%20Documents.aspx
  - The current CIM version as IEC publication is:
    iec61970cim17v16_iec61968cim13v11_iec62325cim03v14
  - The Draft versions are accessible here:
    https://cimug.ucaiug.org/CIM%20Model%20Releases/Forms/AllItems.aspx
  - The current CIM version as draft is:
    iec61970cim17v40_iec61968cim13v13b_iec62325cim03v17b_CIM100.1.1.1
- Ontology date of publication: 7 November 2017 for last IEC published version, 4 July 2022 for last draft version

Ontology Documentation & References
• Ontology Documentation: Technical Specification / Documentation of Ontology (URL) ○ Webinars ○ https://www.youtube.com/channel/UCyOJVYHhInwAxoqYjz-kJuQ ○ IEC standards ○ 61970-301, IEC 61968-11, IEC 62325-301 ○ CGMES profiles created by ENTSO-E and standardized by IEC. ○ https://docstore.entsoe.eu/major-projects/common-information-model-cim/cim-for-grid-models-exchange/standards/Pages/default.aspx ○ https://www.entsoe.eu/news/2022/10/19/cgmes-3-0-publishing/ ○ CGMES conformity ○ https://www.entsoe.eu/news/2022/10/07/csa-specifications-v2-1-and-cost-sharing-ig-v1-0-are-now-available/ ○ CGMES youtube presentation made in the context of Int:net May 2023 interoprability tests ○ https://www.youtube.com/playlist?list=PLP7fkvyH8qQdxRE9fDDzlrsBo6l9xVWwU (14 videos) ○ ESMP Profiles ○ https://www.entsoe.eu/publications/electronic-data-interchange-edi-library/ ○ The notion of profile is key, therefore 2 documents provided by ENTSO-E are interesting : CGMES Profiling User Guide : https://eepublicdownloads.entsoe.eu/clean-documents/CIM_documents/Grid_Model_CIM/CGMES_Profiling_User_Guide_v1.0.pdf ○ ESMP User Guide : https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/cim_esmp/ENTSO-E_CIM%20ESMP%20User%20Guide.pdf • Persistent URI of Ontology File: Refer to : The current CIM version as draft is: iec61970cim17v40_iec61968cim13v13b_iec62325cim03v17b_CIM100.1.1.1 or The current CIM version as IEC publication is: iec61970cim17v16_iec61968cim13v11_iec62325cim03v14 These URI will change if a new version is produced. • Research Papers Describing Ontology: ○ CIM Primer : https://www.epri.com/#/pages/product/000000003002006001/ ○ Many other articles have been published; a Springer book also published: https://link.springer.com/book/10.1007/978-3-642-25215-0

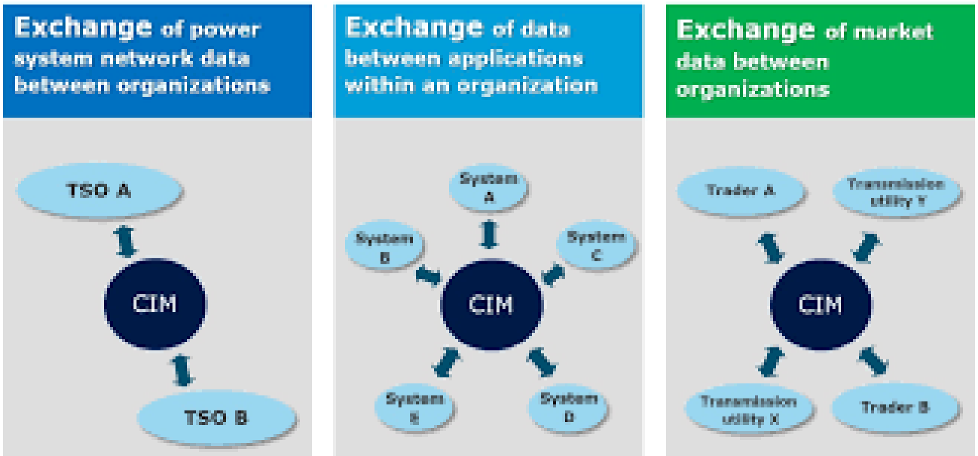
Ontology Domain & Description & Usage
• Select the domain of interest/ Topic/ Scope: Energy : Electricity. Renewable. Local energy : to come with IEC 62746. Flexibility : on-going developments. Power System and related applications

Ontology Domain & Description & Usage

Describe the ontology: IEC CIM is one of the core standards of the smart grid. See CIM Primer : https://www.epri.com/#/pages/product/000000003002006001/.
It supports European Regulation for electricity networks since 2009 (see CGMES, ESMP profiles developed by ENTSO-E). Use in many utilities across the world. See UCA CIMUg sessions/ Smart Grid Forum sessions on CIM. Can be used as a canonical data model to exchange information between Applications of a Utility: see IEC 61968-1 Interface Reference Model. Can be used to exchange information between utilities. CIM supports European regulation associated to Implementing act on customer data access through EUMED Market profile (IEC 62325-451-10), and EUMED Metering profile (IEC 61968-9 Ed 3.0: to be published end of 2023)

- Usage of the ontology: In which context and projects has the ontology been developed? Utility Data Integration European Grid Codes (see ENTSO-E)
- What are the use cases? See IEC 61970: Network modelling and associated calculations (Power flow, load flow, short circuit calculations, …) See IEC 61968 for utility inter-application communication (Planning, Operation, Metering, Customer Management, Asset Management, Operational Planning, …) See IEC 62325 series or Market related use cases See IEC 62746 for Systems interface between customer energy management system and the power management system TSO-DSO use cases: see European projects results like Horizon 2020 TDX-ASSIST
- What are the competency questions? How do you model an electrical network at different voltage level? Can you conduct Electrical calculations? What kind of assets a utility manage? Can you describe utility assets like a Breaker, a Switch, a Transformer, A Line, a BusBar, …? Can you merge different TSO network model to build a pan European Network Model?
- What are the main ontology concepts? Or provide the figure overview.

Ontology Domain & Description & Usage



Ontology Modeling, Reusability and Availability

- Ontology implementation language: CIM is using UML from which it can be exported/transformed in different formats.
- In what language the ontology is implemented? CIM/XML (RDF based), XML-XSD
- Which one (e.g., W3C OWL)? Data format (TTL, JSON-LD, RDF/XML)? : RDF/XML for now. Will also use JSON-LD
- List of CIM profiles from 61968 series : https://cimug.ucaiug.org/CIM%20Profiles/Forms/AllItems.aspx
- Does the ontology have a usage license? Which one?

Copyright
The entire work provided in the UML project file is dedicated to the public domain and is copyrighted under an Apache 2.0 Open Source License. Major portions of this license are owned by the Electric Power Research Institute (EPRI) and the remaining portions are provided by other contributors.

- Ontology semantic web best practices: Is the ontology available online following the semantic web best practices (e.g., FAIR principles)? Explain why? Available on UCA CIM User Group. Documents also available on ENTSO-E Web site. ENTSO-E has a CIM expert group. ENTSO-E is also proposing with EFET and EbIx the Harmonized Electricity Mrket Role Model, which are describing all the Energy Roles. Some of these roles are Market Participants that can be retrieved in IEC CIM ESMP model.
- Ontology Content Negotiation: Does the ontology publication support content negotiation for at least HTML and one OWL serialization? The ontology is managed using Entreprise Architect from Sparx Systems. Several exports of the model can be done (html, XMI, …)

- Ontology Catalog: In what ontology catalogs is registered the ontology? Not registered yet as such or to be investigated if a catalog refers to the last CIM version (draft/IEC)

Ontology Maturity, Maintenance, Adoption, Sustainability

- Define the TRL: TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space) Justify the choice of this TRL: Usage of ESMP and CGMES in Europe
- Ontology Adoption: Is the ontology adopted by the industry and used in practice?
- Are there relevant communities behind it (industry, standardization, research)?
- Is it supported by standards, which? UCA, IEC Conferences from UCACIMUg, SmartGrid Forum
  - Ontology Reuse / Alignment: Have the authors of this ontology aligned/mapped it to other existing ontologies (if any) of similar scope? Harmonisation with 61850 and COSEM
    Did the creators perform an appropriate reuse or extension of suitable high-quality ontologies? Not for now. Will be in CGMES 3.0.0 : see Metadata and document header exchange specification https://eepublicdownloads.entsoe.eu/clean-documents/CIM_documents/Grid_Model_CIM/MetadataAndHeaderDataExchangeSpecification_v2.0.pdf Have upper ontologies been extended? Have ontology design patterns been used? The CIM ontology used by ENTSO-E make use of HEMRM (Harmonized Electricity Market Role Model) https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/HRM/Harmonised_Role_Model_2022-01.pdf
- Has this ontology been used by other ontologies? Don't know?
- Sustainability & Maintainability: Is there a community maintaining the ontology? YES Is there a sustainability plan? YES Is there a plan for the medium and long-term maintenance of the ontology? YES Sustainability & Maintainability Level: There can be different levels, starting from an individual person committed to the maintenance, to a professional organization such as a standardization body. Level 4 - a standardization body (member-based organization)

Reasoning

- Do you employ a reasoner with the ontology? Which type of reasoner? (e.g., provide the name of the reasoner, rule language, rule examples, for which purpose) OCL, SHACL

IoT/Sensor

- What are the sensors used? Add Sensor measurement name and unit. Electric Sensors are modelled
- Did you used IoT ontologies? Unit Ontologies? No

References:

- IEC TC57 : https://www.iec.ch/dyn/www/f?p=103:7:0::::FSP_ORG_ID,FSP_LANG_ID:1273,25
- ENTSO-E : https://www.entsoe.eu/data/cim/
- EbIX reference to HEMRM : https://www.ebix.org/artikel/role_model
- UCACIMUg : https://cimug.ucaiug.org/
- EPRI : https://www.epri.com/#/pages/product/000000003002006001/
- DNV GL : https://www.dnv.com/services/common-information-model-216739
- SmartGridForum : https://www.linkedin.com/posts/smartgrid-forums_smartgrid-ieccim-asset-activity-7057292297448644610-btae/?originalSubdomain=dk
- European funded projects like TDX-ASSIST, EU-SysFlex, Flexiciency, … which used CIM

Annex B DataValueOntology

.

```
@prefix : <https://w3id.org/omega-x/ValueSetOntology#>
@prefix cc: <http://creativecommons.org/ns#>.
@prefix vs: <http://www.w3.org/2003/06/sw-vocab-status/ns#>.
@prefix owl: <http://www.w3.org/2002/07/owl#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xml: <http://www.w3.org/XML/1998/namespace>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix vann: <http://purl.org/vocab/vann/>.
@prefix voaf: <http://purl.org/vocommons/voaf#>.
@prefix dcterms: <http://purl.org/dc/terms/>.
@prefix time: <http://www.w3.org/2006/time#>.
@base <https://w3id.org/omega-x/ValueSetOntology>.

<https://w3id.org/omega-x/ValueSetOntology> rdf:type owl:Ontology ;
                                owl:versionIRI <https://w3id.org/omega-x/ValueSetOntology-0.2>
;
                                dcterms:contributor <https://omega-x.eu/> ;
                                dcterms:issued "2023-09-04"^^xsd:date ,
                                        "This Value Set Ontology helps to define time-series and
events."@en ;
                                dcterms:license    <https://www.apache.org/licenses/LICENSE-
2.0> ;
                                dcterms:modified "2023-09-06"@en ;
                                dcterms:title "Value Set ontology"@en ;
                                vann:preferredNamespacePrefix "ets" ;
                                vann:preferredNamespaceUri <https://w3id.org/omega-x/> ;
                                rdfs:label "Value Set Ontology"@en ;
                                owl:versionInfo "v0.2".

#################################################################
#    Annotation properties
#################################################################

###  http://purl.org/dc/terms/contributor
```

dcterms:contributor rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/creator
dcterms:creator rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/description
dcterms:description rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/issued
dcterms:issued rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/license
dcterms:license rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/modified
dcterms:modified rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/title
dcterms:title rdf:type owl:AnnotationProperty.

http://purl.org/vocab/vann/preferredNamespacePrefix
vann:preferredNamespacePrefix rdf:type owl:AnnotationProperty.

http://purl.org/vocab/vann/preferredNamespaceUri
vann:preferredNamespaceUri rdf:type owl:AnnotationProperty.

http://www.w3.org/2002/07/owl#maxQualifiedCardinality
owl:maxQualifiedCardinality rdf:type owl:AnnotationProperty.

```
###  http://www.w3.org/2002/07/owl#qualifiedCardinality
owl:qualifiedCardinality rdf:type owl:AnnotationProperty.


###  http://www.w3.org/2003/06/sw-vocab-status/ns#term_status
vs:term_status rdf:type owl:AnnotationProperty.


#################################################################
#    Object Properties
#################################################################

###  https://w3id.org/omega-x/period
<https://w3id.org/omega-x/period> rdf:type owl:ObjectProperty ;
                    rdfs:domain [ rdf:type owl:Class ;
                          owl:unionOf ( <https://w3id.org/omega-x/Record>
                                <https://w3id.org/omega-x/Series>
                              )
                        ] ;
                    rdfs:range <http://www.w3.org/2006/time#Interval> ;
                    rdfs:comment "The period global to a series or specific to a record."@en ;
                    rdfs:label "period"@en.

###  https://w3id.org/omega-x/instant
<https://w3id.org/omega-x/instant> rdf:type owl:ObjectProperty ;
                rdfs:domain [ rdf:type owl:Class ;
                      owl:unionOf ( <https://w3id.org/omega-x/Event>
                            <https://w3id.org/omega-x/Record>
                          )
                    ] ;
                rdfs:range <http://www.w3.org/2006/time#Instant> ;
                rdfs:comment "The instant when an event was triggered or a record was created."@en ;
                rdfs:label "instant"@en.
```

```
### https://w3id.org/omega-x/isComposedOf
<https://w3id.org/omega-x/isComposedOf> rdf:type owl:ObjectProperty ;
                              owl:inverseOf <https://w3id.org/omega-x/isElementOf> ;
                              rdfs:domain <https://w3id.org/omega-x/Series> ;
                              rdfs:range <https://w3id.org/omega-x/ValueSet> ;
                              rdfs:comment " The list of elements of a series."@en ;
                              rdfs:label "is composed of"@en.


### https://w3id.org/omega-x/isElementOf
<https://w3id.org/omega-x/isElementOf> rdf:type owl:ObjectProperty ;
                             rdfs:domain <https://w3id.org/omega-x/ValueSet> ;
                             rdfs:range <https://w3id.org/omega-x/Series> ;
                             rdfs:comment "The series that contains an element."@en ;
                             rdfs:label "is element of"@en.

### https://w3id.org/omega-x/step
<https://w3id.org/omega-x/step> rdf:type owl:ObjectProperty ;
                             rdfs:domain <https://w3id.org/omega-x/Series> ;
                             rdfs:range <http://www.w3.org/2006/time#Duration> ;
                             rdfs:comment "The step between two values in a series in case it is
regular spaced."@en ;
                             rdfs:label "step"@en.


#################################################################
#    Data properties
#################################################################

### https://w3id.org/omega-x/cause
<https://w3id.org/omega-x/cause> rdf:type owl:DatatypeProperty ;
                         rdfs:domain <https://w3id.org/omega-x/Event> ;
                         rdfs:range xsd:string ;
                         rdfs:comment "The cause that triggered an event."@en ;
                         rdfs:label "cause"@en.


### https://w3id.org/omega-x/identifier
```

```
<https://w3id.org/omega-x/identifier> rdf:type owl:DatatypeProperty ;
                              rdfs:domain <https://w3id.org/omega-x/ValueSet> ;
                              rdfs:range xsd:string ;
                              rdfs:comment "The identifier of a value set."@en ;
                              rdfs:label "identifier"@en.


###  https://w3id.org/omega-x/name
<https://w3id.org/omega-x/name> rdf:type owl:DatatypeProperty ;
                              rdfs:domain <https://w3id.org/omega-x/ValueSet> ;
                              rdfs:range xsd:string ;
                              rdfs:comment "The name of a value set."@en ;
                              rdfs:label "name"@en.


###  https://w3id.org/omega-x/numberOfValues
<https://w3id.org/omega-x/numberOfValues> rdf:type owl:DatatypeProperty ;
                                          rdfs:domain <https://w3id.org/omega-x/Series> ;
                                          rdfs:range xsd:integer ;
                                          rdfs:comment "The number of values of a series."@en ;
                                          rdfs:label "number of values"@en.


###  https://w3id.org/omega-x/quality
<https://w3id.org/omega-x/quality> rdf:type owl:DatatypeProperty ;
                                   rdfs:domain <https://w3id.org/omega-x/ValueSet> ;
                                   rdfs:range xsd:string ;
                                   rdfs:comment """The property that qualifies a value set.
Possible values (but this list may be extended) are: adjusted, not available, estimated, as provided, incomplete, predicted, planned."""@en ;
                                   rdfs:label "quality"@en.


###  https://w3id.org/omega-x/rank
<https://w3id.org/omega-x/rank> rdf:type owl:DatatypeProperty ;
                                rdfs:domain <https://w3id.org/omega-x/Record> ;
                                rdfs:range xsd:integer ;
```

```
                              rdfs:comment "The position of a record in case it is part of a series."@en
;
                              rdfs:label "rank"@en.


###  https://w3id.org/omega-x/state
<https://w3id.org/omega-x/state> rdf:type owl:DatatypeProperty ;
                              rdfs:domain <https://w3id.org/omega-x/Event> ;
                              rdfs:range xsd:string ;
                              rdfs:comment "The state of a system following the occurence of an
event."@en ;
                              rdfs:label "state"@en.


###  https://w3id.org/omega-x/value
<https://w3id.org/omega-x/value> rdf:type owl:DatatypeProperty ;
                              rdfs:domain [ rdf:type owl:Class ;
                                            owl:unionOf ( <https://w3id.org/omega-x/Event>
                                                          <https://w3id.org/omega-x/Record>
                                                        )
                                          ] ;
                              rdfs:range xsd:string ;
                              rdfs:comment "The value contained in an event or a record."@en ;
                              rdfs:label "value"@en.


#################################################################
#    Classes
#################################################################

###  http://www.w3.org/2006/time#Interval
<http://www.w3.org/2006/time#Interval> rdf:type owl:Class.


###  https://w3id.org/omega-x/Event
<https://w3id.org/omega-x/Event> rdf:type owl:Class ;
                              rdfs:subClassOf <https://w3id.org/omega-x/ValueSet> ;
                              rdfs:comment "Value container for an event."@en ;
```

```
                         rdfs:label "Event"@en.


###  https://w3id.org/omega-x/Record
<https://w3id.org/omega-x/Record> rdf:type owl:Class ;
                         rdfs:subClassOf <https://w3id.org/omega-x/ValueSet> ;
                         rdfs:comment "Value container for a record."@en ;
                         rdfs:label "Record"@en.


###  https://w3id.org/omega-x/Series
<https://w3id.org/omega-x/Series> rdf:type owl:Class ;
                         rdfs:subClassOf <https://w3id.org/omega-x/ValueSet> ;
                         rdfs:comment "Value container for a series."@en ;
                         rdfs:label "Series"@en.


###  https://w3id.org/omega-x/ValueSet
<https://w3id.org/omega-x/ValueSet> rdf:type owl:Class ;
                         rdfs:comment "Value container for a set of data (record, event or series)."@en ;
                         rdfs:label "Value Set"@en.


###  Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z) https://github.com/owlcs/owlapi
```

Annex C EnergyDataSetOntology

```
@prefix : <https://w3id.org/omega-x/EnergyDataSetOntology#>.
@prefix cc: <http://creativecommons.org/ns#>.
@prefix om: <http://www.ontology-of-units-of-measure.org/resource/om#>.
@prefix vs: <http://www.w3.org/2003/06/sw-vocab-status/ns#>.
@prefix eds: <https://w3id.org/omega-x/EnergyDataSetOntology#>.
@prefix ets: <https://w3id.org/omega-x/ValueSetOntology#>.
@prefix owl: <http://www.w3.org/2002/07/owl#>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xml: <http://www.w3.org/XML/1998/namespace>.
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>.
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>.
@prefix time: <http://www.w3.org/2006/time#>.
@prefix vann: <http://purl.org/vocab/vann/>.
@prefix voaf: <http://purl.org/vocommons/voaf#>.
@prefix dcterms: <http://purl.org/dc/terms/>.
@base <https://w3id.org/omega-x/EnergyDataSetOntology>.

<https://w3id.org/omega-x/EnergyDataSetOntology> rdf:type owl:Ontology ;
                                owl:versionIRI                              <https://w3id.org/omega-
x/EnergyDataSetOntology-0.2> ;
                                owl:imports <https://w3id.org/omega-x/ValueSetOntology-0.2> ;
                                dcterms:contributor <https://omega-x.eu/> ;
                                dcterms:issued "2023-09-04"^^xsd:date ,
                                          "This Energy Dataset Ontology helps to define data sets
in Energy Data Spaces."@en ;
                                dcterms:license <https://www.apache.org/licenses/LICENSE-2.0>
;
                                dcterms:modified "2023-09-11"@en ;
                                dcterms:title "Energy Data Set ontology"@en ;
                                vann:preferredNamespacePrefix "eds" ;
                                vann:preferredNamespaceUri <https://w3id.org/omega-x/> ;
                                rdfs:label "Energy Data Set Ontology"@en ;
                                owl:versionInfo "v0.2".

########################################################################
```

Annotation properties
###

http://purl.org/dc/terms/contributor
dcterms:contributor rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/creator
dcterms:creator rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/description
dcterms:description rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/issued
dcterms:issued rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/license
dcterms:license rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/modified
dcterms:modified rdf:type owl:AnnotationProperty.

http://purl.org/dc/terms/title
dcterms:title rdf:type owl:AnnotationProperty.

http://purl.org/vocab/vann/preferredNamespacePrefix
vann:preferredNamespacePrefix rdf:type owl:AnnotationProperty.

http://purl.org/vocab/vann/preferredNamespaceUri
vann:preferredNamespaceUri rdf:type owl:AnnotationProperty.

```
###  http://www.w3.org/2002/07/owl#maxQualifiedCardinality
owl:maxQualifiedCardinality rdf:type owl:AnnotationProperty.


###  http://www.w3.org/2002/07/owl#qualifiedCardinality
owl:qualifiedCardinality rdf:type owl:AnnotationProperty.


###  http://www.w3.org/2003/06/sw-vocab-status/ns#term_status
vs:term_status rdf:type owl:AnnotationProperty.


#################################################################
#    Object Properties
#################################################################

###  https://w3id.org/omega-x/contains
<https://w3id.org/omega-x/contains> rdf:type owl:ObjectProperty ;
                            owl:inverseOf <https://w3id.org/omega-x/isPartOf> ;
                            rdfs:domain <https://w3id.org/omega-x/EnergyDataSet> ;
                            rdfs:range [ rdf:type owl:Class ;
                                         owl:unionOf          (          <https://w3id.org/omega-
x/EnergyValueSet>
                                                     <https://w3id.org/omega-x/EvaluationPoint>
                                                                         <https://w3id.org/omega-
x/BusinessContext>
                                                                         <https://w3id.org/omega-
x/TechnicalContext>
                                                     )
                                        ] ;
                            rdfs:comment "Gives access to the list of data values, evaluation points,
business contexts and technical contexte contained in a data set exchanged using an Energy
Dataspace."@en ;
                            rdfs:label "contains"@en.


###  https://w3id.org/omega-x/hasBusinessContext
<https://w3id.org/omega-x/hasBusinessContext> rdf:type owl:ObjectProperty ;
```

owl:inverseOf <https://w3id.org/omega-x/isBusinessContextOf> ;

rdfs:domain <https://w3id.org/omega-x/EnergyValueSet> ;

rdfs:range <https://w3id.org/omega-x/BusinessContext> ;

rdfs:comment "Links the value set to a specific business context."@en ;

rdfs:label "has business context"@en.

https://w3id.org/omega-x/hasEvaluationPoint

<https://w3id.org/omega-x/hasEvaluationPoint> rdf:type owl:ObjectProperty ;

owl:inverseOf <https://w3id.org/omega-x/isEvaluationPointOf> ;

rdfs:domain <https://w3id.org/omega-x/EnergyValueSet>;

rdfs:range <https://w3id.org/omega-x/EvaluationPoint> ;

rdfs:comment "Links the value set to a specific evaluation point."@en ;

rdfs:label "has evaluation point"@en.

https://w3id.org/omega-x/macroPeriod

<https://w3id.org/omega-x/macroPeriod> rdf:type owl:ObjectProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range time:Interval ;

rdfs:comment "Time period of interest that reflects how the reading is viewed or captured over a long period of time."@en ;

rdfs:label "macro period"@en.

https://w3id.org/omega-x/measuringPeriod

<https://w3id.org/omega-x/measuringPeriod> rdf:type owl:ObjectProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range time:Interval ;

rdfs:comment """Time attribute inherent or fundamental to the reading value (as opposed to 'macroPeriod' that supplies an "adjective" to describe aspects of a time period with regard to the measurement). It refers to the way the value was originally measured and not to the frequency at which it is reported or presented. For example, an hourly interval of consumption data would have value 'hourly' as an attribute. However in the case of an hourly sampled voltage value, the meterReadings schema would carry the 'hourly' interval size information.

It is common for meters to report demand in a form that is measured over the course of a portion of an hour, while enterprise applications however commonly assume the demand (in kW or kVAr) normalised to 1 hour. The system that receives readings directly from the meter therefore shall perform this transformation before publishing readings for use by the other enterprise systems. The scalar used is chosen based on the block size (not any sub-interval size)."""@en ;

rdfs:label "measuring period"@en.

https://w3id.org/omega-x/unitSymbol

<https://w3id.org/omega-x/unitSymbol> rdf:type owl:ObjectProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range om:Unit ;

rdfs:comment "Metering-specific unit."@en ;

rdfs:label "unit symbol"@en.

https://w3id.org/omega-x/hasTechnicalContext

<https://w3id.org/omega-x/hasTechnicalContext> rdf:type owl:ObjectProperty ;

owl:inverseOf <https://w3id.org/omega-x/isTechnicalContextOf> ;

rdfs:domain <https://w3id.org/omega-x/EnergyValueSet> ;

rdfs:range <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:comment "Links the value set to a specific technical context."@en ;

rdfs:label "has technical context"@en.

https://w3id.org/omega-x/isBusinessContextOf

<https://w3id.org/omega-x/isBusinessContextOf> rdf:type owl:ObjectProperty ;

rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;

rdfs:range <https://w3id.org/omega-x/EnergyValueSet> ;

rdfs:comment "Links the business context to a specific value set."@en ;

rdfs:label "is business context of"@en.

https://w3id.org/omega-x/isEvaluationPointOf

<https://w3id.org/omega-x/isEvaluationPointOf> rdf:type owl:ObjectProperty ;

rdfs:domain <https://w3id.org/omega-x/EvaluationPoint> ;

rdfs:range <https://w3id.org/omega-x/EnergyValueSet> ;

```
                                        rdfs:comment "Links the evaluation point to a specific value set."@en ;
                                        rdfs:label "is evaluation point of"@en.


### https://w3id.org/omega-x/isPartOf
<https://w3id.org/omega-x/isPartOf> rdf:type owl:ObjectProperty ;
                              rdfs:domain [ rdf:type owl:Class ;
                                          owl:unionOf ( <https://w3id.org/omega-x/EnergyValueSet>
                                                      <https://w3id.org/omega-x/EvaluationPoint>
                                                      <https://w3id.org/omega-x/BusinessContext>
                                                      <https://w3id.org/omega-x/TechnicalContext>
                                                    )
                                          ] ;
                              rdfs:range <https://w3id.org/omega-x/EnergyDataSet> ;
                              rdfs:comment "Gives access to the value sets, evaluation points, business conexts and technical contexts of a dataset exchanged using an Energy Dataspace."@en ;
                              rdfs:label "is part of"@en.


### https://w3id.org/omega-x/isTechnicalContextOf
<https://w3id.org/omega-x/isTechnicalContextOf> rdf:type owl:ObjectProperty ;
                                        rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
                                        rdfs:range <https://w3id.org/omega-x/EnergyValueSet> ;
                                        rdfs:comment "Links the technical context to a specific value set."@en ;
                                        rdfs:label "is technical context of"@en.


#################################################################
#    Data properties
#################################################################

### https://w3id.org/omega-x/typeId
<https://w3id.org/omega-x/typeId> rdf:type owl:DatatypeProperty ;
```

```
                                rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                                rdfs:range xsd:string ;
                                rdfs:comment "Identifier of the type of the business context."@en ;
                                rdfs:label "type identifier"@en.


###  https://w3id.org/omega-x/typeName
<https://w3id.org/omega-x/typeName> rdf:type owl:DatatypeProperty ;
                                rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                                rdfs:range xsd:string ;
                                rdfs:comment "Name of the type of the business context."@en ;
                                rdfs:label "type name"@en.


###  https://w3id.org/omega-x/typeVersion
<https://w3id.org/omega-x/typeVersion> rdf:type owl:DatatypeProperty ;
                                rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                                rdfs:range xsd:string ;
                                rdfs:comment "Version of the type of the business context."@en ;
                                rdfs:label "type version"@en.


###  https://w3id.org/omega-x/sourceId
<https://w3id.org/omega-x/sourceId> rdf:type owl:DatatypeProperty ;
                                rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                                rdfs:range xsd:string ;
                                rdfs:comment "Identifier of the source of the data exchanged."@en ;
                                rdfs:label "source identifier"@en.


###  https://w3id.org/omega-x/sourceName
<https://w3id.org/omega-x/sourceName> rdf:type owl:DatatypeProperty ;
                                rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                                rdfs:range xsd:string ;
                                rdfs:comment "Name of the source of the data exchanged."@en ;
                                rdfs:label "source name"@en.
```

https://w3id.org/omega-x/sourceType

<https://w3id.org/omega-x/sourceType> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
rdfs:range xsd:string ;
rdfs:comment "Type of the source of the data exchanged."@en ;
rdfs:label "source type"@en.

https://w3id.org/omega-x/targetId

<https://w3id.org/omega-x/targetId> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
rdfs:range xsd:string ;
rdfs:comment "Identifier of the target of the data exchanged."@en ;
rdfs:label "iarget identifier"@en.

https://w3id.org/omega-x/targetName

<https://w3id.org/omega-x/targetName> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
rdfs:range xsd:string ;
rdfs:comment "Name of the target of the data exchanged."@en ;
rdfs:label "target name"@en.

https://w3id.org/omega-x/targetType

<https://w3id.org/omega-x/targetType> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
rdfs:range xsd:string;
rdfs:comment "Type of the target of the data exchanged."@en ;
rdfs:label "target type"@en.

https://w3id.org/omega-x/build

<https://w3id.org/omega-x/build> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
rdfs:range time:instant ;
rdfs:comment "Tilme stamp of the data exchange."@en ;
rdfs:label "build"@en.

```
###  https://w3id.org/omega-x/briefId
<https://w3id.org/omega-x/briefId> rdf:type owl:DatatypeProperty ;
                    rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                    rdfs:range xsd:string ;
                    rdfs:comment "Identifier of the brief associated to the business context."@en ;
                    rdfs:label "brief identifier"@en.


###  https://w3id.org/omega-x/contractId
<https://w3id.org/omega-x/contractId> rdf:type owl:DatatypeProperty ;
                    rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                    rdfs:range xsd:string ;
                    rdfs:comment "Identifier of the contract associated to the business context."@en ;
                    rdfs:label "contract identifier"@en.


###  https://w3id.org/omega-x/subscriptionNb
<https://w3id.org/omega-x/subscriptionNb> rdf:type owl:DatatypeProperty ;
                    rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                    rdfs:range xsd:string ;
                    rdfs:comment "Number of the subscription associated to the business context."@en ;
                    rdfs:label "subscription number"@en.


###  https://w3id.org/omega-x/conditionsOfUse
<https://w3id.org/omega-x/conditionsOfUse> rdf:type owl:DatatypeProperty ;
                    rdfs:domain <https://w3id.org/omega-x/BusinessContext> ;
                    rdfs:range xsd:string ;
                    rdfs:comment "Conditions of use associated to the business context."@en ;
                    rdfs:label "condisions of use"@en.
```

https://w3id.org/omega-x/aggregate

<https://w3id.org/omega-x/aggregate> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment """Salient attribute of the reading data aggregated from individual endpoints. This is mainly used to define a mathematical operation carried out over 'macroPeriod', but may also be used to describe an attribute of the data when the 'macroPeriod' is not defined.

Possible values are: none, average, axcess, highThreshold, lowThreshold, maximum, minimum, nominal, secondMaximum, secondMinimum, thirdMaximum, fourthMaximum, fifthdMaximum, sum, or other."""@en ;

rdfs:label "aggregate"@en.

https://w3id.org/omega-x/argument

<https://w3id.org/omega-x/argument> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment """SArgument used to introduce numbers into the unit of measure description where they are needed (e.g., 4 where the measure needs an argument such as CEMI(n=4)). Most arguments used in practice however will be integers (i.e., 'denominator'=1).

Value 0 in 'numerator' and 'denominator' means not applicable."""@en ;

rdfs:label "argument"@en.

https://w3id.org/omega-x/commodity

<https://w3id.org/omega-x/commodity> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment """Commodity being measured.

"""@en ;

rdfs:label "commodity"@en.

https://w3id.org/omega-x/consumptionTier

<https://w3id.org/omega-x/consumptionTier> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment """In case of common flat-rate pricing for power, in which all purchases are at a given rate, 'consumptionTier'=0. Otherwise, the value indicates the consumption tier, which can be used in conjunction with TOU or CPP pricing.

Consumption tier pricing refers to the method of billing in which a certain "block" of energy is purchased/sold at one price, after which the next block of energy is purchased at another price, and so on, all throughout a defined period. At the start of the defined period, consumption is initially zero, and any usage is measured against the first consumption tier ('consumptionTier'=1). If this block of energy is consumed before the end of the period, energy consumption moves to be reconed against the second consumption tier ('consumptionTier'=2), and so on. At the end of the defined period, the consumption accumulator is reset, and usage within the 'consumptionTier'=1 restarts. """@en ;

rdfs:label "consumption tier"@en.

https://w3id.org/omega-x/cpp

<https://w3id.org/omega-x/cpp> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment """Critical peak period (CPP) bucket the reading value is attributed to. Value 0 means not applicable. Even though CPP is usually considered a specialised form of time of use 'tou', this attribute is defined explicitly for flexibility."""@en ;

rdfs:label "critical peak period"@en.

https://w3id.org/omega-x/currency

<https://w3id.org/omega-x/currency> rdf:type owl:DatatypeProperty ;

rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;

rdfs:range xsd:string ;

rdfs:comment "Metering-specific currency. "@en ;

rdfs:label "currency"@en.

https://w3id.org/omega-x/evaluationPointId

<https://w3id.org/omega-x/evaluationPointId> rdf:type owl:DatatypeProperty ,

owl:FunctionalProperty ;

rdfs:domain <https://w3id.org/omega-x/EvaluationPoint> ;

rdfs:range xsd:string ;

rdfs:comment "The identifier of an evaluation point."@en ;

rdfs:label "evaluation point id"@en.

```
### https://w3id.org/omega-x/technicalContextId
<https://w3id.org/omega-x/technicalContextId> rdf:type owl:DatatypeProperty ,
                owl:FunctionalProperty ;
        rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
        rdfs:range xsd:string ;
        rdfs:comment "The identifier of a technical context."@en ;
        rdfs:label "technical context id"@en.



### https://w3id.org/omega-x/evaluationPointKind
<https://w3id.org/omega-x/evaluationPointKind> rdf:type owl:DatatypeProperty ;
        rdfs:domain <https://w3id.org/omega-x/EvaluationPoint> ;
        rdfs:range xsd:string ;
        rdfs:comment "The kind  of the evaluation point that can be described based on the context of a dataset exchanged using an Energy Dataspace."@en ;
        rdfs:label "evaluation point kind"@en.



### https://w3id.org/omega-x/flowDirection
<https://w3id.org/omega-x/flowDirection> rdf:type owl:DatatypeProperty ;
        rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
        rdfs:range xsd:string ;
        rdfs:comment "Flow direction for a reading where the direction of flow of the commodity is important (for electricity measurements this includes current, energy, power, and demand)."@en ;
        rdfs:label "flow direction"@en.


### https://w3id.org/omega-x/interharmonic
<https://w3id.org/omega-x/interharmonic> rdf:type owl:DatatypeProperty ;
        rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
        rdfs:range xsd:string ;
        rdfs:comment """Indication of a "harmonic" or "interharmonic" basis for the measurement. Value 0 in 'numerator' and 'denominator' means not applicable."""@en ;
        rdfs:label "interharmonic"@en.



### https://w3id.org/omega-x/location
<https://w3id.org/omega-x/location> rdf:type owl:DatatypeProperty ;
```

rdfs:domain <https://w3id.org/omega-x/EvaluationPoint> ;
rdfs:range xsd:string ;
rdfs:comment "The location of an evaluation point."@en ;
rdfs:label "location"@en.

https://w3id.org/omega-x/measurementKind
<https://w3id.org/omega-x/measurementKind> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
rdfs:range xsd:string ;
rdfs:comment """Identifies "what" is being measured, as refinement of 'commodity'. When combined with 'unit', it provides detail to the unit of measure. For example, 'energy' with a unit of measure of 'kWh' indicates to the user that active energy is being measured, while with 'kVAh' or 'kVArh', it indicates apparent energy and reactive energy, respectively. 'power' can be combined in a similar way with various power units of measure: Distortion power ('distortionVoltAmperes') with 'kVA' is different from 'power' with 'kVA'."""@en ;
rdfs:label "measurementKind"@en.

https://w3id.org/omega-x/phases
<https://w3id.org/omega-x/phases> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
rdfs:range xsd:string ;
rdfs:comment "Metering-specific phase code."@en ;
rdfs:label "phases"@en.

https://w3id.org/omega-x/tou
<https://w3id.org/omega-x/tou> rdf:type owl:DatatypeProperty ;
rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
rdfs:range xsd:string ;
rdfs:comment "Time of use (TOU) bucket the reading value is attributed to. Value 0 means not applicable."@en ;
rdfs:label "time of use"@en.

https://w3id.org/omega-x/unitMultiplier
<https://w3id.org/omega-x/unitMultiplier> rdf:type owl:DatatypeProperty ;

```
                                   rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
                                   rdfs:range xsd:string ;
                                   rdfs:comment "Metering-specific multiplier."@en ;
                                   rdfs:label "unit multiplier"@en.



###  https://w3id.org/omega-x/valueDataType
<https://w3id.org/omega-x/valueDataType> rdf:type owl:DatatypeProperty ;
                                  rdfs:domain <https://w3id.org/omega-x/TechnicalContext> ;
                                  rdfs:range xsd:string ;
                                  rdfs:comment "Data type (integer, decimal, boolean, string...) of the values contained in the value set."@en ;
                                  rdfs:label   "value data type"@en.


#################################################################
#    Classes
#################################################################

###  https://w3id.org/omega-x/TechnicalContext
<https://w3id.org/omega-x/TechnicalContext> rdf:type owl:Class ;
                                   rdfs:comment "Technical characteristics of the context where the exchange of data takes place."@en ;
                                   rdfs:label "Technical Context"@en.



###  http://www.ontology-of-units-of-measure.org/resource/om-2/Unit
om:Unit rdf:type owl:Class.



###  http://www.w3.org/2006/time#Duration
time:Duration rdf:type owl:Class.



###  https://w3id.org/omega-x/BusinessContext
<https://w3id.org/omega-x/BusinessContext> rdf:type owl:Class ;
```

```
                    rdfs:comment "Business characteristics of the context where the exchange of data takes place."@en ;
                    rdfs:label "Business Context"@en.


###  https://w3id.org/omega-x/EvaluationPoint
<https://w3id.org/omega-x/EvaluationPoint> rdf:type owl:Class ;
                    rdfs:comment "Evaluation point concerned by the exchange of data takes place."@en ;
                    rdfs:label "Evaluation Point"@en.


###  https://w3id.org/omega-x/EnergyDataSet
<https://w3id.org/omega-x/EnergyDataSet> rdf:type owl:Class ;
                rdfs:comment "Group of data exchanged using an Energy Dataspace."@en ;
                rdfs:label "Energy Data Set"@en.


###  https://w3id.org/omega-x/EnergyValueSet
<https://w3id.org/omega-x/EnergyValueSet> rdfs:subClassOf <https://w3id.org/omega-x/ValueSet>;
                rdfs:comment "Group of values exchanged using an Energy Dataspace."@en ;
                rdfs:label "Energy Value Set"@en .


#################################################################
#    Annotations
#################################################################


###  Generated by the OWL API (version 4.5.9.2019-02-01T07:24:44Z) https://github.com/owlcs/owlapi
```

Annex D Interaction Model Sequence Diagrams

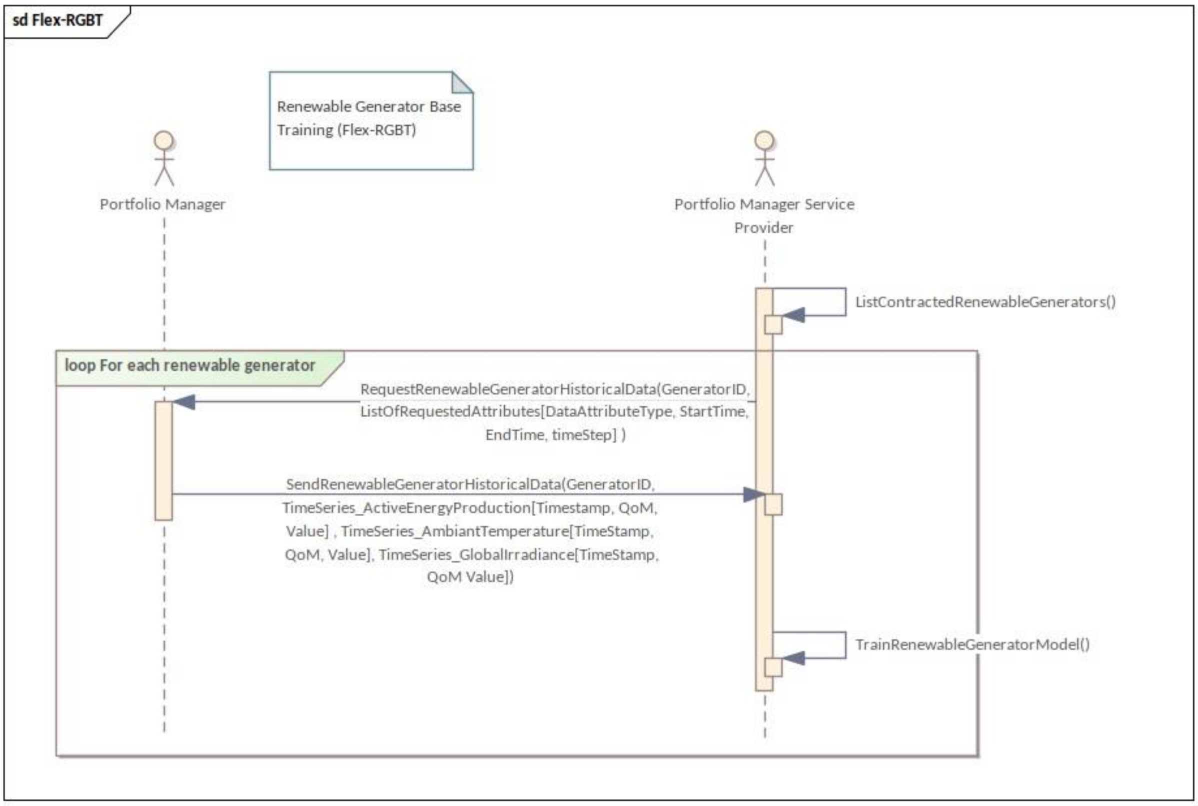


Figure 50 Flex-RGBT Renewable Generator Base Training

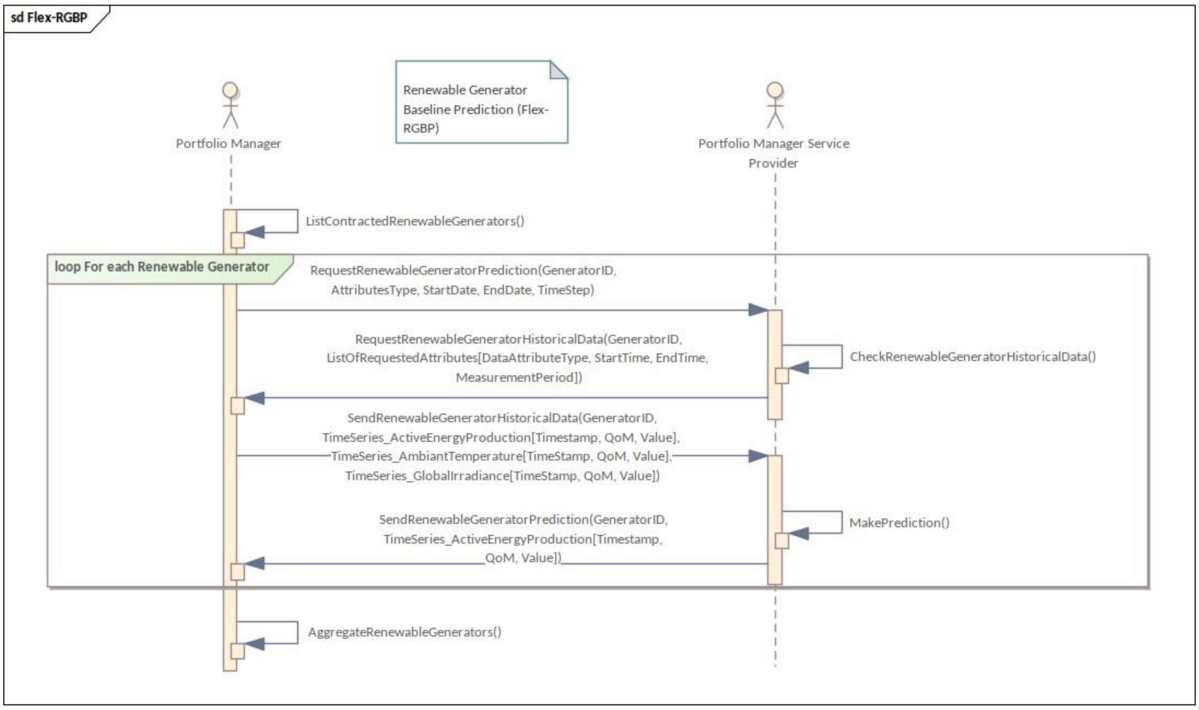


Figure 51 Flex-RGBP Renewable Generator Base line Prediction

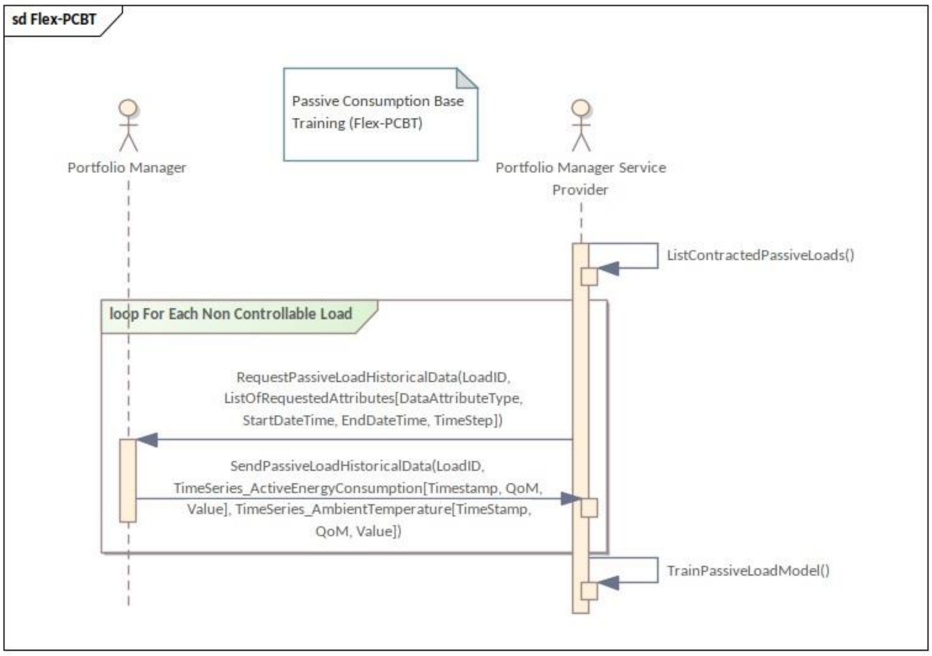


Figure 52 Flex-PCBT Passive Consumption Base Training

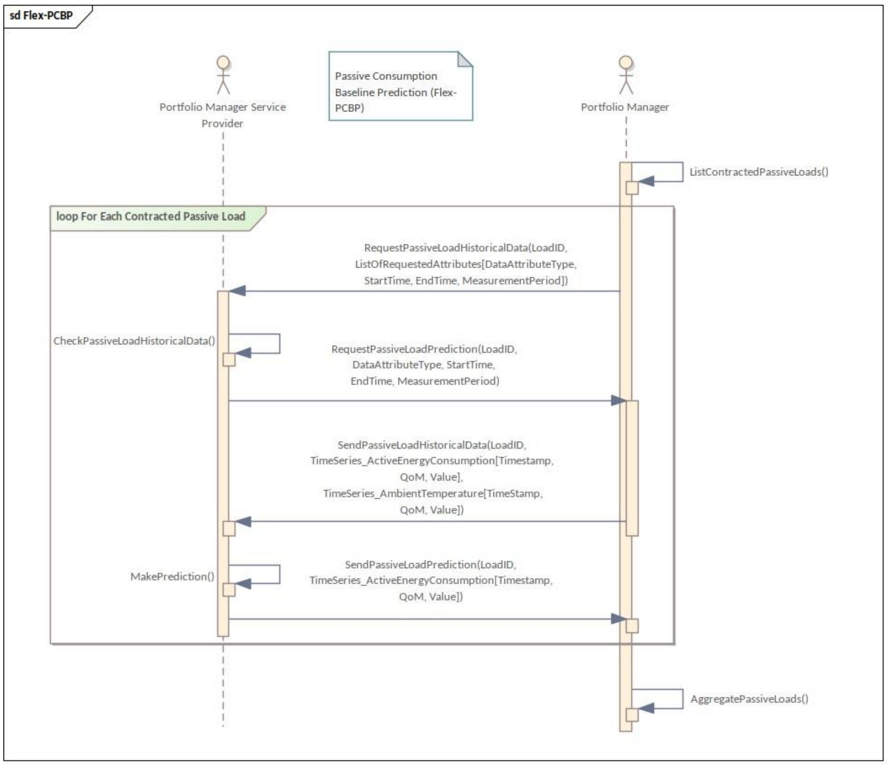


Figure 53 Flex-PCBP Passive Consumption Baseline Prediction

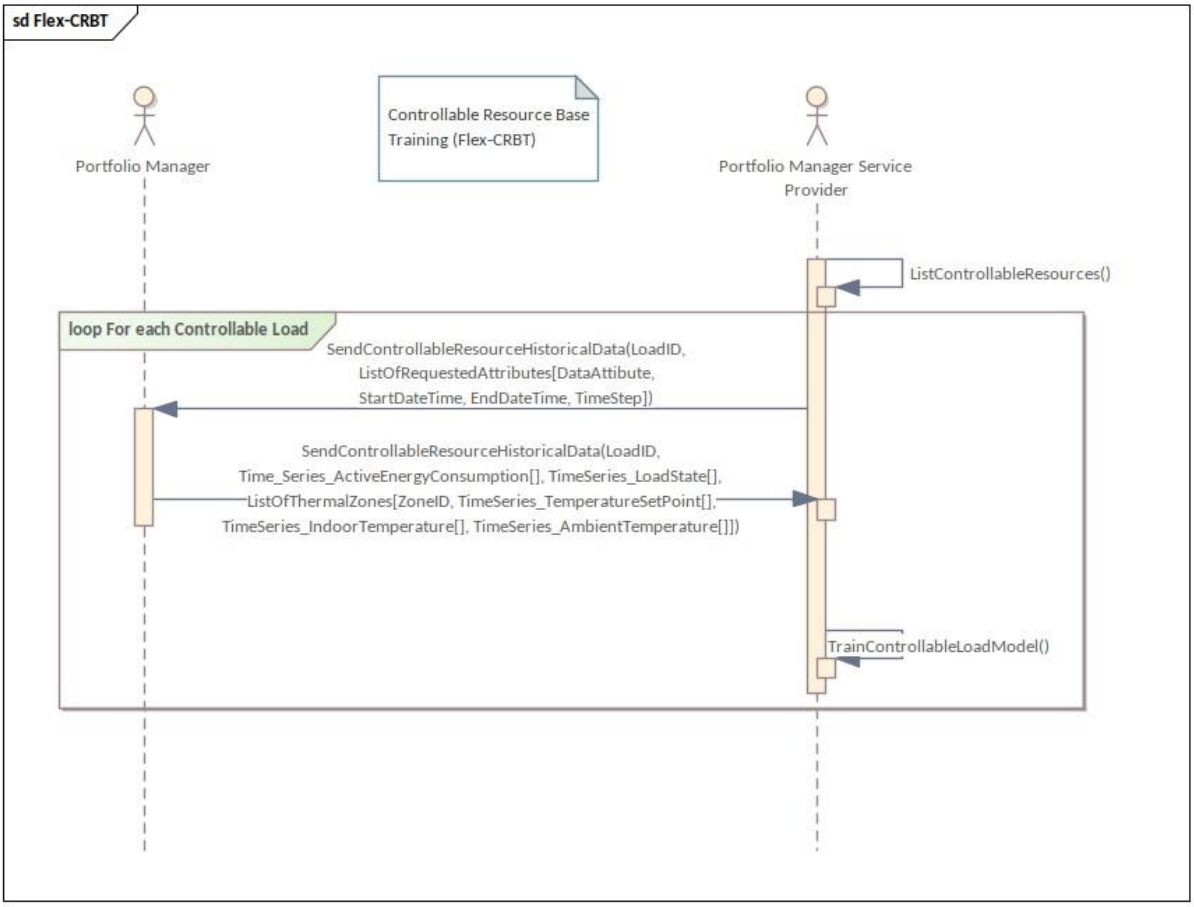


Figure 54 Flex-CRBT Controllable Resource Base Training

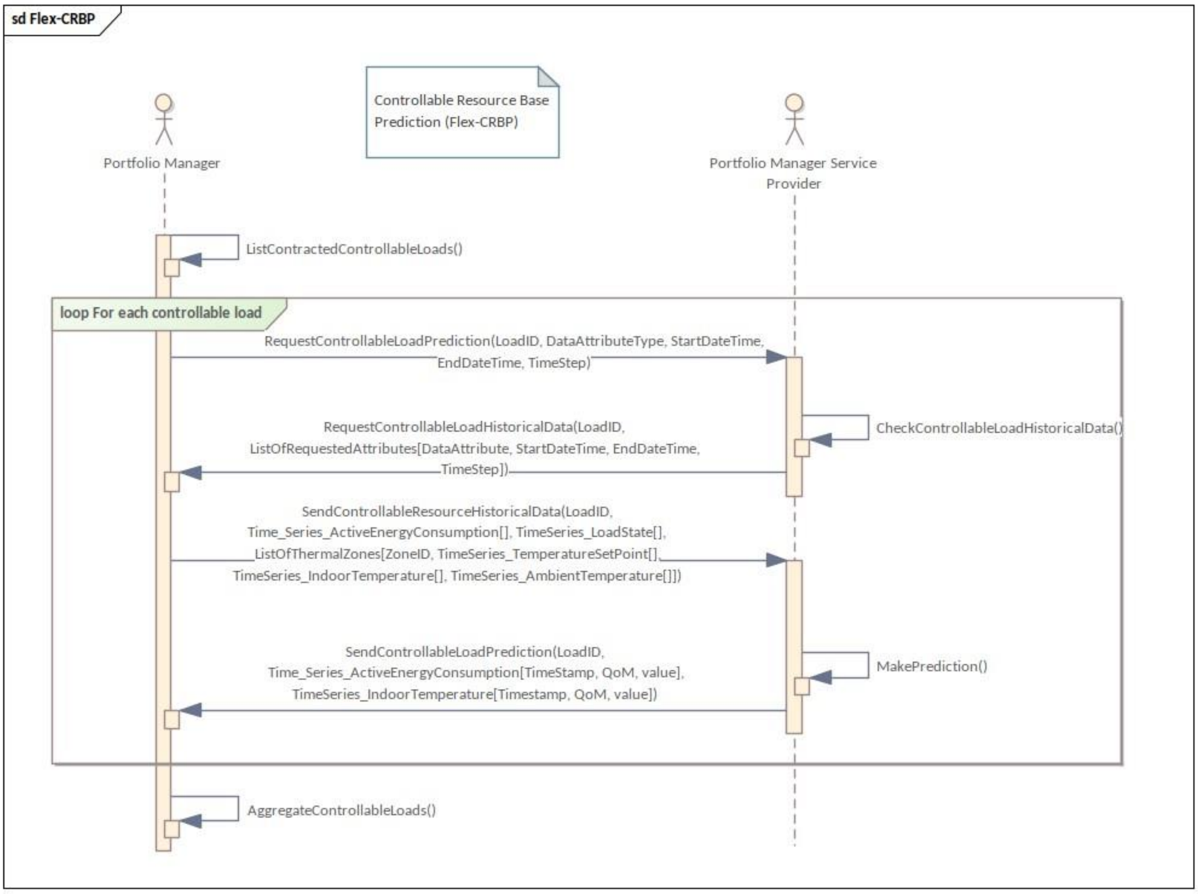


Figure 55 Flex-CRBP Controllable Resource Baseline Prediction

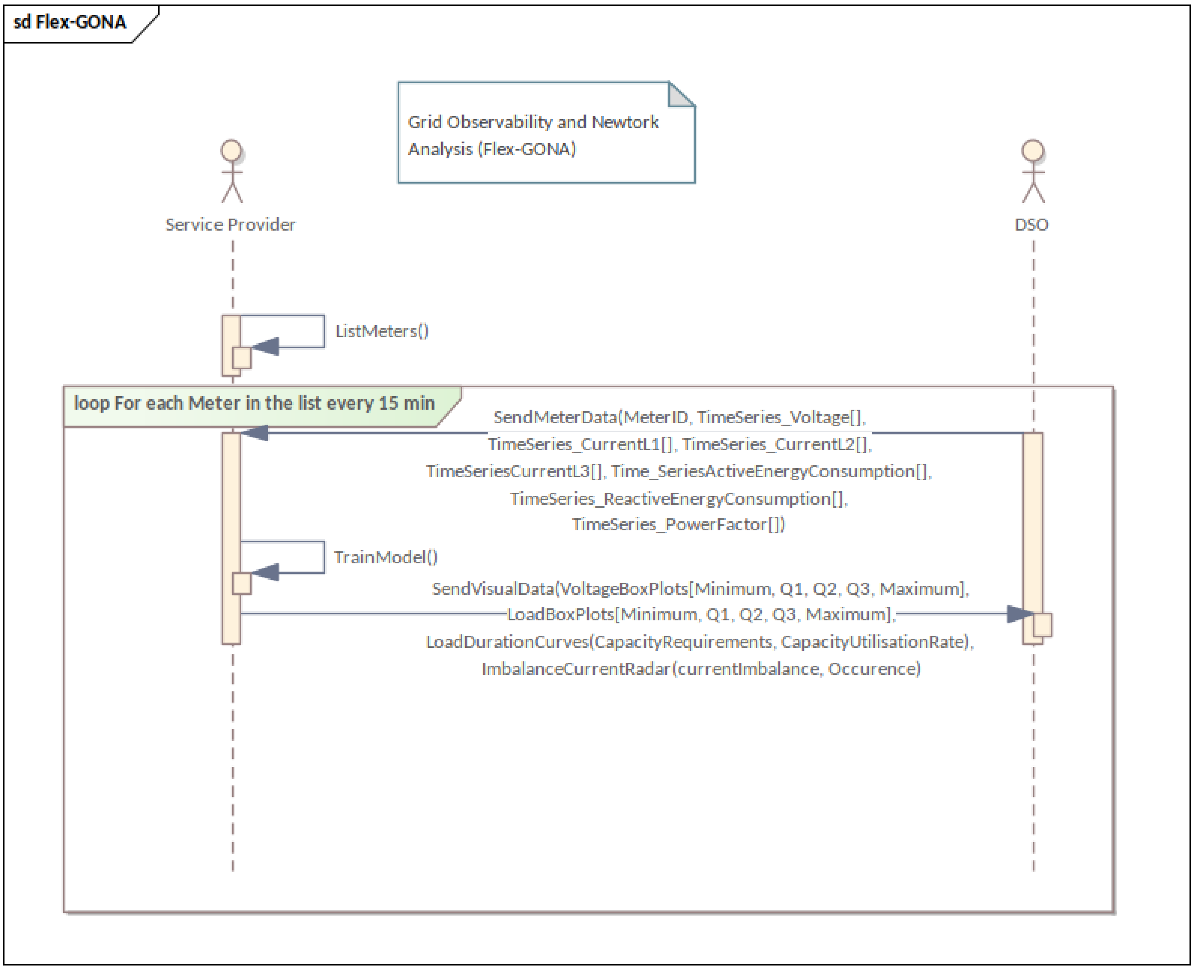


Figure 56 Flex-GONA Grid Observability and Network Analysis

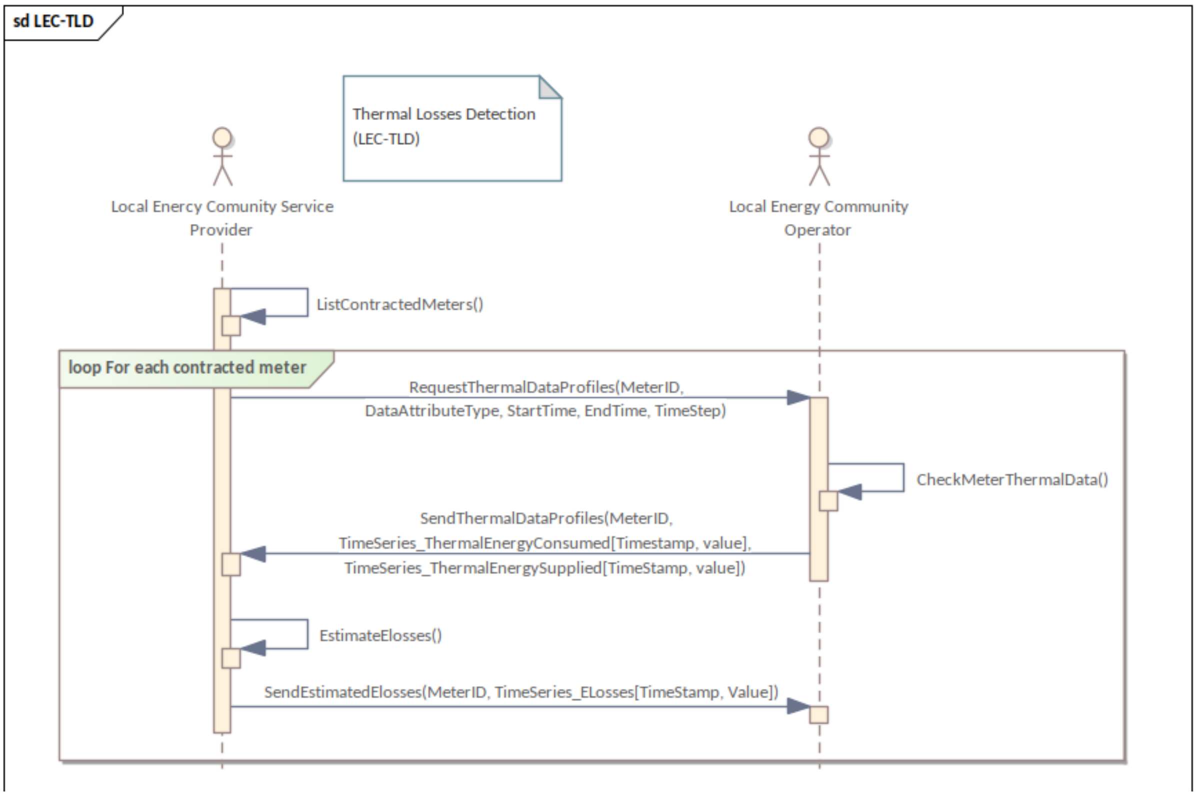


Figure 57 LEC- TLD Thermal Losses Detection

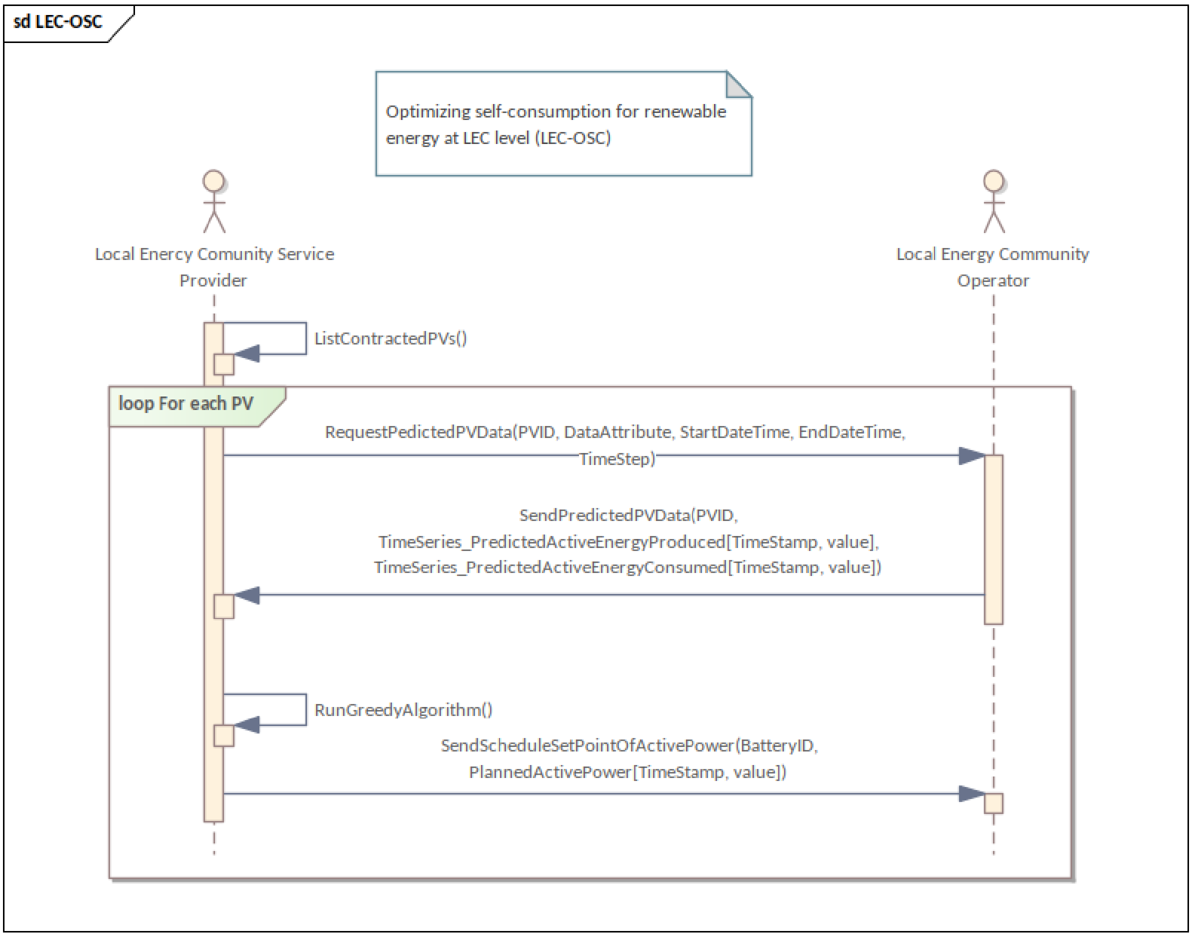


Figure 58 LEC-OSC Optimizing self-consumption for renewable energy at LEC level

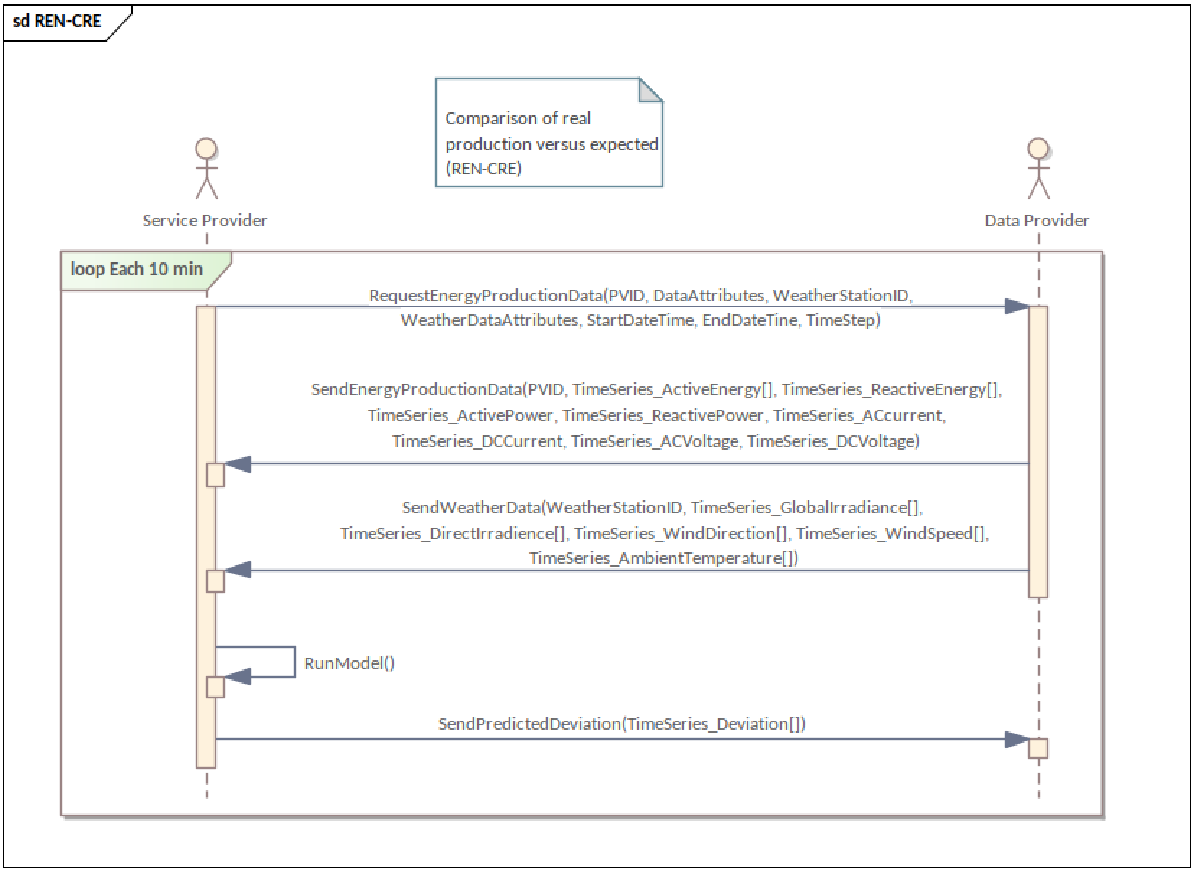


Figure 59 REN-CRE Comparison of real production vs expected

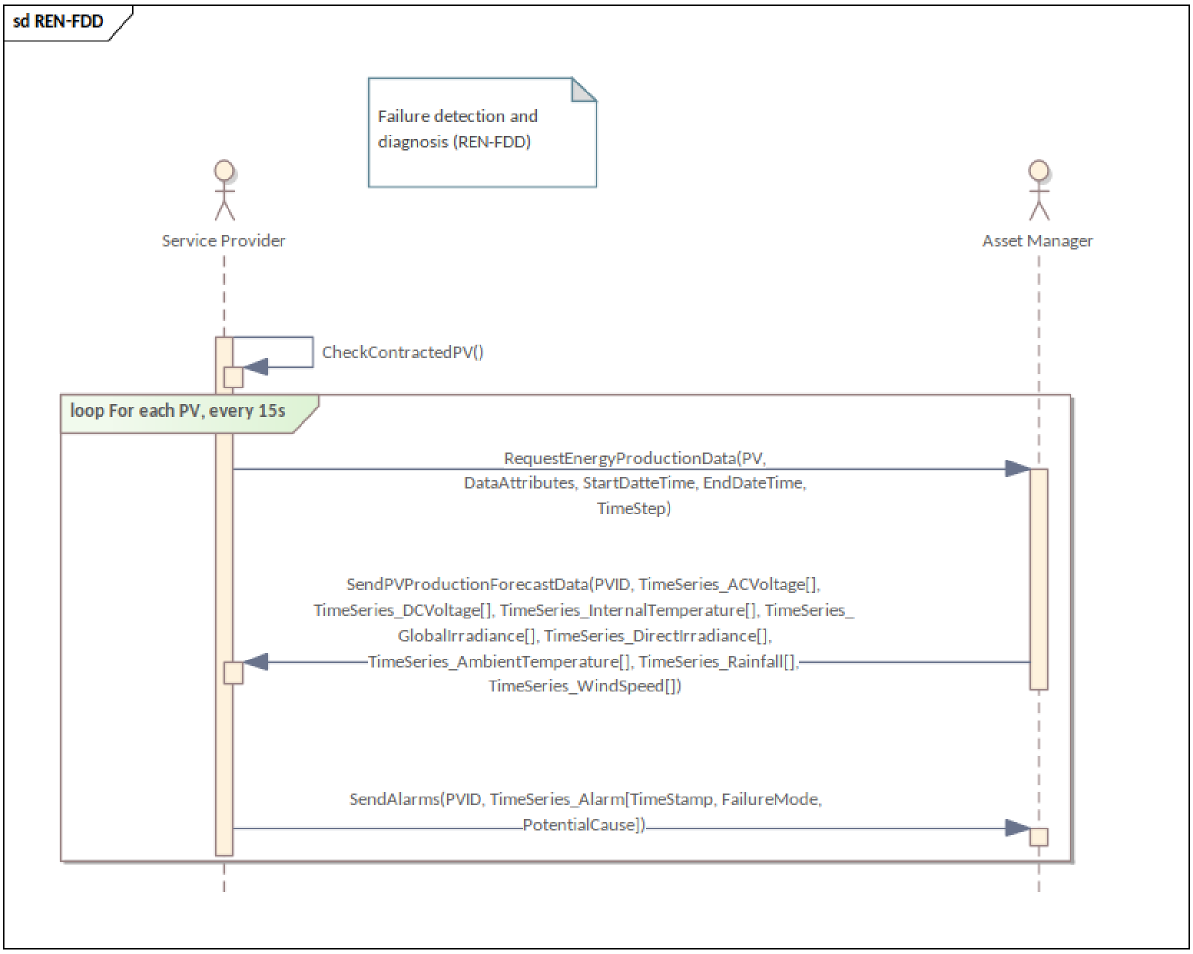


Figure 60 REN-FDD Failure detection and diagnosis

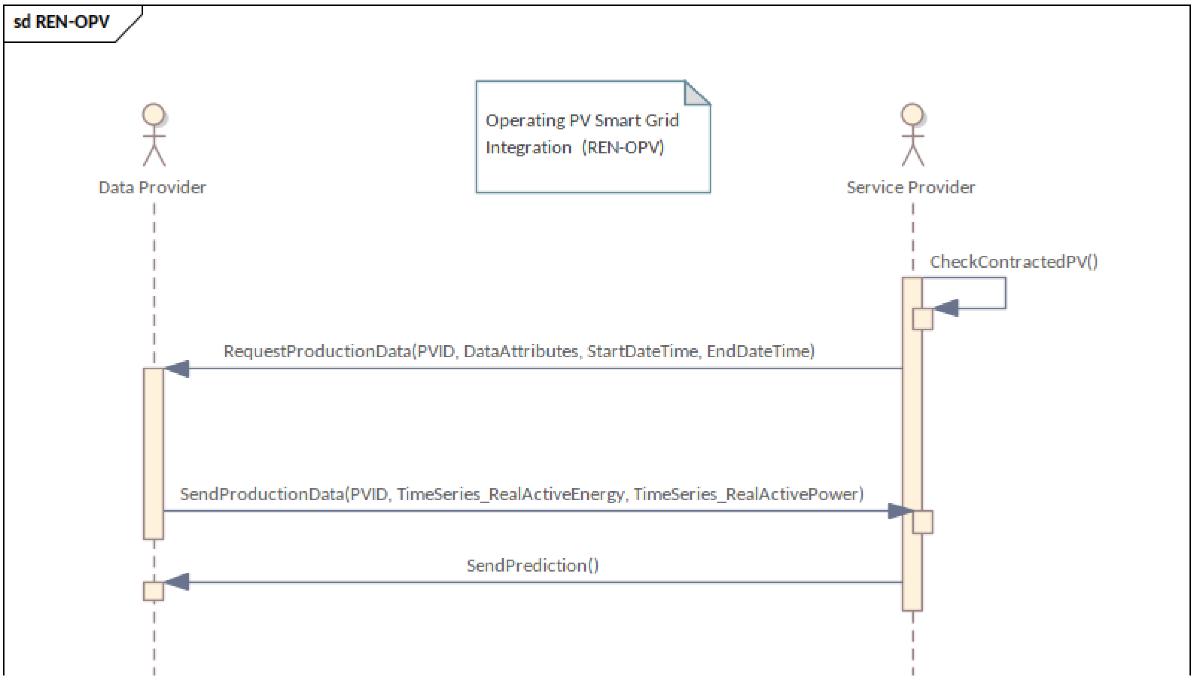


Figure 61 REN Operating smart grid integration

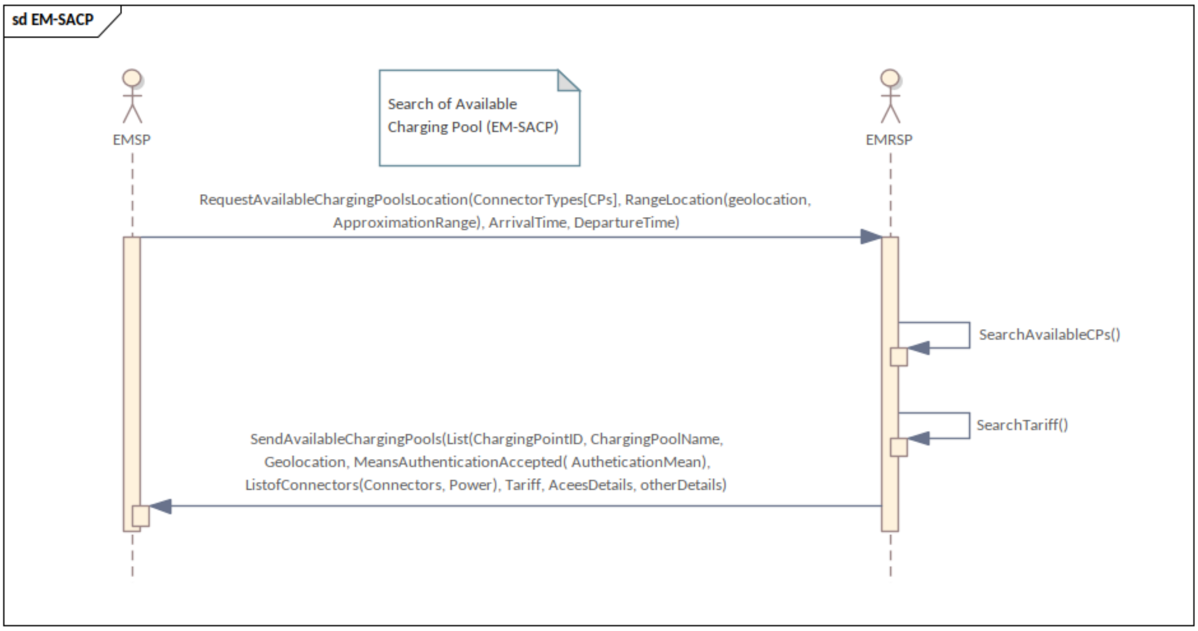


Figure 62 EM-SACP Searching available charging pools