D2.10 SPARCS Standardization Punch-list

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Katerina Vagena[1], Lefteris Lampathakis[1]

[1] Suite5, Alexandrias 2, 3013, Limassol

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No & name	**D2.10 SPARCS Standardization Punch-list**				
Status	Released	Due	M60	Date	2024-09-23
Author(s)	Katerina Vagena, Lefteris Lampathakis (SUITE5)				
Description of the related task and the deliverable. Extract from DoA	**T2.5 Definition of high-level Smart City Standardization Punch-list (Suite5) M24 – M60** All ICT solutions deployed in the frame of the demonstration activities in the SPARCs lighthouse (and Fellow) cities are necessary to comply with available (mainly open) standards, interfaces and data models in the domains of smart cities, smart grids and smart buildings. Towards this direction, existing models, and interfaces (e.g. IEC 61970/61968/ 61850/62746, OpenADR, OneM2M/SAREF, USEF) should be analysed in comparison to the innovative solutions and integration approaches introduced in SPARCs, in order to isolate the novel elements standardization punch-list) introduced by the project. Furthermore, a standardization punch-list will be prepared and provided to standardization bodies, committees and working groups to promote the project results for standardization and prepare the ground for the proliferation and replication of smart city technologies. The most relevant and impacting bodies will initially be identified and contacts will be made (exploiting consortium partners participation in standardization bodies and industrial associations) to collect feedback about their interest in the SPARCs standardization punch-list.				
Participants	VTT, KONE, SIE, PIT, CIT, ADV, LSW, NEW, ON, VEITUR, CVUT, VERD (until M39), NECU, LCE, GOPA, MOH (from M40)				
Comments					

V	Date	Authors	Description
0.10	01/03/24	SUITE5	Draft ToC
0.20	12/04/24	SUITE5	Draft Chapter 1
0.67	24/07/24	SUITE5	Final draft sent for peer review
0.90	19/09/24	SUITE5	Deliverable checked by WP leader and released to the Coordinator and the Quality Manager for quality check and subsequent submission to the EC.
1.00	23/09/24	VTT	Coordinator submits the deliverable to the EC

About SPARCS

Sustainable energy Positive & zero cARbon CommunitieS demonstrates and validates technically and socioeconomically viable and replicable, innovative solutions for rolling out smart, integrated positive energy systems for the transition to a citizen centred zero carbon & resource efficient economy. SPARCS facilitates the participation of buildings to the energy market enabling new services and a virtual power plant concept, creating VirtualPositiveEnergy communities as energy democratic playground (positive energy districts can exchange energy with energy entities located outside the district). Seven cities will demonstrate 100+ actions turning buildings, blocks, and districts into energy prosumers. Impacts span economic growth, improved quality of life, and environmental benefits towards the EC policy framework for climate and energy, the SET plan and UN Sustainable Development goals. SPARCS co-creation brings together citizens, companies, research organizations, city planning and decision making entities, transforming cities to carbon-free inclusive communities. Lighthouse cities Espoo (FI) and Leipzig (DE) implement large demonstrations. Fellow cities Reykjavik (IS), Maia (PT), Lviv (UA), Kifissia (EL) and Kladno (CZ) prepare replication with hands-on feasibility studies. SPARCS identifies bankable actions to accelerate market uptake, pioneers innovative, exploitable governance and business models boosting the transformation processes, joint procurement procedures and citizen engaging mechanisms in an overarching city planning instrument toward the bold City Vision 2050. SPARCS engages 30 partners from 8 EU Member States (FI, DE, PT, CY, EL, BE, CZ, IT) and 2 non-EU countries (UA, IS), representing key stakeholders within the value chain of urban challenges and smart, sustainable cities bringing together three distinct but also overlapping knowledge areas: (i) City Energy Systems, (ii) ICT and Interoperability, (iii) Business Innovation and Market Knowledge.

Partners

Table of Contents

EXECUTIVE SUMMARY

The compliance and use of Open Standards-based data models and ontologies are key success factors for the seamless and interoperable management and processing of city-wide data in the SPARCS project. This highlights SPARCS' compliance with existing standards, making it one of the project's most important deliverables in the context of results' replication. It furthermore paves the way for further contribution to standardization bodies, stepping on gaps identified during the data modelling activities of the project.

This deliverable builds on the SPARCS deliverable D2.4, "Data Gathering and Visualization Specifications for Impact Monitoring". It recaps the activities undertaken to contribute to ongoing standardization efforts in the area of energy systems data modelling and semantic interoperability based on SPARCS findings. Released during the project's initial requirements phase, deliverable D2.4 laid the foundation for defining the Common Information Model of SPARCS. Following this work, this deliverable D2.10 presents a wealth of findings and experiences accumulated over the five years of SPARCS project implementation. It highlights the collaborative efforts of all SPARCS partners in identifying essential data model enhancements needed to successfully achieve the project's goals.

Under this context, D2.10 focuses on the crucial element of the standardization effort, by providing a set of recommendations for improving various existing ontologies and data model standards. The challenges encountered in data modelling and harmonization during SPARCS development have fuelled these standardization initiatives. Market research also reveals that advancing standardization and regulatory compliance could unlock new business and exploitation opportunities in the energy market.

1. Introduction

The deliverable at hand, namely D2.10 – SPARCS Standardization Punch-list, consolidates the outcomes of T2.5 -"Definition of high-level Smart City Standardization Punch-list" activities, undertaken by the SPARCS consortium. It aims towards aligning with existing and open standards within smart city and energy systems frameworks and further enhancing them based on data modelling gaps that have been identified during the project.

In this context, D2.10 emerges from a comprehensive analysis of the current standards, ontological frameworks and data models utilised for the design and implementation of the SPARCS Common Information Model (CIM). It spans across diverse domains such as smart cities, smart grids, and smart buildings, and compares them against the innovative solutions and integration approaches pioneered within the SPARCS.

This comparative analysis has led to the identification of novel elements and enhancements, encapsulated in the SPARCS Standardization Punch-list (see chapter 5). This punch-list not only outlines the deviations and advancements made by SPARCS but also sets the stage for engaging with key standardization bodies, committees, and working groups. Through this engagement, SPARCS seeks to drive forward the standardisation of smart city technologies, ensuring their scalability and replicability across different urban environments. This process is enriched by leveraging the EU's Horizon Standardisation Booster[1], where SPARCS sent an application to receive practical guidance on promoting its findings and recommendations. The aim is to identify and engage with standardisation experts who can advise on integrating these results into standardisation working groups or technical committees. To achieve this, the SPARCS consortium engaged with the Horizon Standardization Booster service and communicated a targeted proposal for enhancements of existing standards-based ontologies to the respective European Telecommunications Standards Institute (ETSI) Technical Committee (TC) of SMART MACHINE-TO-MACHINE COMMUNICATIONS (SMARTM2M); which is part of the CEN/CENELEC/ETSI Coordination Groups focusing on Smart Grids and Smart Manufacturing; while also aiming to support oneM2M, SAREF and IoT Semantic Interoperability. These communications have sparked significant interest, particularly in further extending the SAREF (Smart Applications REFerence) ontology. As a result, SPARCS is currently in the process of organising targeted meetings with the chairs of the SMARTM2M technical committee. Herein, the aim is to further elaborate on the proposed enhancements and proceed through the formal process established by ETSI to give way for the formal adoption of SPARCS' proposed enhancements into the SAREF ontology.

1.1 Purpose of the deliverable

The primary purpose of D2.10 is to document and analyse the activities undertaken in the context of T2.5, focusing specifically on the standardization aspects relevant to Smart City ICT solutions. This deliverable aims to consolidate insights and recommendations derived from the deployment of the SPARCS Platform and its underlying SPARCS CIM, that was implemented to address the interoperability needs of various interventions conducted by SPARCS Lighthouse Cities (LCs). The key objective is to provide recommendations that address standardization gaps identified throughout the deployment and demonstration phases. These

[1] https://www.hsbooster.eu

recommendations aim to enhance the interoperability, efficiency, and scalability of Smart City ICT solutions. Additionally, this document supports standardization efforts by offering targeted suggestions and contributions to further develop and proliferate commonly accepted standards for smart city technologies.

It should be noted that the initial plan according to the DoA was to analyse existing models and interfaces to identify novel elements introduced by the project and to generate a standardization punch-list for both European and international standardization bodies. However, SPARCS' focus has shifted towards standards driven by EU bodies due to the project's engagement with the EU's Horizon Standardisation Booster (HSBooster). An EU initiative utilised by the SPARCS project to facilitate simpler and swifter promotion of the project's results and increase the likelihood of proposal acceptance.

1.2 Structure of the document

To fulfil the scope of the deliverable, the remainder of this document is structured as follows:

- Chapter 2 provides an overview of the standards and ontologies used in the SPARCS CIM design and explains their relevance.
- Chapter 3 conducts a gap analysis of the key standards predominantly employed in the creation of the SPARCS CIM and presents the recommendations from SPARCS.
- Chapter 4 details the additional concepts modelled within the SPARCS CIM. to address the project's needs, along with an overview of the high-level concepts of the SPARCS CIM at project completion.
- Chapter 5 presents the SPARCS standardization Punch-list, outlining the proposed concepts for inclusion in relevant key standards and ontologies.
- Chapter 6 presents the actions undertaken towards promoting the SPARCS standardization Punch-list through liaising with the EU HSBooster initiative.
- Finally, Chapter 7 offers the conclusions of this deliverable.

2. STANDARDS AND DATA MODELS UTILISED IN SPARCS

The SPARCS project targets key domains such as Positive Energy Transformation, eMobility, Digital Integration, and the energy systems of buildings and cities, including their occupants, as reflected through its interventions and corresponding Key Performance Indicators (KPIs).

Leveraging the knowledge provided in D2.4, this section provides an overview of specific standards, and ontologies pertinent to the SPARCS targeted domains that have been leveraged to form the foundations of the SPARCS Common Information Model (CIM). By incorporating these diverse standards, and ontologies, SPARCS ensured a robust, interoperable, and scalable data model that supported the project's diverse objectives in energy transformation, eMobility, and digital integration. This structured approach also ensures that SPARCS CIM can effectively manage and integrate data across its various domains, promoting interoperability, data coherence, and overall project efficiency.

Overall, the SPARCS project introduces a big data management infrastructure, specifically the SPARCS Data Management Platform (see D2.4) to support the collection and processing of real-time data streams. However, for big data management purposes, existing ontologies in their original state , cannot be managed effectively . With this, the ontological models were modified following a formalised process that preserved the semantic concepts and properties of the initial model. This transformation was deemed necessary to create properly configured and structured semantic data models, enabling efficient utilisation within the SPARCS Data Management Platform.

In the following sections, the standard and ontologies utilised in the formation of the SPARCS CIM are presented (section 2.1). Additionally, the relevance to the project is presented, including the key SPARCS concepts and their mapping to the relevant key objects or classes, and their naming adjustments made during the development of the SPARCS CIM (section 2.2).

It should be noted that most of the fields in the SPARCS CIM have been mapped to the corresponding object and data properties in the relevant standards and ontologies. However, due to the large number of fields (2148 in total), documenting all the mappings is beyond the scope of this deliverable and, therefore, has not been included.

The key standards and ontologies utilised in the development of the SPARCS CIM include:

- **IEC CIM v16**: The International Electrotechnical Commission Common Information Model, version 16, which standardizes the information exchanges within the electrical industry.
- **OpenADR 2.0**: Open Automated Demand Response, version 2.0, a standard for automating demand response and distributed energy resources.
- **obXML 1.0.0**: An open-source XML schema for building information models.
- **SAREF v3.1.1**: The Smart Appliances REFerence ontology, version 3.1.1, which facilitates interoperability among smart devices.
- **SAREF4ENER v1.1.2**: An extension of SAREF for the energy domain, version 1.1.2, aimed at enabling energy-efficient solutions.
- **SAREF4BLDG v1.1.2**: An extension of SAREF for buildings, version 1.1.2, supporting building management and energy efficiency.
- **SAREF4CITY v1.1.2**: An extension of SAREF for the smart cities' domain.
- **IFC 4.1**: The Industry Foundation Classes, version 4.1, an open standard for Building Information Modelling (BIM).
- **USEF UFTP 1.01**: The Universal Smart Energy Framework's Unified Flexible Power Transaction Protocol, version 1.01, for flexible energy trading.

- **UN/CEFACT CCTS** 3: The United Nations Centre for Trade Facilitation and Electronic Business Core Components Technical Specification, version 3, a framework for standardizing data components.
- **OGC 16-079 SSN**: The Open Geospatial Consortium's Semantic Sensor Network ontology, version 16-079, which standardizes the description of sensors and their observations.

1.3 Overview of standards and ontologies utilised in SPARCS CIM

1.3.1 IEC CIM v16

The IEC CIM has been originally developed by the Electric Power Research Institute (EPRI) and later adopted under the International Electrotechnical Commission (IEC) umbrella as the IEC 61968/61970/62325 series of standards. This set of standards (IEC 61970-301, IEC 61968-11, IEC 62325-301) represents all the main objects in an electric utility company. IEC CIM is delivered as an object-oriented extensible markup language (XML) data schema, offering a standardized approach for representing power system resources as object classes, defining their parameters and presenting their relationships such as: inheritance, association and aggregation. The IEC CIM is a generic data model, with a wide coverage, in 53 UML packages defining more than 820 classes including more than 8500 attributes. The IEC CIM enables systems interoperability by providing a common definition of management information for systems, networks, applications and services, along with mechanisms for enabling interconnection of network applications developed by different vendors. Transmission System Operators (TSO) have widely adopted this model to develop a model of a power system network. This model serves as a common base for information exchange, replacing the previously applied “largest common denominator” approach.

The IEC 61970 series of standards aims to facilitate the integration of TSO energy management systems (EMS) applications developed independently by various vendors, across entire EMS systems developed independently, or between an EMS system and other systems concerned with different aspects of power system operations, such as generation or distribution management systems (DMS). DMS are designed to monitor and control the entire distribution network, providing support for utilities such as outage management, by linking together the Supervisory Control and Data Acquisition (SCADA) system with e.g., geographic information systems, customer information or support systems (EC 61970-CGMES, 2018). The IEC 61968-11 standard is an extension of the initial model designed to address the Distribution System Operators’ (DSO) requirements by defining the information exchanges between electrical distribution systems on a utility enterprise level, focusing on the DMS functionalities. The last section of the IEC CIM, the IEC 62325-301 “CIM extensions for markets” standard supports the harmonization of the deregulated electricity markets filling their requirement for the exchange of information among different energy market-related stakeholders, covering both wholesale and retail electricity markets and their defined roles. Due to its fundamental role in enabling interoperability within the electricity sector the IEC CIM was widely adopted into numerous processes of TSOs across Europe. Especially, the IEC CIM is adopted by the European Network of Transmission System Operators for Electricity (ENTSO-E, an organisation of 43 electricity TSOs in 36 European countries). The IEC CIM is also widely adopted by TSOs in Europe using the CIM for the Common Grid Model Exchange Standard (CGMES).

1.3.2 OpenADR 3.0

The Open Automated Demand Response (OpenADR) published by the OpenADR Alliance, is a globally accepted smart grid data model that enables the exchange of information related to demand response (DR) programs between electricity service providers, aggregators and consumers. The OpenADR also enables the management of various distributed energy resources (DER) for flexibility providers, such as aggregators and utility companies. In general, the OpenADR is utilised to structure the messages exchanged between different stakeholders involved in automatic demand response (Auto-DR) and distributed energy resources (DER) management. This ensures consistency and interoperability (OPENADR Standard Specifications, n.d). The OpenADR is not a communication protocol per se but relies on existing open standards such as XML for exchanging DR messages and reports. The Open ADR was developed to automate and simplify DR and DER management activities through dynamic pricing and reliability signals allowing electricity consumers to adjust their energy usage behaviour, save money and optimise their energy efficiency, while enhancing the overall effectiveness of power distribution across the electrical grid. It should also be mentioned that recently the IEC has approved OpenADR 3.0. This version, however, is not intended to replace the OpenADR 2.0a/b Profile Specifications; instead, it provides an additional, simplified way to add OpenADR functionalities in existing systems, as well as to introduce different and new scenarios.

1.3.3 obXML 1.0.0

To address the need for a standardized language and new modelling processes to represent occupants' behavior, IEA Annex 66 developed the technical DNAs framework (based on four key components: i) the Drivers of behavior, ii) the Needs of the occupants Actions iii) the Actions carried out by the occupants, and iv) the building systems acted upon by the occupants) and which was delivered as an XML schema and known as the 'Occupant Behavior XML' or obXML schema (obXML Schema Specifications, n.d.). A significant focus of this framework is the behavior component, which models occupant behavior based on Drivers, Needs, Actions, and Systems, effectively connecting three primary elements: buildings, occupants, and their behaviours.

1.3.4 SAREF v3.2.1

The Smart Applications REFerence (SAREF) ontology developed by TNO, a Dutch institute, aims to enable interoperability between different solutions of different providers and among different assets in the smart applications domain (ETSI, 2020). Key objective of SAREF is to provide discrete and reusable elements of the ontology based on the users' requirements. SAREF is designed based on the following key principles:

the concepts in an existing asset can be reused and aligned accordingly,

the different elements of the ontology are allowed to be separated and recombined as per user needs,

the ontology can be further expanded; and

the processes of updating, identifying and correcting defects in the ontology, are easily maintainable (Daniele et al, 2015).

In its latest version SAREF2 enables users to create various device and technology abstraction layers and their corresponding common Application Programming Interfaces (APIs), without the need for explicit knowledge of specific standards. SAREF ontology requires only one set of mappings for each asset, allowing assets to share recurring core concepts . SAREF allows different assets to use their own terminology and data models, while establishing relationships through common semantics. The core classes of the latest SAREF v3.2.1 (see Figure 1) include several high-level concepts, such as device (e.g. sensor or air conditioner), property (e.g. temperature, energy, or time), or command (e.g. OnCommand or OffCommand).

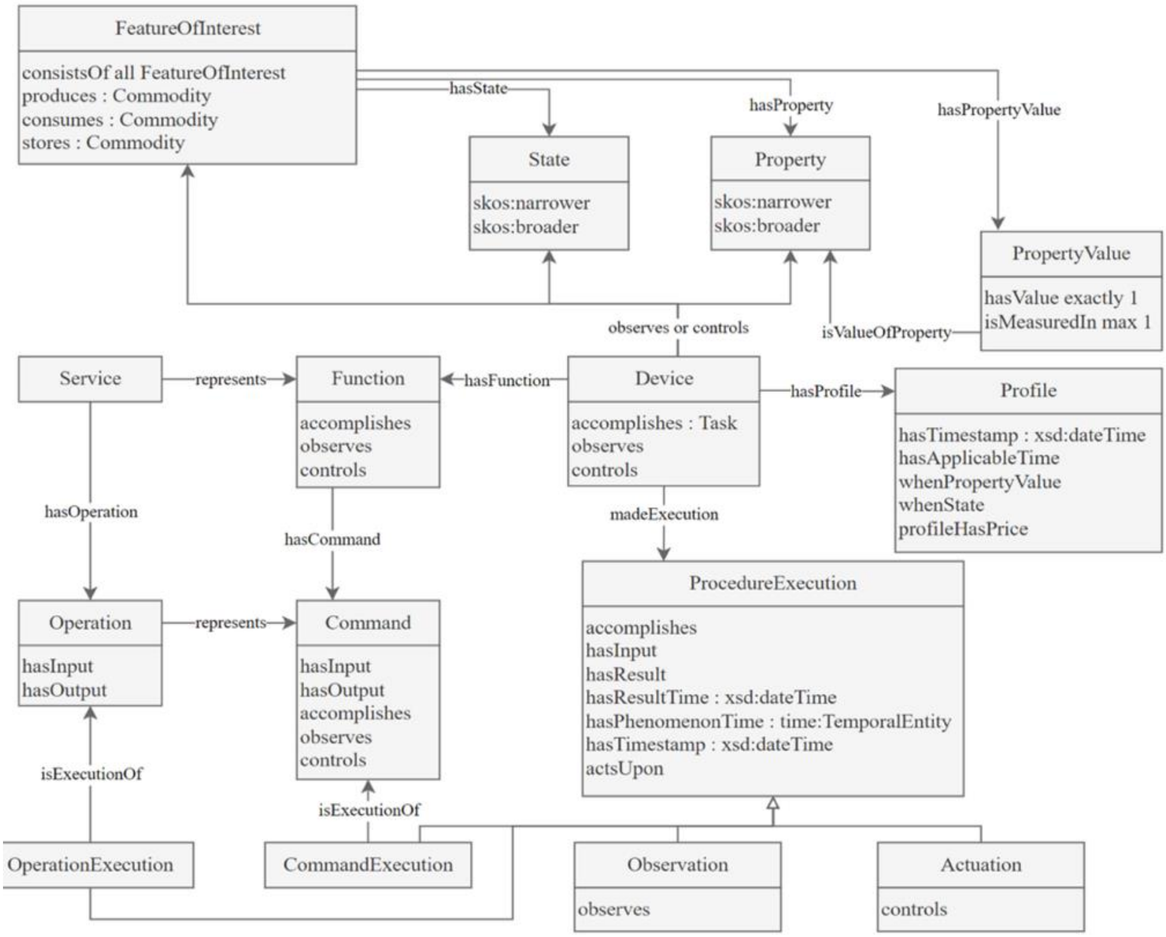

Figure 1 Overview of SAREF ontology[3]

In addition to the core SAREF ontology, further extensions have been published from SAREF for different domains (e.g. energy, environment, building, smart cities, smart agriculture or water domain, and etc.). The SAREF extensions can be seen in the following figure.

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[2] https://saref.etsi.org/index.html

[3] https://saref.etsi.org

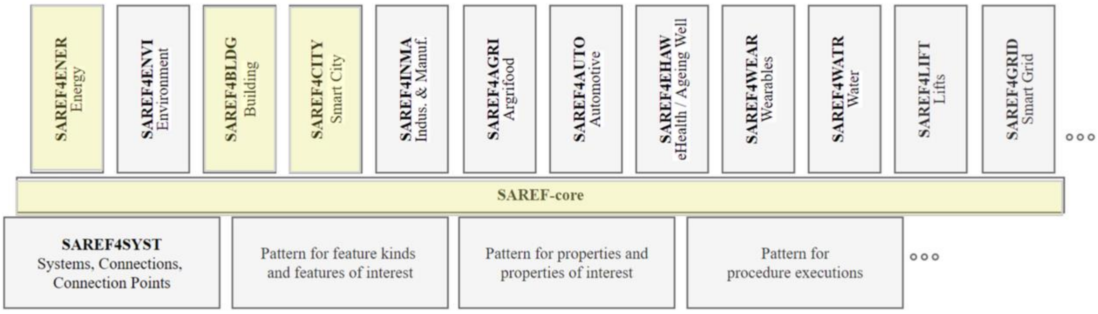

Figure 2 SAREF and its extensions[3]

The extensions identified to be of high relevance to the SPARCS project are highlighted in the Figure 2 above, in yellow and include: the core SAREF ontology, SAREF4CITY extension that links SAREF to the domain of smart cities, SAREF4BLDG for the Building domain and SAREF4ENER that focuses on the energy domain.

1.3.5 SAREF4ENER v1.2.1

SAREF4ENER as mentioned above is one of the SAREF ontology extensions, articulated as an OWL-DL ontology and which is created in collaboration with EEBus4, a major Germany-based industry association, and the Flexiblepower Alliance Network5 (FAN), to enable the interconnection of their (different) data models6. The development of SAREF4ENER was greatly influenced by international domain standards, specifically the EN 50631 series and the EN 50491-12-2. The requirements and concepts of these standards were successfully applied and evaluated in the European Horizon 2020 project InterConnect, which conducted large-scale pilots across multiple countries.

Overall, SAREF4ENER aims to enable interoperability among different solutions developed in the domain of smart home, such as smart appliances. Herein, various smart appliance manufacturers support the FAN or EEBus data models. The purpose of the SAREF4ENER extension is to provide a standardized (protocol-agnostic) set of messages that can be directly adopted by different smart appliance manufacturers. These messages facilitate communication between energy smart appliances and Energy Management Systems (EMS), allowing for optimised energy consumption and production within users' defined limits.

A global overview of the main classes of the SAREF4ENER is presented in the following Figure 3, where the SAREF4ENER's classes are depicted as rectangles, the relationships (object properties) between entities are represented as arrows connecting those rectangles, and datatype properties and class restrictions are visually represented as plain text within the rectangular boxes. The different colours used include: Green distinguishes SAREF's core entities, blue for highlighting classes and properties that already exist in the previous version of SAREF4ENER (V1.1.2); and white which defines the classes and properties introduced in the latest version of SAREF4ENER (V1.2.1).

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[4] http://www.eebus.org/en

[5] https://flexible-energy.eu/

[6] https://saref.etsi.org/saref4ener/v1.2.1/

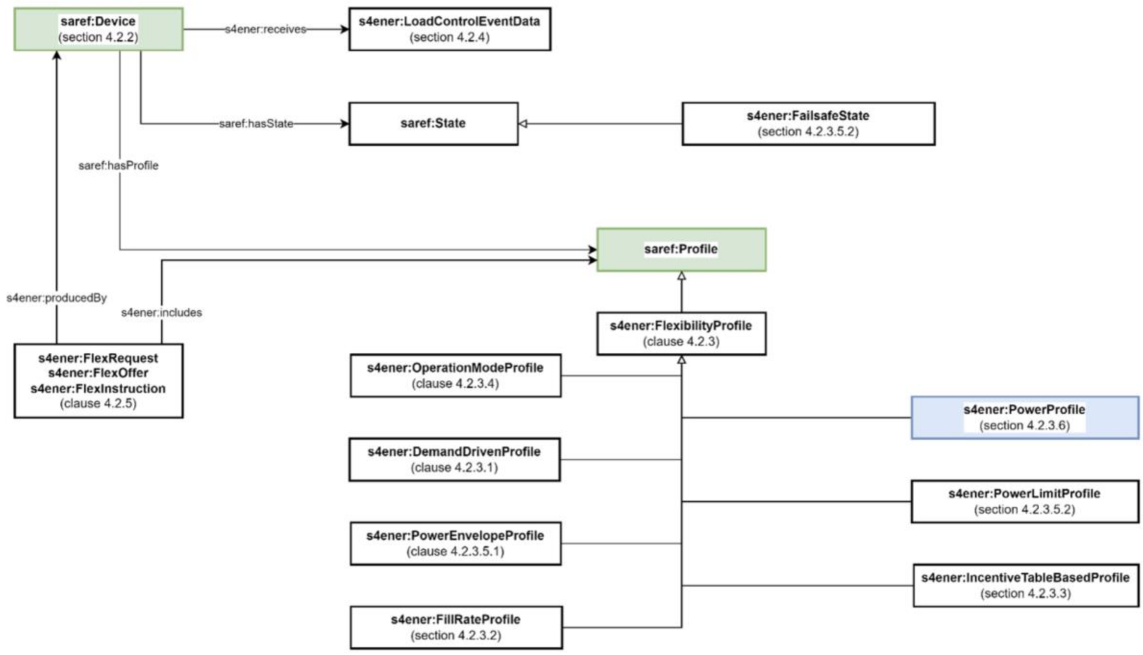

Figure 3 Overview of SAREF4ENER[6]

1.3.6 SAREF4BLDG v1.1.2

SAREF4BLDG is another extension of the SAREF ontology (see Figure 2) based on the Industry Foundation Classes (IFC) standard for building information. It includes the devices and appliances typically found in building spaces as defined by IFC4, and extends the SAREF ontology to include such devices. This extension enables the representation of such devices and other physical objects in building spaces. SAREF4BLDG is designed to facilitate interoperability among various stakeholders, such as architects, engineers, consultants, product component manufacturers, etc. . Furthermore, it connects the applications managing the building information throughout the different phases of the building life cycle (from planning and design, to demolition or recycling)7. By implementing SAREF4BLDG, smart appliances from different manufacturers that support the IFC can easily communicate with each other. To achieve this goal, SAREF4BLDG should be utilized to annotate or generate neutral device descriptions that can be shared among various stakeholders. SAREF4BLDG is expressed as an OWL-DL ontology, extending SAREF by 72 classes (67 introduced in SAREF4BLDG and 5 reprocessed from the SAREF and W3C Geospatial Ontologies8), 179 object properties and 83 data type properties. The high-level classes of the latest version, SAREF4BLDG v1.1.2, are shown in Figure 4 below.

[7] https://saref.etsi.org/saref4bldg/v1.1.2/

[8] https://www.w3.org/2005/Incubator/geo/XGR-geo-ont-20071023/

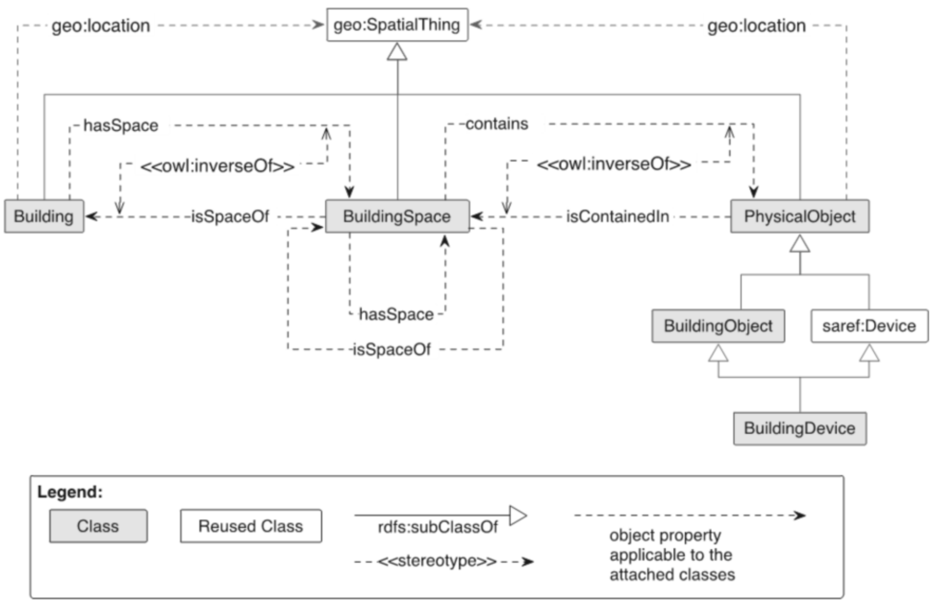

Figure 4 Overview of the top levels of the SAREF4BLDG extension

1.3.7 SAREF4CITY 1.1.2

SAREF4CITY is another extension of the SAREF ontology (see Figure 5), specifically designed to cater the needs of smart cities. Its primary objective is to provide a standardized framework that supports the interoperability of data across various city domains, such as energy, transportation, environment, and public services. By facilitating a common understanding and representation of city-related data, SAREF4CITY aims to improve the efficiency and effectiveness of city operations, enhance the quality of life for citizens, and promote sustainable urban development.

SAREF4CITY is an OWL-DL ontology that builds upon SAREF and integrates elements from six additional ontologies. It comprises 31 classes, with 13 unique to SAREF4CITY and 18 borrowed from the SAREF time, geosp, geo, foaf, dcterms, org, and cpsv ontologies[9]. Additionally, it includes 36 object properties, of which 20 are specific to SAREF4CITY, and 16 are sourced from the SAREF, geosp, geo, and cpsv ontologies. There are also 7 data type properties, with 3 defined in SAREF4CITY and 4 adopted from the SAREF ontology.

The primary aim of SAREF4CITY is to extend SAREF to establish a core set of general concepts relevant to smart city data within the Internet of Things (IoT) context; seeking to pinpoint essential components that can be further expanded to address specific smart city subdomains, such as public transportation. A global overview of SAREF4CITY's main classes and their interrelationships is presented in Figure 5 below, where the orange-coloured rectangles depict the SAREF4CITY introduced classes and in yellow classes borrowed from SAREF-core and other ontologies.

[9] https://saref.etsi.org/saref4city/v1.1.2/

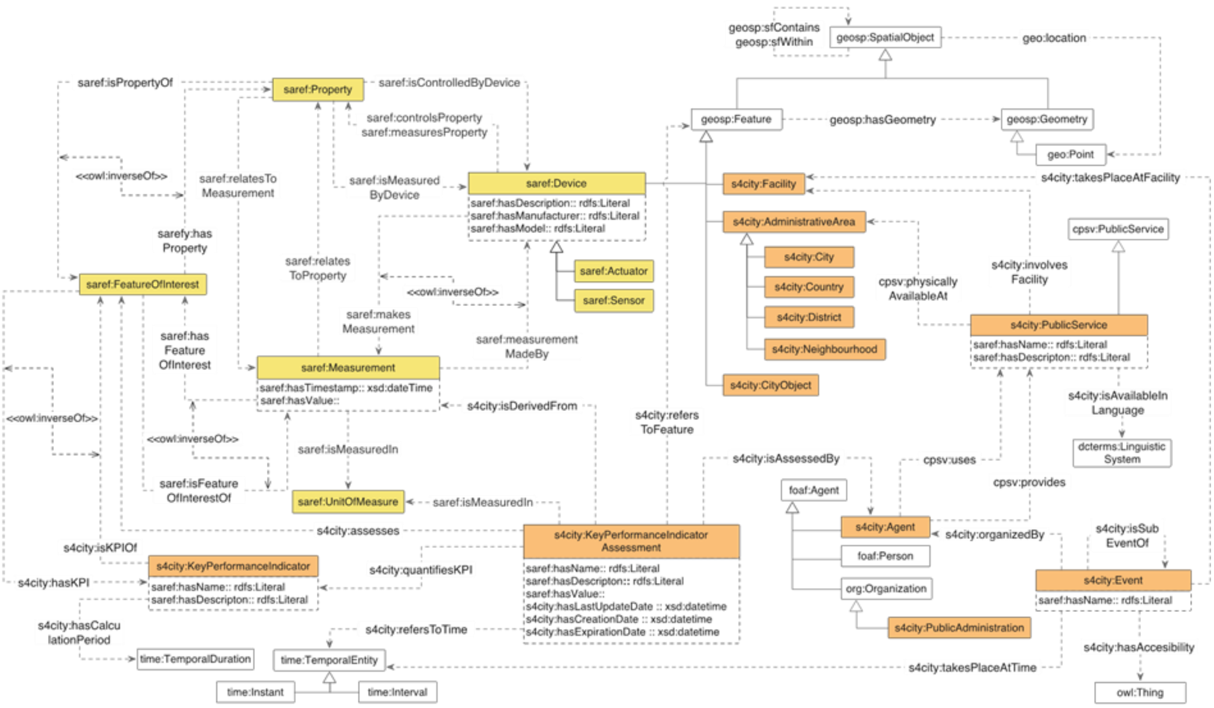

Figure 5 Overview of SAREF4CITY extension[10]

1.3.8 IFC 4.0.2.1

The Industry Foundation Classes (IFC) published by buildingSMART International11, provides a digital representation of the building industry and relevant assets to enable information exchange and sharing among the various stakeholders of the building industry, during the lifecycle of a particular project or asset. In its latest version, the IFC4 is provided as an open specification for Building Information Modelling (BIM) data and includes terms, concepts and data specification items that originate from use within disciplines, trades, and professions in the building industry (IFC data model specifications, n.d.). It includes the data schema, and reference data defined in the EXPRESS data specification language or in XML schema definition (XSD) language. A subset of the data schema and referenced data is referred to as a Model View Definition (MVD), and each particular MVD is defined to support one or many recognised workflows within the construction and facility management industry domain. Each workflow identifies the data exchange requirements for software applications; thus, conforming software applications need to identity the MVD they conform to.

The IFC specification consists of four different conceptual layers namely the:

Resource layer, includes all individual data schemas that contain the definitions of the resources.

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11 https://www.buildingsmart.org/

Core layer, includes the kernel schema and the core extension schemas that contain the most general concept definitions and the fundamental relationships.

Interoperability layer contains entity definitions specific to general products, processes or resource specialization used across various disciplines .

Domain layer, represents the higher-level layer containing entity definitions that are specializations of products, processes or resources related to a certain industry discipline.

1.3.9 USEF 1.3.6

The Universal Smart Energy Framework (USEF) is an international standard facilitating the integration of various smart energy services and products and promoting the concept of energy flexibility trading; by identifying various Energy Market actors (roles) and their interactions, to exploit demand-side participation(USEF Energy, n.d.). In its latest version (v1.3.6) USEF is considered the most important standard regulating the various market mechanisms on energy flexibility trading.

Through USEF, each of the identified roles and their assigned responsibilities can be mapped to their actual application in a local market and are briefly described as follows:

Distribution System Operator (DSO), responsible for the optimum operation of the overall distribution network; depending on the market, a DSO might also carry out BRP responsibilities.

Balance Responsible Party (BRP), responsible for the balance of supply and demand and identifying solutions that can reduce cost for covering possible imbalances in the network.

Aggregator (AGR), responsible for the management of the accumulated energy flexibility provided by the prosumers and based on the requirements set by the BRP.

Common Reference Operator (CRO), responsible for assigning the congestion points and congestions to other involved parties

Meter Data Company, responsible for collecting and validating the metering data.

Active Demand and Supply, the various entities that can be actively controlled with appropriate signals to adjust the energy demand and supply.

Prosumer, the end user that consumes and can produce energy.

The USEF Flex Trading protocol (UFTP) is a subset of the USEF framework and provides a market-focused framework standardizing the energy flexibility trading between AGRs and DSOs. It describes the corresponding market interactions between them to resolve grid constraints by applying congestion management of grid-capacity management. However, it does not constrain how the trading should be implemented, allowing for either bilateral or exchange-based trading. UFTP can be used as a standalone protocol for flexibility forecasting, offering, ordering and settlement processes. Both USEF and UFTP are developed by the USEF Foundation12.

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[12] https://www.usef.energy/usef-foundation/

1.3.10 UN/CEFACT CCTS v3.0

The UN/CEFACT Core Components Technical Specification (CCTS) version 3.0 defines a meta model and the rules necessary for describing the structure and contents of conceptual and logical data models and information exchange models. It offers a common set of semantic building blocks that represent the general types of business data being used, facilitating the creation of new business vocabularies and the restructuring of existing ones. The component models generated using CCTS can be used as the basis for syntax-specific business information exchanges, while remaining independent of any specific technology platform or implementation language.

Therefore, the main scope of this standard is to ensure information interoperability between applications in the e-business area (UN/CEFACT CCTS standard specifications, n.d.).

The foundational concept of CCTS are the core components (see Figure 6), which are semantic building blocks that can be used for all aspects of business data and information modelling and exchange. These core, conceptual in nature, components are the cornerstones for generating interoperable business information entities.

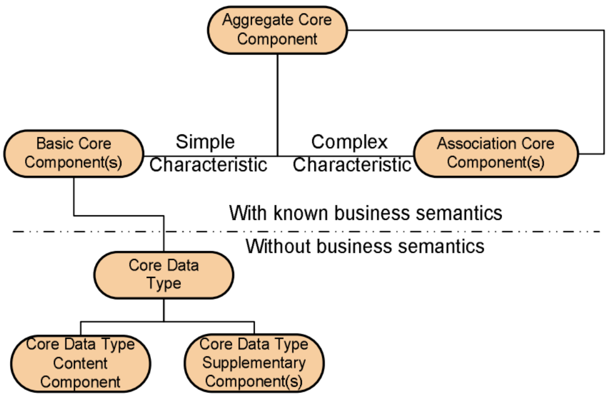

Figure 6 Core Component Overview

While CCTS is defined using the Unified Modelling Language (UML), it does not require UML for its implementation.

1.3.11 OGC 16-079 SSN

The Semantic Sensor Network (SSN) ontology13 is designed to provide a framework for describing various aspects of sensors and their observations. This includes detailing the procedures involved, features of interest being studied, samples utilised, properties observed, and actuators used. However, it does not cover domain-specific concepts, time, or locations, which are aspects intended to be incorporated from other ontologies through OWL imports.

[13] http://www.w3.org/ns/ssn

SSN employs a modular architecture that is both horizontal and vertical, incorporating a streamlined yet comprehensive core ontology known as SOSA14 (Sensor, Observation, Sample, and Actuator), which defines its fundamental classes and properties.

Due to their varying scopes and levels of axiomatization, SSN and SOSA can accommodate a diverse array of applications and use cases. These include satellite imagery, large-scale scientific monitoring, industrial and household infrastructures, social sensing, citizen science, observation-driven ontology engineering, and 'Web of Things'.

1.4 Mappings of SPARCS CIM concepts to relevant standards-based data models/Ontologies

In this section, the relevance of the SPARCS CIM to the aforementioned standards and ontologies is provided by summarising and presenting the mappings of the SPARCS CIM's concepts to the relevant standards-based data models object and ontologies' classes.

- The *IEC CIM* has been utilised to adopt some of its basic concepts, attributes, and parameters aligning the SPARCS CIM with the most widely adopted common information model in the electricity domain. This ensures that the SPARCS CIM is compatible and interoperable with existing systems and standards used in the electricity sector, thereby enhancing data management.
- Alignment with *OpenADR* supports SPARCS goal of optimising energy usage in Positive Energy Districts (PEDs) and Positive Energy Buildings (PEBs) and improving their energy efficiency.
- *obXML* has been used to standardise the representation and modelling of occupants and their comfort zones within their building environments.
- The foundational *SAREF* ontology serves as the backbone of the SPARCS CIM, facilitating the representation of common concepts like devices, units of measure, measurements, features of interest, and more. As these concepts are typically domain-agnostic, they can serve as fundamental building blocks within the SPARCS CIM.
- *SAREF4ENER* extension is utilised to express key concepts related to energy management and device control. By utilising SAREF4ENER, SPARCS enhances its capability to manage and control energy-related devices and their operations/control efficiently, leveraging standardized ontological models to support interoperability and real-time data processing.
- Several concepts from *SAREF4BLDG* have been leveraged and mapped to the concepts of the SPARCS CIM to ensure a standardized representation and management of building-related data within the SPARCS framework. These mappings are also used to denote the order of the various building devices . For example, Smart Appliances are represented by s4bldg:ElectricAppliance, providing a standardized approach to incorporate intelligent devices. Overall, these mappings enhance data coherence and support the comprehensive integration of various building systems within the SPARCS framework.
- *SAREF4CITY* is central to SPARCS due to its alignment with the project's objectives for smart and sustainable urban environments. By incorporating SAREF4CITY's various project-relevant classes, SPARCS CIM enables a comprehensive and interoperable

[14] http://www.w3.org/ns/sosa

representation of city-related data. This ensures that the SPARCS CIM is robust and capable of supporting a wide range of smart city applications.

- Various concepts defined in the *IFC 4.0.2.1* standard have been leveraged to ensure seamless integration and interoperability within smart building environments. For instance, SPARCS aligns its concept of an address with the IFC standard's ifcAddress, ensuring uniformity in location identification. Similarly, key building components concepts (such as boiler mapped to ifcBoiler), are leveraged to facilitate consistent data representation and management. The hierarchical structure of buildings is maintained through mappings to IfcBuildingStorey for individual floors and IfcZone for distinct building zones, while occupancy and occupants' information are standardized with SpaceOccupancy and IfcOccupant, respectively. This enables efficient management of space usage and resident information. Renewable energy systems like photovoltaic systems are aligned with IfcSolarDevice, and building management components such as sensors and heating devices are mapped to IfcSensor and ifcSpaceHeater. These mappings enhance data coherence and support the comprehensive integration of various building systems within the SPARCS framework.
- Leveraging concepts from *USEF UFTP 1.3.6*, enables SPARCS to integrate seamlessly with existing smart energy systems and to support participation in broader energy markets and flexibility trading platforms. It also covers critical roles (such as Aggregator, DSO, and Prosumer) and functions within the energy ecosystem.
- Concepts from *UN/CEFACT CCTS v3.0*. have also been leveraged in the SPARCS CIM with a focus on following a unified approach to defining and utilising address information.
- Leveraging concepts of the *OGC 16-079 SSN* ontology such as (e.g. sosa:Sensor, sosa:Platform, etc.), ensures that the corresponding SPARCS CIM concepts are compatible with the SSN, promoting interoperability in sensor data management and related applications.

The SPARCS concepts mapping to Standards-based data models and ontologies are shown in Table 1 below.

Table 1 SPARCS concepts mapping to Standards-based data model/ ontology

SPARCS Concept	Standards-based Naming Convention	Relevant Standards-based data model/ ontology
Address	Street Address	
Battery	ZBAT	
ConnectivityNode	ConnectivityNode	
Device	Device name plate	
Event	ActivityRecord	
ExternalNetworkSegment	ExternalNetworkInjection	
HydroPowerSystem	HydroPowerPlant	
Incident	Incident	
Location	Location	

SPARCS Concept	Standards-based Naming Convention	Relevant Standards-based data model/ ontology
Measurement	Measure	IEC CIM 16
MeteringSystem	Meter	
Order	Order	
Outage	Outage	
PhotovoltaicSystem	SolarGeneratingUnit	
PowerPlant	Plant	
PowerTransformer	PowerTransformer	
Schedule	ScheduleEvent	
Sensor	Sensor	
Status	Status	
Substation	Substation	
TimePeriod	Period	
TroubleTicket	TroubleTicket	
VirtualPowerPlant	VPP	
WeatherStation	WeatherStation	
TimePeriod	eiActivePeriod	OpenADR 2.0
Comfort	Needs	obXML 1.0.0
Occupant	Occupant	
AirConditioningSystem	saref:HVAC - deprecated	SAREF 3.1.1
Device	saref:Device	
LightingDevice	saref:Light - deprecated	
Measurement	saref:Measurement - deprecated	
MeteringSystem	saref: Meter	
Occupancy	saref: occupancy – deprecated	
Sensor	saref:Sensor	
SmartAppliance	saref:Appliance	

SPARCS Concept	Standards-based Naming Convention	Relevant Standards-based data model/ ontology
Status	saref:State	
AutomatedOperationProfile	s4ener:PowerProfile (Power profile control)	SAREF4ENER 1.2.1
Device	s4ener:Device	
DeviceControlEvent	s4ener:LoadControlEventAction	
DeviceControlStatus	s4ener:LoadControlStateData	
Flexibility	saref4ener:FlexOffer	
Order	saref4ener: FlexibilityInstruction	
Boiler	s4bldg:Boiler	SAREF4BLDG 1.1.2
Building	s4bldg:Building	
BuildingSpace	s4bldg:BuildingSpace	
LightingDevice	s4bldg:Lamp	
PhotovoltaicSystem	s4bldg:SolarDevice	
PowerTransformer	saref4bldg:Transformer	
SmartAppliance	s4bldg:ElectricAppliance	
SpaceHeatingDevice	s4bldg:SpaceHeater	
VentilationSystem	s4bldg:AirToAirHeatRecovery	
CityAuthority	s4city:PublicAdministration	SAREF4CITY 1.1.2
Event	s4city:Event	
KeyPerformanceIndicator	s4bldg: KeyPerformanceIndicator	
KeyPerformanceIndicatorValue	s4city:KeyPerformanceIndicatorAssessment	
Location	s4city:AdministrativeArea	
Address	ifcAddress	IFC 4.0.2.1
Boiler	ifcBoiler	
Building	IfcBuilding	
BuildingSpace	BuildingSpace	
BuildingStorey	IfcBuildingStorey	
BuildingZone	IfcZone	
Occupancy	SpaceOccupancy	

SPARCS Concept	Standards-based Naming Convention	Relevant Standards-based data model/ ontology
Occupant	IfcOccupant	
PhotovoltaicSystem	IfcSolarDevice	
Sensor	IfcSensor	
SpaceHeatingDevice	ifcSpaceHeater	
Address	Address	USEF UFTP 1.3.6
Aggregator	Aggregator	
Contact	ContactDetails	
DistributionSystemOperator	DSO	
Flexibility	Flexibility	
Order	FlexOrder	
Prosumer	Prosumer	
Address	Address	UN/CEFACT CCTS 3
Device	sosa:Platform	OGC 16-079 SSN
Event	sosa:Observation or	
Measurement	sosa:observes	
SensingMeasurement	sosa:ObservableProperty	
Sensor	sosa:Sensor	

3. GAP ANALYSIS: KEY FINDINGS

A preliminary gap analysis was conducted in D2.4 (see Section 3.3 in D2.4 for details), which identified relevant standards, data models, and ontologies for aligning SPARCS CIM to support interoperability. Building on that, this document offers a more focused analysis of the standards and ontologies actually utilized in creating the SPARCS CIM.

The primary goal is to identify gaps between the implemented SPARCS CIM and the most commonly used standards and ontologies. This gap analysis measures the alignment by counting the concepts that match the relevant standards' concepts and ontologies' classes, with a priority on EU-supported standards, such as those from the European ICT standardization body (ETSI).

In this direction, the gap analysis to be presented focuses on identifying main issues and concerns regarding the actual applicability of the missing classes and objects between the SPARCS CIM's concepts and the SAREF-core ontology along with its extensions: SAREF4CITY, SAREF4ENER, SAREF4BLDG, and the IFC standard. The overall aim of the analysis is to identify missing classes and concepts in these ontologies and standards , that could enhance SPARCS objectives if they were available.

SPARCS identified several "gaps" in existing ontologies such as SAREF, SAREF4ENER, SAREF4BLDG, SAREF4CITY, and IFC, which are crucial for enabling interoperability in smart applications, energy systems, buildings, and city management. While SAREF provides a robust foundation for common concepts and reusable elements, it lacks specific device/appliance classes necessary for comprehensive smart application support. SAREF4ENER focusing on the energy domain, requires additional classes for energy market roles, and the integration of electric vehicles to address the evolving landscape of energy management and renewable integration. Similarly, SAREF4BLDG needs more detailed classes for building-device control actions and measurements to enhance smart building performance, devices management and occupant comfort. Additionally, SAREF4CITY, though extending to smart city needs, missed detailed infrastructure-related classes crucial for city management, which can be supplemented by SPARCS CIM's proposed subclasses. Lastly, the IFC widely used in building information modelling, lacks coverage for smart building management systems' control actions and measurements, which can be improved by integrating more detailed device concepts (objects).

Overall, the enhancements suggested by SPARCS CIM aim to bridge these gaps, ensuring better alignment and interoperability across various domains, ultimately supporting more efficient and sustainable smart systems.

Table 2 below presents the main gaps and concerns identified. It also offers suggestions for addressing these gaps by introducing concepts (and their semantic relationships) into the respective ontologies and standards already defined in the SPARCS CIM.

Table 2 Gap Analysis of standards and ontologies utilised in SPARCS CIM

Name	Main Issues/Concerns	Suggestions based on SPARCS CIM
SAREF	An ontology (strongly supported by the EC) designed to enable interoperability between different smart applications and assets by providing reusable elements based on user requirements. It is designed on the principles of reusability, flexibility, expandability, and maintainability, enabling users to create abstraction layers and common APIs without requiring explicit knowledge of specific standards.	The foundational SAREF ontology serves as the backbone of the SPARCS CIM, facilitating the representation of common concepts like devices, units of measure, measurements, and features of interest. Nevertheless, incorporating additional device/appliance-specific classes typically utilised within the smart application domain and which are currently are not fully covered by SAREF's core ontology, could enhance the usability and further adaptation of SAREF.
SAREF4ENER	SAREF4ENER targets the energy domain by offering a standardized ontology for energy-related concepts and relationships, promoting interoperability among various energy systems and devices. A key concern identified, is the lack of specific roles presently available within the energy market domain and the absence of classes related to electric vehicles (EV), which are critical in the rapidly evolving energy landscape.	While SAREF4ENER has been extensively utilised in the SPARCS CIM, the SPARCS CIM can also enhance this ontology by proposing additional detailed classes related to energy generation, storage, and distribution. This includes also introducing classes related to the various energy market stakeholder roles towards supporting more effective energy management and coordination. In addition, SPARCS CIM's detailed concepts of energy power plants and auxiliary infrastructure can provide richer contextual data and relationships, thereby enhancing SAREF4ENER's framework. Additionally, SPARCS considers the introduction of classes related to electric vehicles to be essential to address the ongoing and future needs of the energy domain. By incorporating these elements, SAREF4ENER can better support the comprehensive management of modern energy systems, including the integration of renewable energy sources and the expanding role of electric vehicles (EVs).

SAREF4BLDG	SAREF4BLDG extends the core SAREF ontology to cover the building domain, focusing on the interoperability of devices and systems within buildings. It standardises the representation of information about building devices, systems, and their interactions. However, we identified gaps in the coverage of specific building devices' control actions and detailed measurements, which are increasingly important for modern smart buildings.	Introduction of more specific classes related to building management systems, building devices and their control actions can further enhance SAREF4BLDG applicability and usability, supporting more precise and effective building management. This integration, in turn can lead to improved energy efficiency, enhanced comfort for occupants, and better overall building performance.
SAREF4CITY	SAREF4CITY extends SAREF to address the specific needs of smart cities, incorporating elements from six other ontologies. It includes classes, object properties, and data type properties that represent city-related concepts and relationships. Nevertheless city-specific classes related to city infrastructure (e.g. building devices), are not available. Though arguably these can be borrowed from other extension such as SAREF4BLDG, SAREF4ENER.	SPARCS CIM proposes the introduction of more detailed (sub)classes that cover various aspects of city management and operations. For example, include operation-specific public services by introducing (sub)classes of the saref4city:PublicService. Local energy communities, and specific energy and building specific classes, towards addressing further needs of the overall smart city ecosystem could also be considered for inclusion. This will further support the ability to monitor, manage, and optimise city infrastructure and services and enhance the usability and extensibility of SAREF4CITY.
IFC	IFC4 is a widely used standard for building information modelling, providing a comprehensive data model that represents building and construction industry data. It aims to improve the interoperability and data exchange between different software applications used in the AEC industry. However, IFCv4 has limitations in covering specific devices' control actions and detailed measurements related to smart building management systems. SPARCS considers that it is more applicable in the design and maintenance of the building systems (e.g. HVAC) than in the actual building usage phase.	The SPARCS CIM has consulted the IFCv4 and leveraged many of it to ensure alignment. Nevertheless, the inclusion of more detailed building devices and their control actions (crucial for modern smart building management)can be beneficial for IFC as well. This integration will enable more effective and efficient building management, enhancing the overall performance and sustainability of smart buildings.

4. NEWLY MODELLED CONCEPTS AND ATTRIBUTES

This chapter outlines the concepts and attributes that have been newly modelled within the SPARCS CIM framework in addition to those leveraged from the relevant standards, ontologies. The introduction (and definition) of these concepts has been identified as essential for enhancing the comprehensiveness, applicability and interoperability of the SPARCS CIM, addressing gaps identified in existing standards and ontologies.

Overall, the SPARCS CIM introduced several concepts and measurements to enhance the management and efficiency of smart systems.

For instance, AirConditioningSystemControlAction and BatteryControlAction provide specific control actions to manage indoor climate and optimise energy storage management, respectively. The BoilerControlAction and HeatPumpControlAction are essential for effective heating management, while LightingDeviceControlAction can further support enhancement of energy efficiency and occupant comfort in buildings (see Table 3). These additions align with standards such as SAREF, IFC, and IEC CIM, ensuring interoperability and comprehensive management of building systems.

In addition to control actions, the SPARCS CIM also includes detailed measurement concepts like BuildingMeasurements, EnergyConsumptionMeasurements, EnergyProductionMeasurements, and EnergyStorageMeasurements, which are crucial for monitoring and optimising energy usage at both micro and macro levels.

The introduction of roles such as CityAuthority, EnergyServiceCompany, FacilityManager, and PlantOperator facilitates structured representation and management of city services and energy operations. The inclusion of ElectricVehicle and EVChargingStationControlAction introduced for SPARCS purposes, can generally support the integration of electric vehicles into energy management systems, to reflect the evolving landscape of renewable energy and smart city infrastructure. Overall, these newly modelled concepts are expected to significantly bolster the SPARCS CIM’s capability to support efficient, sustainable, and interconnected smart environments.

The Table 3 below presents, these newly modelled concepts in greater detail, along with their relevance (if applicable) to existing objects-classes of standard ontologies to which they can be applied.

Table 3 SPARCS CIM newly modelled Concepts & applicable Standard/Ontology

SPARCS CIM Concept	Applicable Standard/Ontology	Relevant Class/Object	Purpose
AirConditioningSystemControlAction	SAREF3.1.1 |	AirConditioningSystem	Defines actions to control AC, enhancing the ability to manage indoor climate efficiently.
BatteryControlAction	IEC CIM 16	Battery	Specifies control actions for battery systems, crucial for energy storage management and optimisation
BoilerControlAction	IFC 4.1 SAREF4BLDG 1.1.2	Boiler	Actions to control boiler systems, essential for effective heating management in buildings.
BuildingMeasurements	IFC 4.1 SAREF4BLDG 1.1.2	Building	Comprehensive data on various building-related measurements such as energy usage, temperature, and occupancy rates, vital for building performance monitoring and optimisation
CityAuthority	IEC CIM 16	Location	Introduction of specific city governance entities, enabling structured representation and management of city services and departments
DomesticHotWaterSystem	IFC 4.1 SAREF4BLDG 1.1.2	No relevant class/object available	Introduction of specific building device
DomesticHotWaterSystemControlAction	IFC 4.1 and SAREF4BLDG 1.1.2	No relevant class/object available	Detailed representation and control actions for domestic hot water systems, ensuring efficient hot water management.
ElectricVehicle	SAREF4ENER v1.1.2	No relevant class/object available	Represents electric vehicles, supporting the integration of EVs in energy management systems.

SPARCS CIM Concept	Applicable Standard/Ontology	Relevant Class/Object	Purpose
EnergyConsumptionMeasurements	SAREF4ENER v1.1.2	Measurements	Detailed data on energy consumption essential for monitoring and optimising building and cities (macro-level) energy usage.
EnergyProductionMeasurements	SAREF4ENER v1.1.2	Measurements	Detailed data on energy production essential for monitoring and optimising building and cities (macro-level) energy usage.
EnergyStorageMeasurements	SAREF4ENER v1.1.2	Measurements	Data on energy storage, supporting efficient management of energy storage systems.
EnergyServiceCompany	SAREF4ENER v1.1.2	Role	Represents entities providing energy services, crucial for energy market operations and management.
EVChargingStation	SAREF4ENER v1.1.2	No relevant class/object available	Introduction of EVs for integrating them into the broader energy system
EVChargingStationControlAction	SAREF4ENER v1.1.2	No relevant class/object available	Controls actions for EV charging stations, integrating them into the broader energy system
FacilityManager	SAREF4ENER v1.1.2	Role	Represents individuals or entities managing facilities, ensuring efficient operation and maintenance of building systems
Gateway	SAREF4ENER v1.1.2	Components	Represents devices facilitating communication between different systems, crucial for IoT and smart city applications.
Grid	SAREF4ENER v1.1.2	Components	Represents the electrical grid, essential for understanding and managing energy distribution.
HeatPump	IFC 4.1	Boiler	Represents heat pumps, critical for energy-efficient heating and cooling.

SPARCS CIM Concept	Applicable Standard/Ontology	Relevant Class/Object	Purpose
	SAREF4BLDG 1.1.2		
HeatPumpControlAction	IFC 4.1 and SAREF4BLDG 1.1.2	Boiler	Represents heat pumps control actions, critical for energy-efficient heating and cooling.
IncidentLog	SAREF4ENER v1.1.2	No relevant class/object available	Introduces recording of incidents, supporting better management and troubleshooting of relevant systems
LightingDeviceControlAction	IFC 4.1 SAREF4BLDG 1.1.2	No relevant class/object available	Actions to control lighting devices, enhancing energy efficiency and occupant comfort.
LocalEnergyCommunity	IFC 4.1 SAREF4BLDG 1.1.2 SAREF4ENER v1.1.2	No relevant class/object available	Represents community-based energy initiatives, supporting decentralized energy production and consumption.
OutageLog	SAREF4ENER v1.1.2	Logs	Introduces recording of supporting better management and troubleshooting of relevant systems.
PlantOperator	SAREF4ENER v1.1.2	Role	Represents operators of energy plants, crucial for efficient energy generation and management
RenewableEnergySource	SAREF4ENER v1.1.2	Components	Represents renewable energy sources and their operators, supporting the integration and management of renewable energy in the grid.
RenewableEnergySourceOperator	SAREF4ENER v1.1.2	Role	Represents renewable energy sources and their operators, supporting the integration and management of renewable energy in the grid.
Retailer	SAREF4ENER v1.1.2	Role	Represents energy retailers, essential for the energy market and customer interactions.

SPARCS CIM Concept	Applicable Standard/Ontology	Relevant Class/Object	Purpose
SmartApplianceControlAction	SAREF4BLDG 1.1.2	No relevant class/object available	Control actions for smart appliances, integrating them into the building management system.
SpaceHeatingDeviceControlAction	IFC 4.1 SAREF4BLDG 1.1.2	No relevant class/object available	Actions to control space heating devices, crucial for maintaining indoor climate and energy efficiency.
VentilationSystemControlAction	SAREF4BLDG 1.1.2	No relevant class/object available	Control actions for ventilation systems, important for indoor air quality and energy management

Having introduced the newly modelled concepts above, the following section provides a comprehensive overview of all the high-level concepts of the SPARCS CIM at project completion.

This summary ensures a complete understanding of the SPARCS CIM (in its latest version) and its key attributes, reflecting the conclusion of the project's efforts to integrate and enhance relevant standards and ontologies, while also introducing additional concepts that were required for the SPARCS project's purposes.

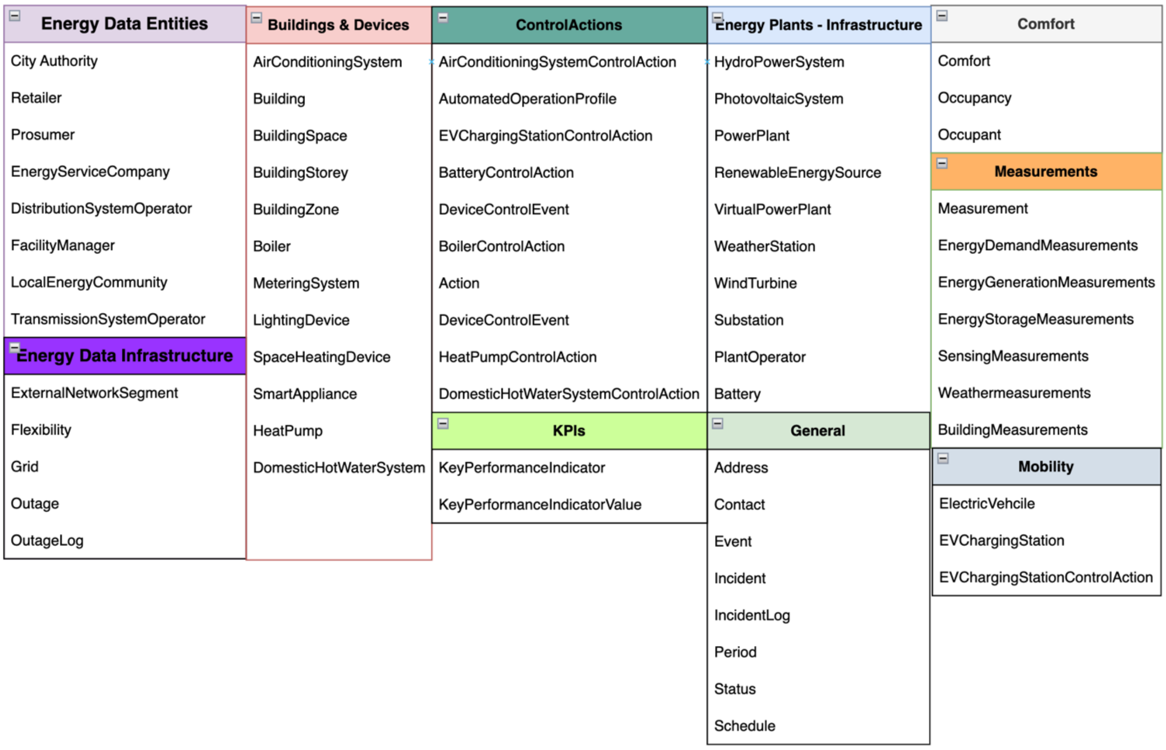

Figure 7 Overview of SPARCS CIM high-level concepts

The total number of high-level concepts of the SPARCS CIM at project completion, has risen to 79 concepts (from the 33 initially reported in D2.4), which in turn include a total of 2148 fields (from the initially recorded 519 in D2.4).

Ten virtual categories were created to serve the presentation needs and provide a more organized and clear structure for understanding the elements in the Figure 7 above; concepts assigned to these categories, along together with the defined fields per concept in the parentheses and the standard used for modelling those concepts, are provided below. These ten virtual categories are namely:

- KPIs,
- Energy Data Entities,
- Energy Data Infrastructure,
- Buildings & Devices,
- ControlActions,
- Energy Plants-Infrastructure,
- Measurements,
- General,
- Comfort,
- Mobility

5. SPARCS STANDARDIZATION PUNCH-LIST – SUGGESTED CONCEPTS

SPARCS aimed to address the data management and interoperability needs of various interventions developed in the SPARCS LCs. To achieve this, the SPARCS CIM was designed, leveraging key concepts and structures from various relevant standards and ontological frameworks. However, both of the specific and common needs of data owners, including smart city stakeholders, necessitated the introduction of custom concepts and fields. These customizations were designed to bridge standardization gaps within the SAREF framework and its extensions for energy and building domains.

Under this context, the objective of the SPARCS Standardization Punch List, is to propose potential enhancements for the utility and applicability of SAREF, ensuring it meets the evolving needs of smart buildings, energy systems, and cities. This chapter presents SPARCS' suggestions for areas in need of upgrades and introduces proposed classes for consideration and inclusion in the relevant ontologies.

Each proposed concept was assessed in terms of its relevance to SPARCS, its correlation to existing ETSI ontologies, and its potential contribution. For the proposed classes, we followed the notation of the ontologies, including their hierarchical structure and presenting their relationships.

Table 4 SPARCS Standardization Punch-list: Suggested concepts

AirConditioningSystemControlAction	AirConditioningSystem: SAREF3.1.1
BoilerControlAction	SAREF4BLDG 1.1.2
BuildingMeasurements	SAREF4BLDG 1.1.2
DomesticHotWaterSystem	SAREF4BLDG 1.1.2
DomesticHotWaterSystemControlAction	SAREF4BLDG 1.1.2
ElectricVehicle	SAREF4ENER v1.1.2
EVChargingStation	SAREF4ENER v1.1.2
EVChargingStationControlAction	SAREF4ENER v1.1.2
HeatPump	SAREF4BLDG 1.1.2
HeatPumpControlAction	SAREF4BLDG 1.1.2
LightingDeviceControlAction	SAREF4BLDG 1.1.2
SmartApplianceControlAction	SAREF4BLDG 1.1.2
SpaceHeatingDeviceControlAction	SAREF4BLDG 1.1.2
VentilationSystemControlAction	SAREF4BLDG 1.1.2

1.5 Addressing the Interoperability Needs within SPARCS CIM

Interoperability is the cornerstone of any modern smart system and refers to the ability of different systems, devices, applications, or products to connect, communicate, and work together effectively. In the context of data, interoperability ensures that data can be shared, understood, and utilised across diverse systems and platforms. This is particularly crucial as stakeholders transition into integrated ecosystems characterised by extensive data-sharing needs and fundamental semantic interoperability requirements.

The incorporation of new (specific) devices is considered as essential for ensuring interoperability among the diverse range of smart devices and systems. As the Internet of Things (IoT) continues to expand, the variety and number of new devices used in smart homes, buildings, and cities is also increasing.

In this context, the following section presents suggestions and recommendations in two axes:

1. ***Addition of new devices***

SPARCS suggest the inclusion of specific devices and infrastructure typically present in the current environment for review and possible inclusion in the SAREF's ontological model and its extensions (such as SAREF4SYST). These inclusions can facilitate seamless communication and integration of new devices into today's smart environments. The following Table 5 provides the proposed class titles, details for considering its inclusion in SAREF and their proposed hierarchical order by their semantic mapping to existing dedicated classes.

Table 5 Addition of New Devices – Proposed Classes

Proposed Class title	Details	has super-classes
saref:Electric Domestic Hot Water (DHW) System	An Electric Domestic Hot Water (DHW) System is a device used to heat water for domestic purposes such as bathing, cleaning, cooking, and space heating. This system relies on electrical energy to heat the water, offering an efficient and controllable solution for household hot water needs.	saref:Device[c]
saref:EV Charging station	An EV Charging Station is a piece of infrastructure designed to supply electric energy for the recharging of electric vehicles (EVs), including cars, trucks, buses, and other types of electric transportation.	saref:FeatureOfInterest[c] s4syst:System[c]

2. ***Introduction of Devices' Control actions***

Control actions on various devices are crucial because they enable precise and dynamic management of smart appliances and energy systems. This ability to control and automate device actions based on real-time data and user preferences enhances the efficiency, interoperability, and functionality of smart home and building environments.

The introduction of control actions (see Table 6 below) is considered particularly important for the SAREF ontology, which aims to facilitate seamless communication and data exchange among smart appliances and systems.

Table 6 *Introduction of (devices) Control actions – Proposed Classes*

Proposed Class title	Details	has super-classes
saref:HVAC Control Action	This enhancement will enable precise management of cooling functions based on real-time environmental data (e.g., temperature, humidity) and user preferences. Control actions may include adjusting cooling output, scheduling on/off times, and integrating with smart home systems for energy optimization	saref:Device[c] saref:controls[op] **min** 1 **saref:HVAC**
saref4ener:Electric Domestic Hot Water (DHW) System Control Action	This will ensure efficient usage and integration with overall household energy management. Control actions can involve setting water temperature, scheduling heating times, and integrating with other home energy systems to optimize hot water production based on demand and energy availability.	saref:Device[c] saref:controls[op] **min** 1 Saref:Electric Domestic Hot Water (DHW) System
saref4ener:EV Charging Station Control Action	This includes control actions for charging management and energy optimization. Features might include scheduling charging sessions, balancing load based on grid demand, and integrating with renewable energy sources to charge during periods of low grid demand or high renewable generation.	
Lighting Device Control Action	Allowing for dynamic and energy-efficient lighting management in smart buildings. Control actions might include dimming lights, changing color temperature, scheduling on/off times, and responding to occupancy sensors to reduce energy usage when spaces are unoccupied.	saref:Light saref:LightSwitch saref:controls[op] **min** 1
Smart Appliance Control Action	To ensure interoperability and efficient energy use, this covers appliances such as refrigerators, washing machines, and dishwashers, enabling them to operate during off-peak hours or when renewable energy is abundant	saref:controls[op] **min** 1
Space Heater Device Control Action	To facilitate effective temperature regulation and energy management. control actions might include setting target temperatures, scheduling heating periods, and integrating	saref:controls[op] **min** 1

	with other heating systems for coordinated operation	

6. ACCELERATING STANDARDISATION: LEVERAGING HSBOOSTER FOR THE SPARCS PROJECT

HSBooster is a pivotal European Commission initiative focused on accelerating the adoption of high-impact standards across diverse sectors. By offering expert guidance and support, HSBooster aims to bridge gaps between innovative projects and standardization bodies, ensuring that cutting-edge solutions meet industry standards and gain widespread acceptance, by contributing to the creation or revision of standards. Their mission is to provide a framework where emerging technologies can seamlessly integrate with existing standards, fostering a more cohesive and efficient technological landscape. This initiative plays a crucial role in unifying efforts towards sustainable and interoperable solutions, essential in addressing global challenges.

In our efforts to promote the results of the SPARCS project, we applied to the HSBooster service. SPARCS has been successfully assessed as a highly impactful project in terms of standardization and was assigned to a dedicated expert of the HSBooster service, acting as the liaison between the SPARCS consortium and the ETSI Technical Committee (TC) SMART MACHINE-TO-MACHINE COMMUNICATIONS (SMARTM2M) – part of the CEN/CENELEC/ETSI Coordination Groups on Smart Grids and Smart Manufacturing to support oneM2M, SAREF and IoT Semantic Interoperability. This engagement represents a significant step towards integrating our project results into established standards and ensuring its outcomes are recognized and utilized within the industry. By connecting with HSBooster, we aim to leverage their extensive network and expertise to enhance the visibility and impact of the SPARCS project and accelerate their adoption and materialization into existing ontologies and data models in a resource-efficient manner. This collaboration is expected to open doors to new opportunities and partnerships, facilitating the broader implementation of our innovative solutions.

In the initial meeting with the HSBooster expert, SPARCS presented an initial standardization punch list, which received a very positive response. The expert recommended that we focus our outreach efforts on the EU standardization bodies rather than international ones, as this would be more effective for the project's goals. They requested additional clarifications on the punch-list and a concise one-page summary of the project to facilitate further understanding.

Following the introductory meeting with the HSBooster expert assigned to SPARCS, the relevant information was provided about the standardization punch-list and recommendations were communicated to the members of the Technical Committee of Smart Machine-to-Machine communications for their assessment and to gauge their interest in our proposals. With the initial feedback being favourable and our suggestions received with great enthusiasm by the Technical Committee members, a follow-up meeting with the SAREF experts within the group is being planned. This formal meeting, scheduled for late September 2024, will provide us the opportunity to present our standardization punch-list and detailed recommendations. The goal is to prepare the grounds for the inclusion of the proposals in the next Quarterly Plenary Meeting of the SMARTM2M group, paving the way for their progressive integration into the new version of the SAREF ontology.

The primary objective of this engagement is to ensure that the SPARCS project outcomes align with industry standards, facilitating broader acceptance and implementation. By presenting our standardization punch-list to SAREF experts, we aim to receive valuable feedback and guidance on enhancing the project's compatibility and effectiveness. This alignment will not only improve the technical robustness of the SPARCS project solutions but also ensure that it meets the high expectations and requirements of industry stakeholders. The goal is to achieve a seamless integration that enhances user experience and maximizes the project's potential for impact.

It has become evident, that SPARCS' collaboration with HSBooster was pivotal in engaging with the targeted standardization bodies and bringing our innovative results even closer to the market. This collaboration is not only expected to promote the results of the SPARCS data modelling activities but also contribute to the broader goal of achieving sustainable and interoperable energy systems. By working together, both projects can drive the adoption of standards that support the transition to more efficient and resilient energy infrastructures.

7. CONCLUSIONS

D2.10, reports the outcomes of T2.5 -“Definition of high-level Smart City Standardization Punch-list” activities, summarising the comprehensive efforts and achievements of SPARCS in supporting smart city standardisation. Under this context, this deliverable underscores the importance of interoperability, and the critical gaps identified. Furthermore, it proposes strategic recommendations to enhance existing standards, to ensure their relevance and applicability in the evolving landscape of smart cities.

Overall, the development and deployment of the SPARCS CIM (which leverages existing frameworks/standards (IEC CIM, OpenADR, IFC, USEF, etc.) and ontologies such as SAREF and its extensions) highlighted the critical need for interoperability and standardisation across diverse smart city domains, including energy management, eMobility, and digital integration. To develop a robust and scalable CIM that supports seamless data integration and management; SPARCS was able to introduce additional concepts and attributes to address specific project needs not fully covered by existing standards. This enhancement improved the model's comprehensiveness and applicability.

D2.10 also includes a gap analysis that identifies several areas where existing standards and ontologies can be enriched; SPARCS provided specific suggestions for enriching these standards through additional practical classes and objects relevant to real-world applications. For instance, the need for additional device-specific classes and devices’ control actions in SAREF and its extensions was highlighted. Incorporating these new concepts/elements within the SPARCS CIM has not only filled these gaps but also provided valuable recommendations for future standardization efforts.

Key output of this deliverable is the SPARCS standardization punch list, including several recommendations aimed at further enhancing the interoperability and scalability of smart city technologies. These recommendations focus on the inclusion of new devices, such as Electric Domestic Hot Water Systems and EV Charging Stations, and the introduction of control actions for various devices to support dynamic and efficient management within smart environments. By adopting these recommendations, standardization bodies can ensure that their frameworks remain relevant and supportive of emerging smart city applications. To further boost and disseminate its outcomes, the SPARCS consortium has engaged with EU’s Horizon Standardisation Booster seeking to promote their findings and recommendations. These experts guided SPARCS on how to feed their results into standardisation working groups or technical committees.

As the SPARCS project concludes, it leaves behind through D2.10 its findings and recommendations which can serve as a valuable resource for standardization bodies and industry stakeholders alike. By building on these achievements, future efforts can further drive the development of smart, sustainable, and resilient cities.

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9. Appendices

List of acronyms used in SPARCS

	Abbreviation
Application Programming Interface(s)	API
Balance Responsible Party	BRP
Common Information Model	CIM
Common Reference Operator	CRO
Distributed Energy Source(s)	DER
Data Management Platform	DMP
Deliverable x.y	Dx.y
Description of Action	DoA
Distribution System Operators	DSO
European Commission	EC
Electric Power Research Institute	EPRI
European Telecommunications Standards Institute	ETSI
European Union	EU
Electric Vehicle(s)	EV
Electric Vehicle Communication Controller	EVCC
Fellow City	FC
Grant Agreement	GA
Geography Markup Language	GML
Horizon Standardisation Booster	HSBooster
Information and Communication Technologies	ICT
International Electrotechnical Commission	IEC
Intelligent Electronic Device	IED
Intellectual property Rights	IPR
International Organization for Standardization	ISO
JavaScript Object Notation	JSON
Key Performance Indicator(s)	KPIs

Light House City	LHC
Level Of Detail	LoD
Occupant Behavior XML	obXML
Open Charge Alliance	OCA
Open Charging Point Protocol	OCPP
Open Automated Demand Response	OpenADR
Open Smart Charging Protocol	OSCP
Publicly Available Specifications	PAS
Positive Energy District(s)	PED
Renewable Energy Sources	RES
Smart Applications REFerence Ontology	SAREF
SAREF for Buildings	SAREF4BLDG
SAREF for Energy	SAREF4ENER
SAREF for City	SAREF4CITY
Supervisory Control And Data Acquisition	SCADA
Smart Communities Information System	SCIS
Supply Equipment Communication Controller	SECC
Smart Machine-to-Machine Communications	SMARTM2M
Sustainable Positive and zero cARbon CommunitieS	SPARCS
SPARCS Visualisation Framework	SVF
Technical Committee	TC
Transmission System Operators	TSO
Task x.y	Tx.y
User Interface	UI
Universal Smart Energy Framework	USEF
Vehicle-to-Grid	V2G
Work Package	WP
eXtensible Markup Language	XML