



Study on ensuring interoperability for enabling Demand Side Flexibility

EXECUTIVE SUMMARY

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Abstract

The transition to sustainable energy sources introduces distributed intermittent energy that requires more flexibility in demand. It is anticipated that consumers will play an active role with self-generation and will pro-actively manage their demand according to their needs and available resources; this is called *Demand Side Flexibility (DSF)*. Energy Management applications will be used to control consumption, generation and storage, so that consumers will be in control, but will not need to execute all the related actions themselves. These applications will take input from Smart Meters and signals from energy market players to control the in-home energy flows. To that end, the data needed for DSF needs to flow seamlessly through an IT infrastructure that connects Smart Meters, Consumer Energy Management Systems, Smart Appliances and Gateways between the home and external networks. The IT infrastructure of DSF is covered by three different industries that all have separately developed technology and standards, i.e., the Utility industry, the Telecom industry and the Home appliances industry. Originated for different purposes and in different context, the communication standards from these industries are not necessarily aligned, leading to barriers in the seamless flow of data in the DSF infrastructure.

In this study, we have investigated the need for alignment among the communication standards from the Utility, Telecom and Home appliances industries. We have selected nine standards that have been compared with the reference ontology SAREF (Smart Appliances REFerence ontology), developed in an earlier project commissioned by DG-Connect, and its extension for the Energy domain, SAREF4ENER. We concluded that alignment between DSF standards is needed and that SAREF/SAREF4ENER can be used as the overarching ontology to facilitate this alignment. Several actions and recommendations for various stakeholders, such as the Standards Development Organisations, have been identified and are listed in the report. Moreover, a proof of concept was demonstrated to show DSF interoperability through the complete, end-to-end IT infrastructure, from Smart Grid to Smart Meters and Smart Appliances. The next step to be taken is to scale up the proof of concept that we demonstrated, implementing the resulting SAREF-based solution in more use cases for Demand Side Flexibility, in more smart devices and at real consumer sites.

Executive Summary

The Background

The energy transition can generally be described as the shift from power generation with fossil fuels (oil, coal, natural gas) to renewable energy sources such as wind, solar power, geothermal and ocean power. The nature of renewable energy sources, unlike conventional power generation, is that they are intermittent, meaning that they are not continuously available to meet the demand. Since our society is very dependent on access to an uninterrupted power supply, implementation of renewable energy requires an intelligent energy system to cope with intermittent energy sources by balancing electricity demand and supply.

Balancing electricity will require flexibility on both the demand and supply sides, requiring interconnection, storage, flexible generation, and flexible demand. Flexibility on the demand side is necessary as flexibility on the supply side is limited, increasing generation may take too much time or it may be too expensive to operate, and demand can at times exceed the total generation capacity. In this study the flexibility of energy demand is studied.

Demand Side Flexibility (DSF) is the ability of consumers to adapt their electricity consumption in response to market signals. The end-consumer may adjust power demand by postponing some tasks that require large amounts of electric power, or may decide to pay a higher price for their electricity.

End-consumers can in principle be industrial consumers or residential consumers. However, this study explicitly focusses on residential consumers and thus on residential demand side flexibility.

The residential end-consumer requires power demanding appliances that offer flexibility. For instance, postponing the operation of a washing machine shifts the power demand and thus offers flexibility to the energy company. Other examples are provided by home appliances such as heat pumps, Electric Vehicle (EV) charging stations and refrigerators. Nowadays, home appliances are highly intelligent (“smart”) and networked devices that form complete energy consuming, producing and managing systems, which can be controlled automatically through internet communication.

A suitable configuration to enable and realise demand side flexibility includes a number of components, such as smart appliances that can respond to market signals, an in-home energy management system that controls and monitors the smart appliances and communicates with the

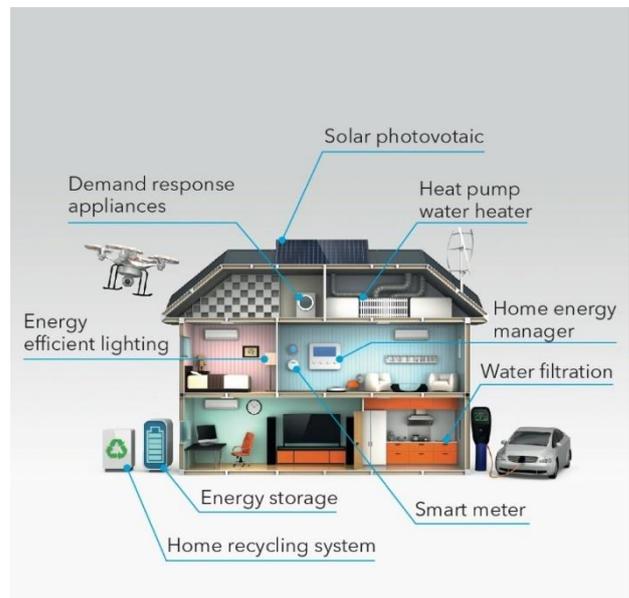


Figure 0-1: Home configuration

energy companies, a smart meter for settlement purposes, and an in-home display for consumers to monitor what is happening in their home. Included in the demand side flexibility chain, but outside the residential premises, are the energy companies that push requests for flexibility.

The Study

An important condition for the introduction of demand side flexibility is that smart appliances, smart meters, EV charging stations, energy management systems, etc., can all communicate with each other. In other words, the smart appliances and systems involved in the demand side flexibility chain need to be interoperable and interoperability is fostered when the communication is based on standard interfaces.

Alignment is needed because of the fragmentation and lack of harmonization among standards that have been developed at different times and with different purposes by various standards development organisations (SDOs) active in the telecom industry, utility industry and home appliances industry. The European Commission therefore issued a tender for a study on addressing the lack of interoperability in the end-to-end Demand-Side Flexibility flow, by identifying the need for alignment between data standards in this flow and providing a solution for several relevant use cases.

TNO, ESMIG and DNV GL were invited to perform this study. The study has identified gaps in the current standardisation landscape in the field of demand side flexibility, analysed alignments needed to achieve (semantic) interoperability on data level using SAREF (a reference ontology for smart appliances developed in an earlier project promoted by DG-CNCT), proposed consequent actions towards the realisation of these alignments, and demonstrated an integrated demand side flexibility infrastructure as a proof-of-concept of interoperability.

The scope of the study was residential consumers, not including storage. The focus was on smart appliances and the use of SAREF for DSF, where SAREF also studied residential consumers instead of industrial or commercial consumers. The use of storage in residential homes is out of scope for this study, as use cases and data definitions are under development and therefore are considered not mature yet.

The Approach

The first step was to identify on which data elements interoperability should be reached. Therefore, we have identified relevant use cases in the DSF domain and listed its associated data elements. In the second step, we identified the standards that cover the various interfaces of the DSF infrastructure. Thirdly, we have identified the alignments needed between these standards on the identified data elements. Finally, a proof-of-concept solution for alignment has been demonstrated.

The study closely involved various SDOs, stakeholders from industry, Utilities and the European Commission at different stages, to be informed about the intermediate results, gather feedback and

assist to the final demonstration of the resulting integrated infrastructure for demand side flexibility. In this demonstration, the manufacturing industry clearly showed its intention to use the standards and the alignments proposed in this study to create a seamless information infrastructure for demand side flexibility. The demonstration took place at three different venues, namely 1) the European Utility Week conference and exhibition in Amsterdam, 3-5 October 2017, 2) the ETSI IoT week in Sophia Antipolis, 23-26 October 2017, and 3) the DG-Connect's premises in Brussels on 27-29 November 2017.

The Results

The domain of demand side flexibility is broad in the sense that there is a large amount of use cases and standards that cover or touch upon it. Therefore, a sample of relevant use cases has been selected (10 use cases). The use cases and the extracted data elements are shown in the table below.

Table 0-1: Selected use cases and the extracted DSF core data elements

USE CASE	DSF CORE DATA ELEMENTS
Device Registration & Configuration	<ul style="list-style-type: none"> - Device Identifier - Device capabilities
Flexible start of Smart Device	<ul style="list-style-type: none"> - Control parameters, e.g. profile selection - Preferred time slot of operation per Device - Flex start enabled - Energy consumption - Energy Profile - Start time/ time slot of operation - New tariff information - Recalculated start time / time slot - Operation commands
Response of Smart Home to Emergency	<ul style="list-style-type: none"> - Emergency signal - Emergency load command
Control of non-smart Device by CEM	<ul style="list-style-type: none"> - Tariff threshold - Real Time Tariff - Operation commands (increase or decrease power and turn off/on)
Direct Load Control of Smart Device via CEM	<ul style="list-style-type: none"> - Id of participating devices - Power thresholds - Load management signal - Load adjustment command - Feedback about adjustment - Expected change in consumption
Demand-supply adjustment by cooperation between supplier and customer	<ul style="list-style-type: none"> - Price information of electrical energy based on time of use (TOU) - Planned load profile (expected consumption in time)
Exchanging information on (partial) consumption	<ul style="list-style-type: none"> - Actual Individual Appliances (= partial) consumption/generation - Forecasted partial consumption/generation



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	- Actual total house consumption
	- Forecasted total house consumption
External Actor Retrieves status of smart devices	- Device Status Request
	- Device Status
	- Status is displayed to consumer
CEM requests time from Smart Meter GW and Smart Meter GW synchronizes time of CEM	- Actual time request
	- Actual time
Smart Meter GW notifies actual tariff to CEM	- Active tariff notification

We have further selected a sample of relevant standards that cover the interfaces of the DSF flow (10 standards):

- CEN 16836 (ZigBee SEP2)
- CENELEC EN 50491-11 Smart Metering
- CENELEC EN 50631-1 (SPINE)
- ETSI TS 103 264 (SAREF)
- ETSI TS 103 410-1 (SAREF4ENER)
- IEC 61968-9 CIM for metering
- IEC 61970 CIM
- IEC/CENELEC 62056 COSEM
- CENELEC EN 50090 (KNX)
- oneM2M TS 0012 Base Ontology

The SAREF and SAREF4ENER ontologies have been used as the overarching ontologies to make alignments on the assumption that, if the considered standards could be aligned with SAREF/SAREF4ENER on the core data elements in the DSF domain, then these standards would be semantically interoperable also with each other. SAREF and SAREF4ENER themselves have also been analysed for missing DSF core data elements.

SAREF and SAREF4ENER were both checked for the coverage of all core data elements. Subsequently, the eight remaining standards have been analysed on their alignment with SAREF/SAREF4ENER. The conclusion is that a certain level of alignment already exists. SPINE and oneM2M are fully aligned with SAREF/SAREF4ENER. Four standards need further alignment, for which actions are defined. The remaining two standards, CENELEC EN 50491-11 and IEC 61968-9 CIM for Metering, do not have a direct alignment with SAREF/SAREF4ENER, but are aligned through the COSEM standard, which covers the same interface.

Table 0-2: Level of alignment

Standard	Level of alignment	Alignment required
EN 50631-1 (SPINE)	Fully Aligned with SAREF/SAREF4ENER	No
oneM2M Base ontology	Fully Aligned with SAREF	No
IEC/CENELEC 62056 COSEM	Fair alignment with SAREF/SAREF4ENER	Yes
CEN 16836 (ZigBee SEP2)	Fair alignment with SAREF/SAREF4ENER	Yes
CENELEC EN 50090 (KNX)	Potential alignment with SAREF/SAREF4ENER	Yes
IEC 61970 CIM	Potential alignment with SAREF/SAREF4ENER	Yes
CENELEC EN 50491-11 Smart Metering	Aligned with IEC/CENELEC 62056 COSEM	No
IEC 61968-9 CIM for Metering	Aligned with IEC/CENELEC 62056 COSEM	No

We further concluded that full alignment between the selected standards and full coverage of the core data elements can be achieved by executing the actions as defined in this study.

Overall, we conclude that alignment between standards for DSF is needed and that SAREF/SAREF4ENER can be used as the overarching ontology to facilitate this alignment. Several actions and recommendations for various stakeholders, such as the Standards Development Organisations, have been identified and are listed in the report. The next step to be taken is to scale up the proof of concept that we demonstrated, implementing the resulting SAREF-based solution in more use cases for Demand Side Flexibility, in more smart devices and at real consumer sites.



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Glossary

Advanced metering infrastructure	An architecture for automated, two-way communication between a smart utility meter with an IP address and a utility company. The goal of an AMI is to provide utility companies with real-time data about power consumption and allow customers to make informed choices about energy usage based on the price at the time of use.
Aggregator	A market participant that combines multiple customer loads or generated electricity for sale, for purchase or auction in any organised energy market
Core data elements	Core data elements are defined in this study as recurring, common concepts in the DSF domain that define the meaning (or <i>semantics</i>) of the data exchanged between standards.
Demand response	The change of electricity load by final customers from their normal or current consumption patterns in response to market signals, including time-variable electricity prices or incentive payments, or in response to acceptance of the final customer's bid, alone or through aggregation, to sell demand reduction or increase at a price in organised markets as defined in Commission Implementing Regulation (EU) No 1348/2014 ¹
Demand side flexibility	The ability to change electricity output or demand in reaction to an external signal.
Device [4]	This study adopts the definition given in [4] according to which a device is a tangible object designed to accomplish a particular task in households, common public buildings or offices. In order to accomplish this task, the device performs one or more functions. Examples of devices are a light switch, a temperature sensor, an energy meter and a washing machine. A washing machine is designed to wash (task) and to accomplish this task it performs a start and stop function.
Distribution system operator	A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity or gas.
Energy service company	A commercial or non-profit business providing a broad range of energy solutions including designs and implementation of energy savings projects, retrofitting, energy conservation, energy infrastructure

¹ Commission Implementing Regulation (EU) No 1348/2014 of 17 December 2014 on data reporting implementing Article 8(2) and Article 8(6) of Regulation (EU) No 1227/2011 of the European Parliament and the Council on wholesale energy market integrity and transparency (OJ L 363, 18.12.2014, p. 121).

outsourcing, power generation and energy supply, and risk management.

Explicit demand side flexibility [1]

Committed, dispatchable flexibility that can be traded (like generation flexibility) on the different energy markets (wholesale, balancing, system support and reserves markets). This is usually facilitated and managed by an aggregator that can be an independent service provider or a supplier. This form of DSF is often referred to as “incentive driven” DSF.

Home Energy Management System

A technology platform comprised of both hardware and software that allows the user to monitor energy usage and production and to manually control and/or automate the use of energy within a household.

Implicit demand side flexibility [1]

Consumer’s reaction to price signals. Where consumers have the possibility to choose hourly or shorter-term market pricing, reflecting variability on the market and the network, they can adapt their behaviour (through automation or personal choices) to save on energy expenses. This type of DSF is often referred to as “price-based” DSF.

Ontology [4]

Formal specification of a conceptualization, used to explicit capture the semantics of a certain reality

Smart appliance [4]

This study adopts the definition given in [4] according to which smart appliances are devices, which are used in the household, e.g. for performing domestic work, and which have the ability to communicate with each other and which can be controlled via Internet. NOTE: The following appliances are covered: 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); white goods, as classified by CECED; HVAC (heating, ventilation, and air conditioning), classified by Eu.bac; lighting, with use cases as defined by LightingEurope; micro renewable home solutions (solar panels, solar heaters, wind, etc.).

Transmission system operator

A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity.

Abbreviations

AAL	Ambient Assisted Living
ADR	Automated Demand Response
AE	Application Entity
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
CD	Committee Draft for IEC standards
CEM	Customer Energy Manager
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electro technique
CIM	Common Information Model
CLC TC	CEN-CENELEC (CLC) Technical Commission (TC)
COaP	Constraint Application Protocol
COSEM	Companion Specification for Energy Metering
CSE	Common Services Entity
DLMS	Device Language Message Specification
DNV-GL	Det Norske Veritas – Germanischer Lloyd
DMS	Distribution Management Systems
DHW	Domestic Hot Water
DR	Demand Response
DSF	Demand Side Flexibility
DSO	Distribution System Operator
E@h	Energy@home association
EEBUS	EEBUS Initiative
EFI	Energy Flexibility Interface
EHS	European Home System

EIB	European Installation Bus
EMG	Energy Management Gateway
EMS	Energy Management Systems
EN	European Norm
ESCO	Energy Service Company
ESMIG	European Smart Metering Industry Group
ETSI	European Telecommunications Standards Institute
H/B/I	Home/Building/Industrial
HES	Head End System
HEMS	Home Energy Management System
HTTP	Hyper Text Transfer Protocol
HVAC	Heating, ventilation and air conditioning
IEC	International Electrotechnical Commission
IoT	Internet of Things
ISO	International Organization for Standardisation
KNX	KNX association
LNAP	Local Network Access Point
MDM	Meter Data Management
MOU	Memorandum Of Understanding
MS	Metering System
M2M	Machine-to-Machine
NSE	Network Services Entity
NNAP	Neighbourhood Network Access Point
NSB	National Standardization Bodies
OBIS	Object Identification System
oneM2M	Global standards initiative for Machine to Machine Communications
OpenADR	Open Automated Demand Response alliance

OSI	Open Systems Interconnection
OWL-DL	Web Ontology Language – Description Logic
RDF	Resource Description Framework
SAREF	Smart Appliances REference ontology
SAREF4ENER	SAREF for Energy
SCADA	Supervisory Control And Data Acquisition
SGAM	Smart Grid Architecture Model
SHACL	Shapes Constraint Language
SHIP	SmartHome IP
SmartM2M	Smart Machine-to-Machine communications
SPINE	Smart Premises Interoperable Neutral-Message Exchange
SD	Smart Device
SDO	Standard Development Organisation
SMG	Smart Meter Gateway
TC	Technical Committee
TNO	Netherlands Organisation for Applied Scientific Research TNO
ToU	Time of Use
TSO	Transmission System Operator
TTL	Turtle format
UDI	Universal Device Interface
UML	Unified Modeling Language
URL	Uniform Resource Locator
VEE	Validating, Editing and Estimating
W3C	World Wide Web Consortium
XSD	XML Schema Definition Language

Reading Guide

To meet the needs of readers of all types, with different backgrounds and interests, this report is setup in a way that all readers can find the topic of their interest quickly and grasp the essence of this study.

For those readers who are interested in the setup and the basic result of the study we refer to the executive summary as it explains all that succinctly and on a non-technical level.

Readers who want to understand the study beyond the level of the executive summary can basically be divided into two groups; 1) the reader who want to understand more about the specific approach of each task, how several steps of the study have been executed and the results from these individual steps, and 2) the reader who want to understand each technical detail.

To accommodate both type of readers we have created a specific reporting structure for the technical chapters:

- Section 2: Selecting uses cases and data elements in the DSF domain (task 1);
- Section 3: Selecting relevant standards (task 2);
- Section 4: Aligning the standards on the selected data elements (task 3).

Each technical chapter is structured similarly:

- The first section explains the *Objective* of the task;
- The second section shows the *Approach* that has been chosen to execute the task;
- The third section describes the *Technical analyses* that have been performed and the results coming from these analyses;
- The final section shows the *Results* of the task.

To the reader who wants to understand the study thoroughly without reading all technical details we suggest to read the *Objective*, *Approach* and *Results*. To the reader who is also interested in all technical details we suggest to read the *Technical analyses* as well.

For the technical readers, we would like to point out that Section 3.3 contains an extensive description of all standards that have been longlisted (20 standards).

Tasks 4 and 5 of this study have been reported in the Appendix:

- Appendix B describes the details of the workshop that has been held with many of the stakeholders to discuss the interim results;
- Appendix C shows the detailed results of the demonstrations that have been held as a “Proof of Concept” of an integrated DSF infrastructure.

Finally, Section 5 contains the conclusions from this study. Surely the most important results of this study are the actions that have been defined to close the gaps and reach semantic interoperability between standards. Next to that, we have defined a set of recommendations to reinforce the actions and pave the road to interoperability within the DSF domain.

1. Introduction

1.1. Policy context

Demand Side Flexibility (DSF) indicates the flexibility offered by residential-consumers (i.e., the “demand side”) to voluntarily change their typical electricity usage patterns in response to market signals, such as time-variable electricity prices or incentive payments, or to sell their will to modify their demand for electricity at a given point in time in organised energy electricity markets, following the acceptance of consumers' bids (on their own or through aggregation).

Demand side flexibility can help to relieve the electricity system and the transmission and distribution grid, preventing black-outs and the costs related to them. Moreover, flexible demand side has the potential to reduce the total generation capacity needed in peak hours, avoiding investments in increasing transportation and distribution capacity.

The benefits of DSF consist of structural and real-time congestion management (e.g. to accommodate distributed generation and increased variability of demand); balancing of the electricity system with respect to the procurement of power reserves, by ensuring that demand is equal to supply in real-time; and ancillary services contracted by transmission system operators guaranteeing system security.

Demand side flexibility is a resource that benefits and empowers residential consumers and reduces total system costs, facilitates renewables integration and contributes to building Europe’s smart energy leadership. The ‘Clean energy for all Europeans’ package, proposed by the European Commission (EC) in November 2016, suggests updates of several directives, such as the Energy Efficiency Directive², the Energy Performance of Buildings Directive³ and the Electricity Directive⁴. The package contains various provisions related to consumer engagement, demand side flexibility, new energy market entrants (e.g., aggregators) and interoperability. The Electricity Directive calls for “activation and full realisation of the flexibility potential that the demand side can offer” and the Market Design initiative suggests an environment where short term markets are fully developed and integrated, and flexibility plays a key role in enhancing the market value of renewables.

Large scale implementation of DSF has not taken off yet, although several countries are already implementing flexible tariffs and some form of Demand Response. The barriers for implementation are regulatory (e.g., regulated tariffs and market rules for operating flexibility) and technical (e.g., interoperability and security).

The implementation of demand side flexibility not only requires energy market players, such as Distribution System Operators (DSOs) and Energy Service Companies (ESCOs) to cooperate, but also their technical infrastructures that manage demand to be coupled. Interoperability is key especially where the DSO infrastructure provides information (e.g., smart meter data) that is needed by demand side flexibility applications.

On the side of the consumer premises, an important step in addressing the issue of fragmentation and the need for interoperability in the smart appliances industry was made by the EC (DG-Connect)

² <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1485938766830&uri=CELEX:52016PC0761>

³ <http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1490877208700&uri=CELEX:52016PC0765>

⁴ <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016PC0864R%2801%29>

in 2013, by launching a standardisation initiative (SMART 2013/0077) in collaboration with the European Telecommunications Standards Institute (ETSI) to create a shared semantic model of consensus to enable interoperability in the smart appliances domain (<https://sites.google.com/site/smartappliancesproject>). The development of a reference ontology was targeted as the main interoperability enabler for smart appliances relevant for energy efficiency. This resulted in the definition of the Smart Appliances REference ontology (SAREF) [4]. Following the momentum gained during the smart appliances study, SAREF was published in 2015 by ETSI as a Technical Specification (TS 103 264 V1.1.1).

SAREF was created with the intention to interconnect data from different protocols and platforms, for instance ZigBee (<http://www.zigbee.org>), UPnP (now OCF, <https://openconnectivity.org/>) and Z-Wave (<http://www.z-wave.com>), enabling the communication between in-home devices that use different protocols and standards. SAREF is not about the actual communication with devices and has not been set up to replace existing communication protocols and standards, but it lays the base for enabling the translation of information coming from existing (and future) protocols and standards to and from all other protocols and standards that are referenced to SAREF.

The SAREF initiative has been welcomed by the Smart Appliances and IoT industry that clearly indicated the intention to adopt the SAREF ontology and its related communication framework (i.e., oneM2M). As confirmed in the European Commission GROW Rolling Plan for ICT Standardisation 2016, SAREF is a first ontology standard in the IoT ecosystem, and sets a template and a base for the development of similar standards for the other verticals to unlock the full potential of IoT.

In 2016, ETSI requested a Specialists Task Force (STF) to provide input on the management of SAREF and create dedicated extensions for specific domains. To that end, the STF 513 was established and, in March 2017, the latest version of SAREF has been published (SAREF 2.0), including an extension for the energy domain, called SAREF4ENER, with the goal to interconnect smart appliances from different manufacturers in demand response use cases by means of a Customer Energy Manager (CEM) that communicates using SAREF. New extensions of SAREF to the Smart Cities, Smart Industry & Manufacturing, and Smart AgriFood domains are currently under development (<https://portal.etsi.org/STF/STFs/STFHomePages/STF534>), turning SAREF into the umbrella that enables better integration of semantic data from and across various vertical domains in the IoT.

1.2. Main objective of this study

In August 2016, the EC (DG-Connect) has issued a tender for a study on “ensuring interoperability for demand side flexibility” (SMART 2016/0082), referred to as *DSF study* in the rest of this document. A consortium consisting of DNV GL, TNO and ESMIG was subsequently invited by the EC to conduct the study with the goal to identify gaps in standardisation, recommend on alignments needed to achieve DSF interoperability on data level and demonstrate an integrated DSF infrastructure.

The purpose of the study is to address the lack of interoperability in the end-to-end Demand-side Flexibility flow, by identifying the need for alignment between data standards in this flow and providing a solution for several especially relevant use cases.

With the results of this study and the demonstration of a possible solution, the relevant stakeholders will receive clear recommendations on how to adapt/extend their standards to reach interoperability

at the level of semantics and data elements, and initiate activities to perform the necessary modifications.

The study focusses on data standards (at the semantic level) under the assumption that if data elements specified by different standards are aligned, the information can seamlessly flow through the various interfaces of the DSF flow as shown in [Figure 1-1](#). The existing interfaces in the DSF flow can and will be implemented using different communication standards depending on specific choices made at national level. To address the issue of the multiple and heterogeneous data standards existing within the smart home, the SAREF ontology⁵, provides a valuable contribution. The goal of SAREF is to provide a common language for the communication with smart appliances, by aligning the data definitions adopted by multiple industries involved in home automation. Although the physical connection with smart appliances can differ depending on what specific protocol is implemented, SAREF can be used to provide a shared language at the semantic level for common concepts that are exchanged between different devices from various manufactures and systems/platforms from multiple vendors that all co-exist in the same home/building environment.

Building further on the work started with SAREF on smart appliances at the consumer premises, additional effort is needed for achieving semantic interoperability along the entire flexibility value chain, from the Smart Grid to smart appliances and smart meters in the home. The purpose of this follow-up study is to come to a possible solution for the problem of the multitude of non-aligned (or in some cases non-existing) standards on a semantic level on the different interfaces between the components of the end-to-end DSF flow. With the result of this study, it is expected that from a semantic interoperability and standardisation point of view the market for demand side flexibility will become fully functional and the most common and important use cases will be made technically possible.

Through the demonstration of an implementation of data models made interoperable using SAREF, the stakeholders will have a reference implementation of an integrated DSF infrastructure via SAREF, and a general approach that can guide them to generate interoperability solutions also for standards that are not considered in this study.

Towards these objectives and per the EC Tender requirements, the DSF study is structured in the following tasks:

Task1: Identify representative use cases for DSF and provide an overview of the most recurrent data elements in these use cases. The identified use cases are used as basis for the selection of data elements for DSF and for the demonstrator in Task 5.

Task 2: Identify (a long list of) relevant standards specified by standards developing organisations (SDOs) and industry alliances active in the DSF infrastructure, and identify alignments needed among these standards.

Task 3: For (a short list of) standards that sufficiently cover the various interfaces of the DSF infrastructure and address the use cases identified in Task 1, elaborate on the alignments that are needed to enable DSF interoperability. Provide recommendations to the stakeholders concerned of

⁵ <https://sites.google.com/site/smartappliancesproject>

implementing these alignments. Some alignments are implemented by the study itself in Task 5, as an example for the stakeholders.

Task 4: Organize a workshop with relevant stakeholders to present the intermediate results of the study and receive their feedback.

Task 5: Organize a demonstrator (proof of principle) of a possible solution for DSF interoperability based on 1) the use cases selected in Task 1, and 2) the short-listed standards selected in Task 3, showing how the corresponding misalignments have been solved for the considered use cases and standards

1.3. DSF business process

Figure 1-1 provides a functional representation of the DSF communications architecture. Energy services can be provided by any party⁶ (suppliers, balance responsible parties, aggregators or energy service companies) using typically a public channel (such as the internet) to access consumer premises. Metering services are most commonly provided by the distribution system operator (DSO) that also operates the advanced metering infrastructure (AMI) using a dedicated channel to consumer premises (regulated channel). This channel is used by one party and includes the smart meter. In some countries (such as the UK) the two channels are combined in one physical channel that is operated by a neutral Data Communication Company.

The consumer energy management system controls and monitors the smart appliances and communicates with the suppliers of the energy services.

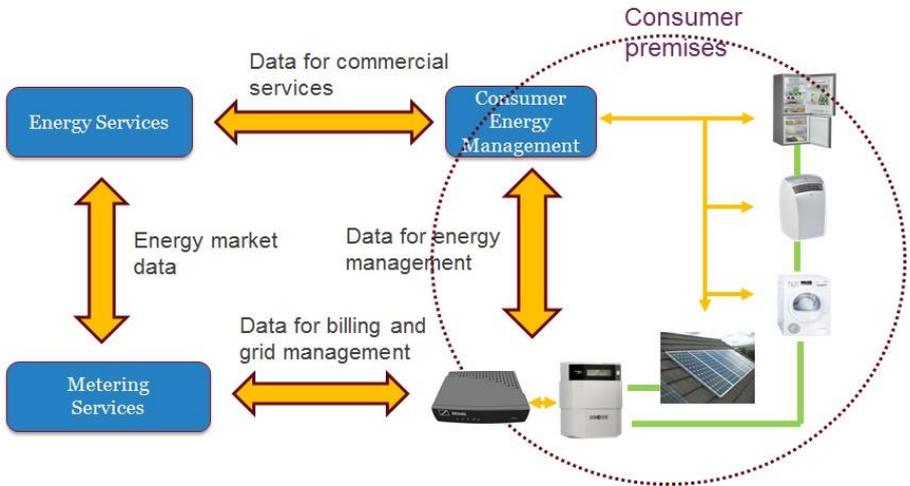


Figure 1-1 Overview of DSF interfaces

Consumers can offer flexibility with smart appliances such as heat pumps, smart refrigerators, smart washing machines or electric cars. The Consumer Energy Management (CEM) system, that can be located within the consumer premises or in a “cloud application”, controls the smart appliances by harmonising all the information from the smart appliances, the requests for flexibility from the grid operators or Energy Service Companies, and the comfort level set by the consumer.

⁶ One or more commercial companies offering an energy related service to consumers, also referred to as Energy Service Company (ESCO).

The activities of the consumer in the DSF process are, for example, to enable a smart washing machine for flexibility control, increase or decrease the in-home temperature, and set the electric vehicle to be fully loaded at a specific time. In case of unbalances in the network, the grid operator can request for flexibility on the market place or directly intervene in the normal operation by sending an 'Emergency signal' via the AMI.

What happens in the DSF infrastructure in case of one of these triggers? Suppose the consumer enables the washing machine to start washing in the afternoon, with the constraint that it needs to be finished not later than the day after morning at 10. The smart washing machine sends this information to the CEM including the forecasted demand-profile applicable to the washing-program selected by the consumer. The CEM also receives the time-of-use tariff profile from the Energy Service Company. From this information, the CEM derives the optimal starting-time of the smart washing machine to reduce consumer energy cost as much as possible and sends a start command to the appliance.

When at a certain moment, a DSO experiences generation shortage or network overload and requires flexibility in the next few hours, they can request for flexibility at the Energy Service Company, who can send a decrease consumption request to the CEM, or set a power limit in the smart meter which is forwarded to the CEM via the AMI.

1.4. Scope

The scope of the study is residential consumers because we focus on smart appliances and the use of SAREF for DSF. The SAREF study also studied residential consumers instead of industrial or commercial consumers. The use of storage in residential homes is out of scope for this study, as use cases and data definitions are being developed and therefore are considered not mature yet.

The study covers the data standards for the interfaces between applications shown in [Figure 1-1](#). The upper horizontal channel is mainly used for commercial consumer-focused energy services and operations (including demand response). Regulated smart grid communications/operations typically use the metering channel, shown in the lower half of the diagram. In most Member States, the metering channel is operated by the Distribution System Operator. This channel is excluded from this study, because the data standards in this domain have been developed and aligned by the utility industry for electricity meters (CENELEC TC13) and Gas/Water/Heat Meters (CEN TC294).

A relevant interface is the connection between the metering infrastructure (AMI, lower horizontal part in [Figure 1-1](#)) and the commercial infrastructure (upper horizontal part in [Figure 1-1](#)) because this interface connects the regulated domain with commercial applications. Commercial applications need to have an open, standards based connection, so that end users can acquire these applications anytime and anywhere after the implementation of the AMI.

The use cases and data standards considered in this study cover all kind of DSF applications and the use of flexibility from smart appliances, heating/cooling devices, lighting and EV charging.

1.5. Approach

To reach the objectives as described in Section 1.2, the DSF study is structured in the following way.

The first step was to create insight in the exchange of data needed for the operation of DSF using the interfaces shown in [Figure 1-1](#). This was done by making an inventory of use cases that focus on data

exchange for DSF. The objective was to assure focus on the right data elements for DSF throughout the study. Various Technical Committees of SDOs have identified use cases to be used as input for defining data communication standards. Since the objective of this study is to reach interoperability using official and international standards, the first step focused on use cases specified by technical SDO Documents for DSF and their related data elements.

The second step was to identify existing data Standards developed by SDOs for implementation of DSF to provide the current state of standardisation for DSF. There are several data standards developed by various organisations in both the utility and the IoT sectors. The Invitation to Tender of the EC already listed SAREF and oneM2M among the standards to be considered. Criteria used to further populate the list of relevant standards includes whether candidate standards are official standards specified by SDOs (such as CEN, CENELEC, ETSI, IEC, etc.) or industry alliances active in the DSF infrastructure (such as EEBUS, Energy@Home, OpenADR, etc.), but most importantly whether these standards are widely adopted in practice by the industry. The identification of standards was used to assess whether the identified standards cover the main data elements associated to the use cases selected in step one.

The third step was to identify and elaborate on the data elements alignments needed among standards in the short list. The underlying idea is that these standards can become interoperable if the data elements that they contain are aligned.

When alignment needs are discovered, actions are recommended to solve the misalignments. The SAREF ontology plays an important role in these alignments, as it can be used as a tool to link data elements originating from different standards in the DSF landscape.

Through a workshop, relevant stakeholders were informed about the study and its status. The objective of the workshop was to check whether all relevant use cases and standards for DSF are covered.

Finally, solutions providers from the telecom, utility and smart appliances industries demonstrated the implementation of a few use cases and its related data alignments at the European Utility Week conference and exhibition, October 2017 in Amsterdam. This demonstration served as a “Proof of Concept” of an integrated DSF infrastructure and the use of SAREF as enabler of interoperability among standards specified by different standards organisations.

2. Use Cases and Data Elements

2.1 Objective

This section presents the results of the identification of use cases and data elements task, whose objective is to identify a set of existing, relevant use cases for DSF and their associated data elements. The resulting set of data elements is used to assess whether the standards identified in the subsequent task (i.e., state of standardisation for DSF analysis), sufficiently cover the use cases of interest for this study. The use cases and associated data elements have been identified from technical reports developed by SDOs.

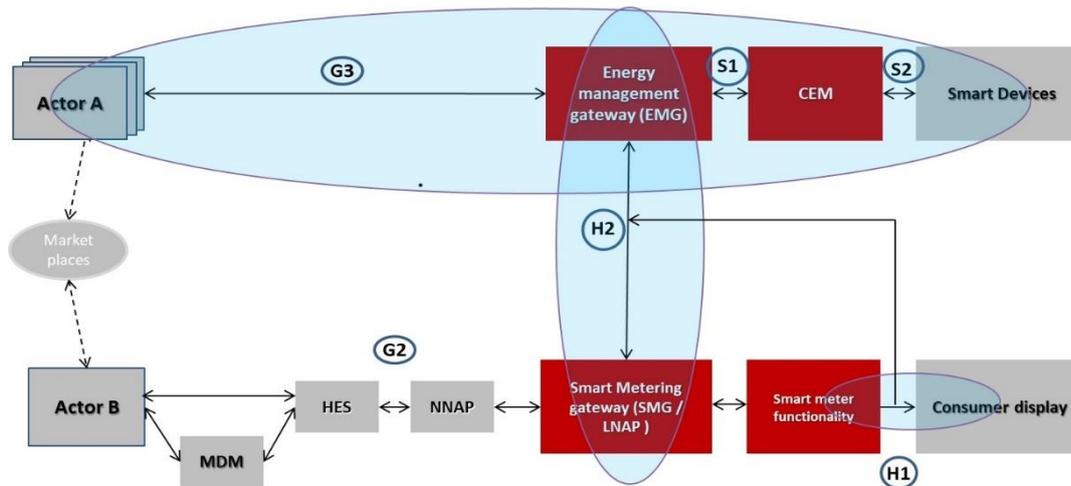


Figure 2-1: DSF architecture and its interfaces

Figure 2-1 provides a technical representation of the high-level DSF data flow previously shown in Figure 1-1. This technical representation shows:

- the upper channel, which consists of the systems and interfaces of the commercial domain from Actor A (i.e., the Energy Services Company) to the smart appliances, located in the home; and
- the lower channel, which consists of the systems and interfaces of the regulated domain from Actor B (i.e., the Metering Services Company) to the smart meter.

In the lower channel (in the regulated domain) typical systems and devices used are: Meter Data Management (MDM), Head End System (HES) that collects the meter data on regular intervals, Neighbourhood Network Access point (NNAP) that collects data on neighbourhood level (also referred to as Data Concentrator), Smart Meter Gateway (or Local network Access Point) and the Smart Meter. The Consumer Energy Management system (CEM) monitors and controls local Demand Side Flexibility by having a direct interface with smart appliances, local storage and generation sources.

Please note that this architecture is functional: functions can be combined in one device and some functions (such as NNAP, LNAP) are optional.

This study focuses on interfaces G3, S1, S2, H1 and H2. The interfaces G3, S1 and S2 are in the commercial domain where several different standards exist that need to become interoperable for the information to flow seamlessly through the end-to-end DSF data flow. The H2 and H1 interfaces

are in scope as they interact with the commercial domain; directly in case of the H2 interface, and indirectly (via the consumer) in case of the H1 interface. These H interfaces are important because they connect the metering infrastructure in the regulated domain with the commercial infrastructure.

The G3 interface represents a Wide Area Network that is used by Actor A (Energy Services Company) to connect to the consumer. Often, this is the Internet. Standards positioned in this interface are usually developed by the telecom industry.

The H1 interface provides a connection to the smart meter, in most cases used to connect an In-Home-Display (IHD) for consumers to get consumption data. H2 is an important interface connecting the AMI (smart grid component) with commercial applications. Interoperability on this interface is therefore key for the market development of DSF applications. The standards for these interfaces are originating from both the utility and Home Automation industries.

The CEM interfaces S1 and S2 are developed and standardized by the Home Automation industry specifically.

2.2 Approach

European standardisation organisations and international standard development organisations are continuously working on so called ‘technical reports’ in which use cases, and technical requirements are being described. Relevant standardisation organisations in the scope of this study are Comité Européen de Normalisation (CEN), Comité Européen de Normalisation Electro technique (CENELEC) and European Telecommunications Standards Institute (ETSI). The international standard development organisation that fits the scope of this study is the International Electrotechnical Commission (IEC). IEC and CENELEC are working together to facilitate a consensus-finding process between European and international standards development activities in the electrical sector.

These standardisation organisations have collected existing use cases and/or developed use cases for evaluating or defining their communication standards. Their technical reports can therefore be considered as a fair representation of the existing use cases for this study. The first step in the approach was to put together a long list of use cases from the technical reports from the mentioned standardisation organisations.

The second step was to create a short list of use cases that can be used as representative to further proceed with the study. The short list has been selected based on the following criteria:

1. The data exchange resulting from the use case should not cover a single interface, but multiple interfaces in [Figure 2-1](#). This criterion makes sure that the use cases are relevant for the mapping of data elements from different standards via the SAREF ontology (i.e., if only one interface was involved, there would not be an interoperability issue, as only one standard could be used for the data exchange). Note that this criterion can also be satisfied by grouping use cases that individually involve one interface, into a more complex use case that involves the combination of individual interfaces.
2. The description of the use case should be detailed enough to identify data elements. If the use case description is too general, the data elements cannot be identified and thus it is not possible

to link the use cases to the data standards for DSF considered in the state of standardization analysis of task 2.

3. The use case should involve smart appliances in consumer homes.

The third step was to identify the data elements that are exchanged through the interfaces in [Figure 2-1](#) for the short-listed use cases.

Finally, a sanity check has been performed to secure that the selected use cases sufficiently cover the field of DSF. The sanity check is done leveraging the extensive knowledge of the study team regarding the work of the Universal Smart Energy Framework (USEF) foundation, which has described the interaction between energy companies (Actor A in [Figure 2-1](#)), consumers and smart appliances. The use cases should cover all major functionalities described by USEF.

2.3 Technical analysis

2.3.1 Long-list of use cases

The first step in composing a long list of uses cases is to identify officially and internationally recognized use cases regarding the DSF flow. As mentioned in the approach CEN, CENELEC, ETSI and IEC are recognized as official organisations that have been active in the field of DSF, working on technical reports in which use cases have been described, relevant to the scope of this study. The technical reports that are considered relevant for this study are:

- **IEC/TR 62746-2:2015**; *Systems interface between customer energy management system and the power management system – Part 2: Use cases and requirements*;
- **IEC/TS 62913-2-3 ED1**; *Generic Smart Grid Requirements - Part 2-3: Domains - Resources connected to the grid related domains, these include Bulk Generation, Distributed Energy Resources, Smart Home / Commercial / Industrial / DR-Customer Energy Management, and Energy Storage*;
- **prEN 50631-1**; *Household appliances network and grid connectivity - Part 1: General Requirements, Generic Data Modelling and Neutral Messages*;
- **ETSI TR 103 411 V1.1.1**; *Smart M2M; Smart Appliances, SAREF extension investigation*.

These technical reports have a broader scope than just DSF, such as “metering” or “energy management”. The focus has been on the parts of these data standards that can be used for DSF.

Assessment technical reports

DNV GL has assessed these technical reports on the described use cases applicable for the DSF domain and its associated data elements. The following observations have been made:

IEC/TR 62746-2:2015 The document contains a large set of use cases that in most cases involve Smart Devices in the consumer home. The level of detail and the use of sequence diagrams, make this document very useful for this study. The data elements used on several interfaces can be derived in a straightforward way from the sequence diagrams.

IEC/TS 62913-2-3 The use cases are described generic and data elements are not explicitly mentioned like in IEC/TR 62746-2:2015. In section A.2 it is shown that all use

ED1 cases from the DSF domain are linked to one or multiple use cases in document IEC/TR 62746-2:2015, meaning that this document does not provide new uses cases in addition to the ones found in IEC/TR 62746-2:2015.

prEN 50631-1 All use cases in this document refer to the use cases from IEC/TR 62746-2:2015 (see section 5.1 of *prEN 50631-1*), meaning that this document does not provide new uses cases in addition to the ones found in IEC/TR 62746-2:2015.

ETSI TR 103 411 V1.1.1 The use cases in this document were based on the use cases from IEC/TR 62746-2:2015 (see text on page 14 of the technical report), except for use case 1 (Device Registration & Configuration) which is not present in IEC/TR 62746-2:2015.

Based on these observations it can be concluded that technical report IEC/TR 62746-2:2015 should be considered as the main contributor of use cases and associated data elements.

The long list of use cases selected for this study is composed by collecting use cases from each of the four technical reports. The long list is presented in Appendix A, where for each technical report a table is included with the reference to the use case description used in the technical report.

2.3.2 Selection of use cases

Short-listing the identified use cases from the long list has resulted in a selection of ten use cases. The use cases have been selected based on the criteria as mentioned in the approach (section 2.2). Appendix A elaborates in more detail on the rationale behind the selection process. Table 2-2 presents the short-listed use cases.

Table 2-2: Selected use cases

#	Name	Description
1	Device Registration & Configuration	<p>Before a smart device can be used in DSF, it needs to be incorporated in the system.</p> <p>The new smart device must become visible to the CEM to be added to the list of products to manage. During the registration process, the new smart device must provide its ID and capabilities to CEM so that it can be properly configured.</p> <p>Actor A may also use this use case to register all local CEMs, as they need to register flexibility potential of all their customers.</p>
2	Flexible start of Smart Device	<p>In some cases, smart devices provide flexibility towards their operation time. The device can manage its flexible running times by itself and communicates them to the CEM. Flexible running times also depend on ‘profiles’ selected by the consumer.</p> <p>Optimal time slots for operation can be recalculated because of external information, like price information received by the CEM from the Energy Supplier.</p>
3	Response of Smart Home to	<p>The grid is close to a black-out and will soon have to cut off sections of the grid. As a means of preventing this by limiting the overall energy consumption to a certain</p>

#	Name	Description
	Emergency	minimum, the grid sends an emergency message to all connected CEMs. The CEM informs the Smart Devices. A notification is provided to the consumer.
4	Control of non-smart Device by CEM, based on pre-set tariff threshold (set by user) and actual tariff	This use case deals with the control of a domestic heat pump or other non-smart controller by a CEM system based upon real time tariff (price) information received from the Energy Supplier. The EMS requests the controller to either turn on/increase operation power or turn off/decrease operating power depending upon both real time price information received from the Energy supplier and a price threshold set by the consumer. By doing so, a 'non-smart' device is operated smart.
5	Direct Load Control of Smart Device via CEM	Demand Side Management messages are sent to the CEM to trigger a program that manages load by interacting with several in home smart devices connected to the CEM.
6	Demand-supply adjustment by cooperation between supplier and customer	This use case is intended to achieve lower total energy cost by means of cooperation between more than one consumer and an energy supplier. Every consumer makes a profile of energy consumption regarding initial information on prices from the energy supplier. The energy supplier aggregates a profile of energy consumption.
7	Exchanging information on (partial) consumption	The Smart Devices send consumption information to the CEM. The CEM sends the information to the energy Supplier. Consumption information can be partial consumption or total consumption. Consumption information can be actual or forecasted consumption. Actual consumption can also be send by the Smart Meter.
8	External Actor Retrieves status of smart devices	This use case describes how an external actor retrieves the state of a smart device directly from the CEM. In case of a remote controllable smart device is connected to the CEM, the CEM asks status information to individual remote controllable devices. The status information gives e.g. insight in the available flexibility.
9	CEM requests time from Smart Meter GW and Smart Meter GW synchronizes time of CEM	Since the CEM can manage local consumption / generation based on flexible tariffs while the billing will take place on information in the smart meter, both the smart meter and the CEM need to have the same tariff schedule and need to know when a new tariff applies. This can be achieved by time synchronisation between the CEM and the smart meter.
10	Smart Meter GW notifies actual tariff to CEM	Since the CEM can manage local consumption / generation based on flexible tariffs while the billing will take place on information in the smart meter, both the smart meter and the CEM need to have the same tariff schedule and need to know when a new tariff applies. This can be achieved by tariff change notification by the smart meter towards the CEM.

Several of the short-listed use cases have been assembled from multiple use cases. As described in the approach, one use case may not comply with the criteria, however, when grouped with other use cases, together they can form a use case that does comply with the criteria.

Use case 2 is an example of a grouped use case. As you can see in Appendix A, the first five use cases from technical report IEC/TR 62746 do not all cover multiple interfaces (criterion 1), however combined into one use case, a quite sophisticated use case appears that does cover multiple interfaces.

The five use cases from technical report IEC/TR 62746 are:

- Flexible start of a Smart Device
- Smart Device informs CEM about flexible start
- CEM informs Smart Device about starting time
- CEM informs SD about slot shift
- Control of Smart appliances based on price information by time slot

These individual use cases have been grouped into *Flexible Start of Smart Device*. The data elements corresponding with the five individual use cases are all integrated in the grouped use case, thus creating one general but at the same time detailed use case, covering all aspects of, in this specific case, the flexible start of smart devices.

In the same way use cases 3, 4, 7 and 8 have been grouped as well. We refer to Appendix A for more details.

Recommendation

During the analysis, we found a use case regarding Power Limitation to be missing in the technical reports. Therefore, we recommend the following:

A common smart meter use case is Power Limitation, in which a power limit is set into the smart meter via Actor B (the DSO). The CEM can use this power limit, together with the actual power consumption of smart devices, to control the power consumption of individual smart devices. However, the technical reports selected for this study do not mention this specific use case. It is recommended that this use case is being developed with the data elements power limit and actual power consumption.

2.3.3 Data elements

From the short-listed use cases, the data elements that are associated with these use cases have been identified and are presented in Table 2-3, positioning them with respect to the corresponding interfaces (G3, S1, S2, H1 and H2) from Figure 2-1.

The data elements are derived from the use cases descriptions provided in the technical reports. For use cases that are only described in one technical report, that description is used as source to extract the associated data elements. For use cases described in more than one document, the description from IEC/TR 62746-2:2015 is used, as this technical report explicitly provides definitions of data elements associated to its use cases.

Table 2-3: Selected use cases and involved interfaces and data-elements

#	Use case	Involved interfaces	Identified data elements
1	Device Registration & Configuration	S1, S2, G3	<ul style="list-style-type: none"> - Device Identifier - Device capabilities
2	Flexible start of Smart Device	G3, S1, S2, H2	<ul style="list-style-type: none"> - Control parameters, e.g. profile selection - Preferred time slot of operation per Device - Flex start enabled - Energy consumption - Energy Profile - Start time/ time slot of operation - New tariff information - Recalculated start time / time slot - Operation commands
3	Response of Smart Home to Emergency	S1, S2, H2	<ul style="list-style-type: none"> - Emergency signal - Emergency load command
4	Control of non-smart Device by CEM, based on pre-set tariff threshold (set by user) and actual tariff	G3, S1, S2	<ul style="list-style-type: none"> - Tariff threshold - Real Time Tariff - operation commands (increase or decrease power and turn off/on)
5	Direct Load Control of Smart Device via CEM	G3, S1, S2	<ul style="list-style-type: none"> - Id of participating devices - Power thresholds - Load management signal - Load adjustment command - Feedback about adjustment - Expected change in consumption
6	Demand-supply adjustment by cooperation between supplier and customer	G3, S1, S2	<ul style="list-style-type: none"> - Price information of electrical energy based on time of use (TOU) - Planned load profile (expected consumption in time)
7	Exchanging information on (partial) consumption	G3, S1, S2, H2, H1	<ul style="list-style-type: none"> - Actual Individual Appliances (= partial) consumption/generation - Forecasted partial consumption/generation - Actual total house consumption - Forecasted total house consumption
8	External Actor Retrieves status of smart devices	G3, S1, S2	<ul style="list-style-type: none"> - Device Status Request - Device Status - Status is displayed to consumer
9	CEM requests time from Smart Meter GW and Smart Meter GW synchronizes time of CEM	S1, H2	<ul style="list-style-type: none"> - Actual time request - Actual time

#	Use case	Involved interfaces	Identified data elements
10	Smart Meter GW notifies actual tariff to CEM	S1, H2	- Active tariff notification

2.3.4 Sanity check

In this section a final assessment, or “sanity check”, is performed to evaluate whether the short-listed use cases sufficiently cover the field of DSF, checking the risk that important use cases are missing.

The sanity check is performed based on the work of the Universal Smart Energy Framework (USEF) foundation⁷. USEF is created by and applicable in multiple Member States, its applicability is not limited by location or technology. Compared to similar market models USEF describes the interaction within the DSF flow comprehensively; the interaction between a market actor (energy company or consumer) and the smart appliances. For these reasons USEF is well suited for performing the sanity check.

According to USEF, actor A (from figure 2.1) can be covered by multiple roles; an energy supplier, an aggregator, a distribution operator (DSO) or a transmission operator (TSO). USEF identifies main functionalities for each role. The sanity check is performed by checking if:

- all roles that Actor A could assume are covered;
- all main functionalities are covered;

Main functionality of the supplier:

- *Providing price signals*; the information exchange between the supplier and the home is limited to price signals. Based on these price signals, the consumer can choose to adapt its behaviour (through automation, personal choices or manual interventions) to save on energy expenses.

Main functionalities of the aggregator:

- *(De)Commissioning*; prior to operation devices need to be configured and registered. When taken out of operation, decommissioning is required. The devices need to be known by the CEM (interface S2), but also by Actor A (interface G3).
- *Maintenance*; devices may require maintenance, such as software updates.
- *Monitoring*; the aggregator communicates with the devices to understand the flexibility that is available and thus can be offered. The aggregator for instance needs to monitor the status and consumption of the devices to be able to offer, request and schedule flexibility.

⁷ USEF, *the framework explained*, USEF, Nov 2015; USEF, *the framework specifications*, USEF, Nov 2015; *Recommended practices and key considerations for a regulatory framework and market design on explicit Demand Response*, USEF, Nov 2016

- *Scheduled activation*; the aggregator needs control elements to be able to dispatch the exact amount of energy or power required. The aggregator needs to be able to schedule a device to start or stop consuming or producing.
- *Instantaneous activation*; the aggregator needs control elements to be able to dispatch the exact amount of energy or power required. The aggregator needs to be able to immediately activate a device to start or stop consuming or producing.
- *In-home optimization*: the aggregator can offer a proposition to optimize the prosumers flexibility profile to optimize its savings or earnings. Based on price signals and status of devices each individual profile can be optimized.

Main functionality of the operator:

- *Instantaneous activation*; In exceptional situations where the market is not able to maintain the grid load within acceptable limits, the distribution operator temporarily overrules the market to prevent a complete power outage. The DSO can differentiate its connection conditions, thereby providing different levels of reliability to different types of connections. These conditions establish connection priorities, enabling the DSO to differentiate between clients who critically depend on energy (such as nursing homes) and connections where a service interruption has a lesser impact (such as public charging stations for electric vehicles). As soon as the system restores itself, the market can take over again.

Mapping use cases to functionalities

In the table below the short-listed use cases are mapped in the main functionalities.

Table 2-4: Mapping of selected use cases on the actors' functionalities

Actor A	Main functionality	Use Case
Supplier	Provide price signals	6 - Demand-supply adjustment by cooperation between supplier and customer 10 - Smart Meter GW notifies actual tariff to CEM
Aggregator	(De)Commissioning	1 - Device Registration & configuration
	Maintenance	No use case mapped
	Monitoring	7 – Exchanging information within the home 8 - External Actor Retrieves status
	Scheduled activation	2 - Flexible start of Smart Device 9 - CEM requests time from Smart Meter GW
	Instantaneous activation	5 - Load Control of Smart Device by CEM.
	In-home optimization	4 - Control of Smart Device by CEM
DSO / TSO	Instantaneous activation	3 - Response of Smart Home to Emergency

Mapping use cases on supplier functionality

There are three paths the information on energy price can follow:

- G3 – S1 - S2: Through the deregulated infrastructure to the flexibility resources
This may trigger an automated response. This is covered by use case 6.
- G2 – H2 – S1 – S2: Through the smart meter gateway to the flexibility resources
This may trigger an automated response. This is covered by use case 10.
- G2 – H1: Through the smart meter gateway to the in-home display
This may trigger a manual intervention. This is not covered by the use cases, and not taken in account in the study, since it concerns only one interface in the scope of the study and therefore alignment is not needed.

It can be concluded that the main functionality, providing the home with tariff information, is included in the use cases. Two paths can be followed, either through the deregulated infrastructure, or through the smart meter infrastructure.

Mapping use cases on aggregator functionality

The main functionalities as described can be mapped as follows:

- (De)Commissioning is covered by use case 1
Use case 1 describes the commissioning of a smart appliance. Decommissioning is not described.
- Maintenance is not covered by any use case
There is no use case mapped on the maintenance functionality. We have found that maintenance functions are not yet covered by international standards.
- Monitoring is covered by use case 7 and 8
Use cases 7 and 8 describe all relevant elements of the monitoring process.
- Scheduled activation is covered by use case 2 and 9
If there is time between the notification and the activation of the flexibility within an energy market or product, the aggregator can apply a scheduled activation. This is sufficiently covered by use case 2. Internal clocks need to be synchronized for this functionality and therefore use case 9 can be mapped here as well. However, use case 9 is an operational functionality that can also be mapped on other functionalities such as monitoring, and in-home optimization.
- Instantaneous activation is covered by use case 5
If there is no time between the notification and the activation of the flexibility within an energy market or product, the aggregator must apply an instantaneous activation. This is sufficiently covered by use case 5.
- In-home optimization is covered by use case 4
Although the ESCo is the more logical role to facilitate in-home optimization (which does

not create value for an Aggregator), USEF recognizes that in-home optimization may create value for the Prosumer/customer. This is covered by use case 4.

It can be concluded that the use cases sufficiently cover the monitoring and control activities of the aggregator in all relevant markets and products. Decommissioning is not covered.

Mapping use cases on operator functionality

The most obvious technology a DSO can apply is the switch in the smart meter, if installed. Also, the DSO can temporarily define a threshold on the capacity. When this threshold is exceeded, the switch will be triggered. If the HEMS is informed about the level of the threshold, it can ensure (by using the available flexibility) that the total consumption does not exceed the threshold. This functionality is covered by use case 3.

Since this is limited to emergency situations, the functionality is also rather limited. This is fully covered by use case 3.

Conclusion of the sanity check

From the analysis, it can be concluded that the short-listed use cases;

- Cover all roles that Actor A could assume;
- Cover all main functional decompositions that USEF describes;

2.4 Results

Ten use cases and their associated data elements are identified as relevant for further use in the project. These uses cases are selected from the work done by relevant Standard Development Organizations (SDO) such as the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC), the European Telecommunications Standards Institute (ETSI) and International Electrotechnical Commission (IEC).

The selected use cases are identified as a good fit with the scope of Demand Side Flexibility. The scope of the selected use cases has been verified with the scope of the Universal Smart Energy Framework (USEF). It has been concluded that the scope of the selected use cases fits the relevant functionalities described by USEF.

The selected use cases and its associated data elements are presented in the table below.

Table 2-5: Selected use cases and the associated data elements

Use case	Description	Data elements
Device Registration & Configuration	<p>Before a smart device can be used in DSF, it needs to be incorporated in the system.</p> <p>The new smart device must become visible to the CEM to be added to the list of products to manage. During the registration process, the new smart device must provide its ID and capabilities to CEM so that it can be properly configured.</p>	<ul style="list-style-type: none"> - Device Identifier - Device capabilities

Use case	Description	Data elements
	Actor A may also use this use case to register all local CEMs, as they need to register flexibility potential of all their customers.	
Flexible start of Smart Device	<p>In some cases, smart devices provide flexibility towards their operation time. The device can manage its flexible running times by itself and communicates them to the CEM. Flexible running times also depend on 'profiles' selected by the consumer.</p> <p>Optimal time slots for operation can be recalculated because of external information, like price information received by the CEM from the Energy Supplier.</p>	<ul style="list-style-type: none"> - Control parameters, e.g. profile selection - Preferred time slot of operation per Device - Flex start enabled - Energy consumption - Energy Profile - Start time/ time slot of operation - New tariff information - Recalculated start time / time slot - Operation commands
Response of Smart Home to Emergency	The grid is close to a black-out and will soon have to cut off sections of the grid. As a means of preventing this by limiting the overall energy consumption to a certain minimum, the grid sends an emergency message to all connected CEMs. The CEM informs the Smart Devices. A notification is provided to the consumer.	<ul style="list-style-type: none"> - Emergency signal - Emergency load command
Control of non-smart Device by CEM, based on pre-set tariff threshold (set by user) and actual tariff	This use case deals with the control of a domestic heat pump or other non-smart controller by a CEM system based upon real time tariff (price) information received from the Energy Supplier. The EMS requests the controller to either turn on/increase operation power or turn off/decrease operating power depending upon both real time price information received from the Energy supplier and a price threshold set by the consumer. By doing so, a 'non-smart' device is operated smart.	<ul style="list-style-type: none"> - Tariff threshold - Real Time Tariff - Operation commands (increase or decrease power and turn off/on)
Direct Load Control of Smart Device via CEM	Demand Side Management messages are sent to the CEM to trigger a program that manages load by interacting with several in home smart devices connected to the CEM.	<ul style="list-style-type: none"> - Id of participating devices - Power thresholds - Load management signal - Load adjustment command - Feedback about adjustment - Expected change in consumption
Demand-supply adjustment by cooperation between	This use case is indented to achieve lower total energy cost by means of cooperation between more than one consumer and an energy	<ul style="list-style-type: none"> - Price information of electrical energy based on time of use (TOU) - Planned load profile

Use case	Description	Data elements
supplier and customer	supplier. Every consumer makes a profile of energy consumption regarding initial information on prices from the energy supplier. The energy supplier aggregates a profile of energy consumption.	(expected consumption in time)
Exchanging information on (partial) consumption	The Smart Devices send consumption information to the CEM. The CEM sends the information to the energy Supplier. Consumption information can be partial consumption or total consumption. Consumption information can be actual or forecasted consumption. Actual consumption can also be send by the Smart Meter.	<ul style="list-style-type: none"> - Actual Individual Appliances (= partial) consumption/generation - Forecasted partial consumption/generation - Actual total house consumption - Forecasted total house consumption
External Actor Retrieves status of smart devices	This use case describes how an external actor retrieves the state of a smart device directly from the CEM. In case of a remote controllable smart device is connected to the CEM, the CEM asks status information to individual remote controllable devices. The status information gives e.g. insight in the available flexibility.	<ul style="list-style-type: none"> - Device Status Request - Device Status - Status is displayed to consumer
CEM requests time from Smart Meter GW and Smart Meter GW synchronizes time of CEM	Since the CEM can manage local consumption / generation based on flexible tariffs while the billing will take place on information in the smart meter, both the smart meter and the CEM need to have the same tariff schedule and need to know when a new tariff applies. This can be achieved by time synchronisation between the CEM and the smart meter.	<ul style="list-style-type: none"> - Actual time request - Actual time
Smart Meter GW notifies actual tariff to CEM	Since the CEM can manage local consumption / generation based on flexible tariffs while the billing will take place on information in the smart meter, both the smart meter and the CEM need to have the same tariff schedule and need to know when a new tariff applies. This can be achieved by tariff change notification by the smart meter towards the CEM.	<ul style="list-style-type: none"> - Active tariff notification

3. State of Standardisation

3.1 Objective

The main problem addressed in the DSF study is that a multitude of data communication standards exist in the end-to-end DSF flow, which are not semantically aligned. Therefore, after identifying the most relevant use cases and associated data elements, it was relevant to take stock of the existing standards that cover these data elements.

The underlying assumption was that if the data elements specified by the DSF standards are aligned, then the information exchanged in the use cases under consideration can seamlessly flow through the different interfaces between smart appliances, consumer energy management system, energy management gateway, energy services, smart meter gateway and smart meters (see Figure 2-1). Therefore, an important part of our state of standardization analysis was to elaborate on the data elements defined by different standards, as a basis for further alignment.

To guarantee that the standards identified in Section 3 cover the data elements of interest for the use cases in this study, it was assessed whether their data elements match the data elements identified in the use case analysis in Section 2.

The main objectives of our state of standardisation analysis can be summarized as follows:

- Identify existing standards developed by SDOs for implementation of DSF;
- Assess whether the identified standards cover the main data elements exchanged in the DSF flow, as described by the use cases in Section 2, by using SAREF and SAREF4ENER as a common mapping tool.

3.2 Approach

As a first step, a long list of relevant standards has been identified to clarify which existing standards are relevant for DSF, based on the following Long List (LL) criteria:

- Criterion LL1: The standard should be applicable for (residential) Home Energy Management/DSF and cover (one or more of) the interfaces relevant for the study between smart appliances, smart meters, consumer energy management system, energy management gateway, smart meter gateway, energy services and metering services (see Figure 2-1);
- Criterion LL2: The standard should be widely adopted by the industry and used in practice. Preferably, the standard is officially published by SDOs (e.g., ISO, IEC, CEN/CENELEC, ETSI, etc.) or planned to be. However, also “de facto” standards used in practice by the industry can be included, if no official standard exists.

Regarding the identification of existing standards developed by SDOs for implementation of DSF, the Invitation to Tender of the EC already listed SAREF and oneM2M among the standards to be considered. The long list was further populated using the criteria mentioned above and leveraging the comprehensive knowledge of the DSF study’s team members concerning the DSF standardisation

landscape. In addition, the input provided by the EC⁸ and industry stakeholders involved in European research projects⁹ was considered.

To present the identified standards in a consistent and systematic way and provide the reader with a structured and easy to read overview of the state of standardisation for DSF, a common template to describe each standard in the long list was adopted, as it was done in the previous SAREF study [4]. The template consists of the following fields:

- Acronym/Full Name;
- Issuing Organisation;
- Most relevant URL/ precise references;
- Overall description;
- Description of semantic coverage and main data elements; and
- Interface covered in the end-to-end DSF flow.

The second step was to narrow down the long list to a short list of representative standards to be used in the rest of the study to further investigate the alignment of DSF standards¹⁰. The short list has been selected based on the following Short List (SL) criteria:

- Criterion SL1: The standard should contain data definitions that allow us to extract data elements. For example, a standard like IEC TR 62746-2 (see Section 3.3.3), although relevant for this study and the interfaces of interest, is about use cases and provides limited input to the identification of data elements for alignments, therefore it is not included in the short list;
- Criterion SL2: The data elements covered by the standard should match (some of) the data elements associated with the use cases in the scope of this study as described in Section 2.3.3;
- Criterion SL3: The standard should be publicly accessible for stakeholders (e.g., via a URL). Industry standards that require one to become a member of an industry group to access them are not considered in this study. Open (i.e., freely available) standards are preferred, as they facilitate accessibility for stakeholders, but this is not a mandatory requirement for inclusion in the short list;
- Criterion SL4: The standard should preferably offer a machine-readable format that facilitates the extraction of data elements and the (automatic) alignment with SAREF concepts (e.g., ontologies in RDF/OWL, XSD schemas, UML diagrams). For example, standards that are only specified as PDF documents may be considered, but they are not preferred, as they entail a lot of manual effort to extract the semantics from text and tables, which is error-prone and may lead to misinterpretations.

The reader should be aware that this short list is not an endorsement by DNV-GL, TNO, ESMIG or the European Commission, nor does it signify anything about the relevance of the standards, nor any

⁸ For example, the database on Smart Grid standardisation developed in the context of the **STARGRID** project (<http://stargrid.eu>). The web interface allows to search for documents (standards and related publications) or institutions (organisations and committees).

⁹ For example, the H2020 **Interflex** project (<http://interflex-h2020.com>).

¹⁰ Note that standards that are not included in our short list can also be aligned by the interested stakeholders following the alignment approach proposed in Section 4.

other commercially valuable qualification. It simply provided a good basis to further proceed with the alignments.

As a third step, a workshop has been conducted in the context of this study on the 19th of June 2017 in Brussels (see Appendix B) to check with relevant stakeholders whether all the relevant standards for DSF were covered by our state of standardisation analysis, and whether the proposed short list was sufficiently representative. As a result, two additional standards have been taken into account, in particular, the KNX specification has been added to the short list (see Section 3.3.2) and the EFI specification to the long list (see Section 3.3.3).

Finally, it has been specifically assessed whether the short-listed standards sufficiently cover the main data elements exchanged in the DSF flow as identified in task 1 (criterion SL2). The assessment was performed by comparing 1) the data elements associated with the main use cases (see Section 2.3.3) with 2) SAREF and SAREF4ENER classes (see Section 3.3.2). It was concluded that SAREF and SAREF4ENER sufficiently cover the main data elements exchanged in the DSF flow and provide a good basis as a “common mapping tool” to the other short-listed standards. The alignment of the short-list standards via SAREF and SAREF4ENER as a common mapping tool is elaborated in Section 4.

3.3 Technical analysis

3.3.1 Long list of standards

A long list of 19 existing standards developed by SDOs for implementation of DSF has been identified according to the approach described in Section 3.2. From this list, a short list of 10 standards suitable to proceed with further alignments has been subsequently selected. The long list of identified standards is given in Table 3-1, followed by a short description of the issuing SDOs and Technical Committees (TCs). The standards highlighted in bold are the short-listed standards. Each short-listed standard is described in detail in Section 3.3.2, while the non-selected standards are described in Section 3.3.3.

Table 3-1: Long list of standards identified in the DSF study

#	Reference/ Issued by	URL
1	CEN EN 13757 (TC 294) Communication systems for meters	https://standards.cen.eu/dyn/www/f?p=204:32:0:::FSP_ORG_ID,FSP_LANG_ID:6275,25&cs=1A1D2A71837AB4AB1532B872DBD554033
2	CEN EN 16836 (TC 294) / ZigBee SEP2 (ZigBee Alliance) Communication systems for meters - Wireless mesh networking for meter data exchange	https://standards.cen.eu/dyn/www/f?p=204:32:0:::FSP_ORG_ID,FSP_LANG_ID:6275,25&cs=1A1D2A71837AB4AB1532B872DBD554033 OR http://www.zigbee.org/about/centc294
3	CENELEC EN 50491-11 (TC 205) General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 11: Smart Metering - Application Specifications - Simple External Consumer Display	https://www.cenelec.eu/dyn/www/f?p=104:110:1686791285416701:::FSP_ORG_ID,FSP_PROJECT,FS_P_LANG_ID:1258281,42730,25
4	CENELEC prEN 50491-12 (TC 205) General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Smart grid	https://www.cenelec.eu/dyn/www/f?p=104:110:1344658983181101:::FSP_ORG_ID,FSP_PROJECT,FS_P_LANG_ID:1258281,63376,25

#	Reference/ Issued by	URL
5	CENELEC prEN 50631-1 (TC59 WG7) Household appliances network and grid connectivity - Part 1: General Requirements, Generic Data Modelling and Neutral Messages	https://www.cenelec.eu/dyn/www/f?p=104:110:1438163728984601:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,47024,25
6	EFI - Energy Flexibility Interface, FAN Alliance (input to prEN 50491-12-2, CLC TC 205 WG18)	https://github.com/flexiblepower/efi
7	ETSI SAREF TS 103 264 (SmartM2M TC) SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping	http://www.etsi.org/deliver/etsi_ts/103200_103299/103264/02.01.01_60/ts_103264v020101p.pdf
8	ETSI SAREF4ENER TS 103 410-1 (SmartM2M TC) SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain	http://www.etsi.org/deliver/etsi_ts/103400_103499/10341001/01.01.01_60/ts_10341001v010101p.pdf
9	ETSI TR 103 411 (SmartM2M TC) SmartM2M; Smart Appliances; SAREF extension investigation	http://www.etsi.org/deliver/etsi_tr/103400_103499/103411/01.01.01_60/tr_103411v010101p.pdf
10	IEC 61968-9 CIM for Metering (TC 57 WG14) Common Information Model (CIM)/ Distribution Management	http://www.iec.ch/smartgrid/standards/
11	IEC 61970-301 CIM Core (TC 57) Common information model (CIM)/Energy Management	http://www.iec.ch/smartgrid/standards/
12	IEC/CENELEC 62056 COSEM (TC 13 WG 14) Electricity metering - Data exchange for meter reading, tariff and load control	https://webstore.iec.ch/publication/34317 OR http://dlms.com/PASSWORD/Books/Blue_Book_1_1th_edition.pdf
13	IEC TR 62746-2 (TC 57 WG21) Systems interface between customer energy management system and the power management system	https://webstore.iec.ch/publication/22279
14	IEC TS 62913-2-3 (TC8 SyC Smart Energy WG6) Generic Smart Grid Requirements	http://www.iec.ch/dyn/www/f?p=103:38:7354931541404:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:11825,23,22240
15	KNX specification for home building and control (KNX Association)/CENELEC EN 50090 (TC 205)	https://my.knx.org/en/shop/knx-specifications
16	oneM2M Functional Architecture TS 0001	http://onem2m.org/technical/published-drafts
17	oneM2M Base Ontology TS 0012 and TS 0030 Ontology based Interworking	http://onem2m.org/technical/published-drafts
18	OpenADR Specification (OpenADR Alliance)	http://www.openadr.org/specification
19	SPINE (Smart Premises Interoperable Neutral-message Exchange) Specification (EEBUS and Energy@home)	https://www.eebus.org/en/downloads/

3.3.1.1 Issuing SDOs and TCs

CEN (<https://www.cen.eu>) is the European Committee for Standardization, one of the three European Standardization Organizations (together with CENELEC and ETSI). CEN supports standardization activities in relation to a wide range of fields and sectors including: air and space, chemicals, construction, consumer products, defense and security, energy, the environment, food

and feed, health and safety, healthcare, ICT, machinery, materials, pressure equipment, services, smart living, transport and packaging. The entire collection of CEN published and under development standards (Work Programme) can be searched online at <https://standards.cen.eu/dyn/www/f?p=CENWEB:105::RESET>

- **TC 294, Communication systems for meters** has the scope to standardize communication interfaces for systems with meters and remote reading of meters for all kind of fluids and energies distributed by network. Cooperation with CENELEC and ETSI for consistent interface definitions is essential condition for achieving interoperability between entities in systems.

CENELEC (<https://www.cenelec.eu/>) is the European Committee for Electrotechnical Standardization and is responsible for standardization in the electrotechnical engineering field. The entire collection of CENELEC published standards and standards under development (Work Programme) can be searched online at http://www.cenelec.eu/dyn/www/f?p=104:105:748461397861594:::FSP_LANG_ID:25

- **TC 59X, Household appliances network and grid connectivity** has the scope to prepare European Standards on methods of measurement of characteristics which are of importance to determine the performance of electrical appliances for household use or of electrical appliances for commercial use and that are of interest for the user. The standards are developed to suit the needs of EU Regulations and Directives and in the context of the European market.
- **TC 205, Home and Building Electronic Systems (HBES)** has the scope to prepare standards for all aspects of home and building electronic systems in relation to the Information Society. The scope is to ensure integration of a wide spectrum of control applications and the control and management aspects of other applications in and around homes and buildings.

ETSI (<http://www.etsi.org/>) is the European Telecommunications Standards Institute, one of the three European Standardization Organizations. ETSI produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, aeronautical, broadcast and internet technologies. The entire collection of ETSI standards can be searched online at <http://www.etsi.org/standards-search>.

- **SmartM2M TC, Smart Machine-to-Machine communications** is responsible for the SAREF standard and its related communication framework based on oneM2M.

IEC (<http://www.iec.ch/>) is the International Electrotechnical Commission, a not-for-profit, quasi-governmental organization that prepares and publishes International Standards for all electrical, electronic and related technologies. The entire collection of IEC publications can be searched online at <https://webstore.iec.ch/>.

- **TC 8, Systems aspects for electrical energy supply** has the scope to prepare and coordinate, in co-operation with other TC/SCs, the development of international standards and other deliverables with emphasis on overall system aspects of electricity supply systems and acceptable balance between cost and quality for the users of electrical energy. Electricity supply system encompasses transmission and distribution networks and connected user installations (generators and loads) with their network interfaces.
- **TC 13, Electrical energy measurement and control** does standardization in the field of a.c. and d.c. electrical energy measurement and control, for smart metering equipment and

systems forming part of smart grids, used in power stations, along the network, and at energy users and producers, as well as to prepare international standards for meter test equipment and methods. Excluded from the work of TC 13 is the standardization for the interface of metering equipment for interconnection lines and industrial consumers and producers (covered by TC 57).

- **WG 14, Data exchange for meter reading, tariff and load control** in TC 13 has the scope to establish standards, by reference to ISO/OSI Standards, necessary for data exchanges by different communication media, for automatic meter reading, tariff and load control, and consumer information. The media can be either distribution line carrier (DLC), telephone (including ISDN), radio or other electrical or optical system and they may be used for local or remote data exchange.
- **TC 57, Power systems management and associated information exchange** has the scope to prepare international standards for power systems control equipment and systems including EMS (Energy Management Systems), SCADA (Supervisory Control And Data Acquisition), distribution automation, tele protection, and associated information exchange for real-time and non-real-time information, used in the planning, operation and maintenance of power systems.
 - **WG 14, System interfaces for distribution management (SIDM)** in TC 57 has the scope to identify and establish requirements for standard interfaces of a Distribution Management System (DMS) based on an interface architecture.
 - **WG 21, Interfaces and protocol profiles relevant to systems connected to the electrical grid** in TC 57 has the scope of identifying use cases which involve systems connected to the electrical grid. The focus is on interaction between power system management (TC 57 standards) and home/building/industrial (H/B/I) energy management systems.

oneM2M (<http://www.oneM2M.org>) is the global standards initiative for Machine to Machine Communications and the Internet of Things. It is a Global Partnership that includes 8 of the world's leading ICT standards bodies, 6 global fora and SDOs, and over 200 companies from all industrial sectors. The purpose and goal of oneM2M is to develop technical specifications that address the need for a common M2M Service Layer that can be readily embedded within various hardware and software, and relied upon to connect the myriad of devices in the field with M2M application servers worldwide. oneM2M published specifications are available for free for download at <http://onem2m.org/technical/published-drafts>.

3.3.2 Short list of standards

The following standards fulfil the criteria described in Section 3.2 and provide a suitable basis to further proceed with data element alignments:

- CEN 16836 (ZigBee SEP2)
- CENELEC EN 50491-11 Smart Metering
- CENELEC EN 50631-1 (SPINE)
- ETSI TS 103 264 (SAREF)
- ETSI TS 103 410-1 (SAREF4ENER)
- IEC 61968-9 CIM for metering
- IEC 61970 CIM

- IEC/CENELEC 62056 COSEM
- CENELEC EN 50090 (KNX)
- oneM2M TS 0012 Base Ontology

3.3.2.1 CEN EN 16836 (ZigBee SEP2)

Standard Acronym and Full Name

EN 16836 “Communication systems for meters - Wireless mesh networking for meter data exchange”

Parts 1 to 3:

- EN 16836-1:2016 “Communication systems for meters - Wireless mesh networking for meter data exchange - Part 1: Introduction and standardization framework”
- EN 16836-2:2016 “Communication systems for meters - Wireless mesh networking for meter data exchange - Part 2: Networking layer and stack specification”
- EN 16836-3:2016 “Communication systems for meters - Wireless mesh networking for meter data exchange - Part 3: Energy profile specification dedicated application layer”

Issuing Organisation/ Technical Committee/ Industry Alliance

CEN, the European Committee for Standardization, TC 294 Communication systems for meters (see Section 3.3.1). CEN TC 294 has a technical liaison agreement with the ZigBee Alliance (<http://www.zigbee.org/>) in order to exchange documents, share knowledge, and report on meetings. There is also a Memorandum Of Understanding (MOU) in place between the organizations under the Consortium Bridge procedure within CEN/CENELEC, which allows CEN and CENELEC to reference published ZigBee documents. This MOU allows CEN to produce an European Norm (EN) standards series referencing ZigBee documents so that the ZigBee Smart Energy standard can effectively be published as an EN standard within the context of CEN TC 294.

Most relevant URLs, and other precise references

The EN 16836 series is publicly available from the TC 294 Work Programme, the download requires credentials (standard to be purchased from CEN National Standardization Bodies (NSBs) for a fee):

- EN 16836-1:2016 Part 1: Introduction and standardization framework
https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:41098&cs=144AD5A86F9C7CD56BC47BB022D48A7DC
- EN 16836-2:2016 Part 2: Networking layer and stack specification
https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:41099&cs=148DC18DC5EF70796F3D6AFC57140D4E1
- EN 16836-3:2016 Part 3: Energy profile specification dedicated application layer
https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:41100&cs=1B059B31255F6A18CCBCF05239A915DB2

The EN 16836 series parts 1 to 3 produced by CEN TC 294 references the following ZigBee documents, which can be freely downloaded at <http://www.zigbee.org/about/centc294> after registration:

- ZigBee Smart Energy Profile Specification Standard – 07-5356 Rev 19, December 3, 2014
- ZigBee Cluster Library – 07-5123 Rev 04, April 26, 2010
- ZigBee OTA Cluster Specification – 09-5264 Rev 23, March 12, 2014

- ZigBee Specification – 05-3474 Rev 20, September 7, 2012
- ZigBee PRO Stack Profile – 07-4855 Rev 05, January 2008

Overall description

The EN 16836 series of standards provides a list of references to ZigBee documents in compliance with the Bridge Consortium and additionally the Memorandum of Understanding between the ZigBee Alliance and CEN/CENELEC. One of these referenced documents is ‘ZigBee Smart Energy Profile Specification Standard – 07-5356 Rev 19, December 3, 2014’, which defines devices and interfaces for Smart Energy applications in residential or light commercial environments, ranging from a single home to an entire apartment complex. A neighbourhood area networks is used for meters, where ZigBee is used for sub-metering within a home or apartment and for communication to devices within the home. Note that for security reasons, a ZigBee Smart Energy network, characterized by higher security, does not interact with a consumer ZigBee Home Area Network, unless explicitly configured.

Description of the semantic coverage and main data elements

Main areas of interest for the ZigBee Smart Energy Profile specification (so-called “clusters” supported by the Energy Service Interface) are Metering, Price, Messaging, Demand Response/Load Control, Time.

Concepts of interest for Metering include:

- Commodities (such as electric, gas, water, and thermal)
- Type of Meters
 - Electric Metering
 - Gas Metering
 - Water Metering
 - Thermal Metering (deprecated)
 - Pressure Metering
 - Heat Metering
 - Cooling Metering
 - End Use Measurement Device (EUMD) for metering electric vehicle charging
 - PV Generation Metering
 - Wind Turbine Generation Metering
 - Water Turbine Generation Metering
 - Micro Generation Metering
 - Solar Hot Water Generation Metering
 - Electric Metering Element/Phase 1
 - Electric Metering Element/Phase 2
 - Electric Metering Element/Phase 3
- Units of measure for international support (such as kWh, kW, Watts, Cubic Meters, Cubic Feet, US Gallons, Imperial Gallons, Liters, etc.)
- Measurement types (such as load profile, power factor, summation, demand, and tiers)
- Real-time information
- Historical information (previous day, today, etc.)
- Status indicators (e.g. battery low, tamper detected)

- Generation (delivered) and consumption (received)

Concepts of interest for Price include:

- Block tariff (inclining/declining rates)
- Prepayment
- Commodities (e.g., electric, gas, water, and thermal)
- Units of measure for international support
- Multiple currencies for international support (using ISO 4217)
- Generated (delivered) and consumed (received) prices

Concepts of interest for Demand Response/Load Control include:

- Events for specific groups of devices, such as HVAC Compressor or Furnace, Strip Heaters/Baseboard Heaters, Water Heater, Pool Pump/Spa/Jacuzzi, Smart Appliances, Irrigation Pump, Managed Commercial & Industrial (C&I) loads, Simple misc. (Residential On/Off) loads, Exterior Lighting, Interior Lighting, Electric Vehicle, Generation Systems.
- Control methods, including temperature set points and offsets, criticality levels (such as emergency signals) and duty cycling. Criticality levels include:
 - Green/ Voluntary (energy delivered uses an abnormal amount from non-“green” sources. Participation in this event is voluntary)
 - Emergency/ Mandatory (participation in “Emergency” event is mandatory and the expected response is termination of all non-essential energy use, as defined by the utility)
 - Planned Outage/ Mandatory (participation in “Planned Outage” event is mandatory and the expected response is termination of delivery of all non-essential energy, as defined by the utility)
 - Service Disconnect/ Mandatory (participation in “Service Disconnect” event is mandatory and the expected response is termination of delivery of all non-essential energy, as defined by the utility)
 - Utility Defined
- Start and end times to avoid spikes

Devices defined in the ZigBee Smart Energy Profile specification include:

- Metering Device, i.e., meters (electricity, gas, water, heat, etc.) that can provide immediate readings (requested) or periodical readings (sent autonomously). They may also communicate status indicators (e.g. battery low, tamper detected). Supported cluster (mandatory): Metering.
- In-Home Display Device, i.e., graphical or text displays to show energy consumption data to the user (not necessarily with an interactive interface). Data to be displayed consists of current energy usage, a history over selectable periods, pricing information, or text messages. Also show critical pricing information may be shown to advise the customer when peaks are due to occur so that appropriate action can be taken.
- Programmable Communicating Thermostat (PCT) Device to control the premises heating and cooling systems. Supported cluster (mandatory): Demand Response/Load Control.

- Load Control Device, i.e., devices such as water heaters, exterior lighting, and pool pumps that can receive Demand Response and Load Control events to manage consumption on a range of devices. Supported cluster (mandatory): Demand Response/Load Control.
- Range Extender Device, i.e., a simple device that acts as a router for other devices.
- Smart Appliance device, i.e., smart appliances that can participate in energy management activities, for example, when Utilities initiate a demand response or pricing event, or the appliance actively informs customers via in-home displays of when or how energy is being used (e.g., Washer switching to cold water during periods of higher energy costs, Washer/Dryer/Oven/Hot Water Heater reporting cycle status, over-temperature conditions in Freezers and Refrigerators). Supported clusters (mandatory): Price, Time.
- Prepayment Terminal Device, i.e., a device that accepts payment (e.g. credit card, code entry), display remaining balances, and alert the user of a balance approaching zero. This device is used to allow utility customers or other users (e.g. sub-metered tenants) to pay for consumption in discrete increments rather than establishing a traditional billing agreement. Supported clusters (mandatory): Price, Time, Prepayment.

Interface covered in the end-to-end DSF flow

Interface H2, H1 (see Figure 3-1).

3.3.2.2 CENELEC EN 50491-11 Smart Metering

Standard Acronym and Full Name

CENELEC EN 50491-11 “General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 11: Smart Metering - Application Specifications - Simple External Consumer Display”

Issuing Organisation/ Technical Committee/ Industry Alliance

CENELEC, European Committee for Electrotechnical Standardization, TC 205 Home and Building Electronic Systems (HBES) (see Section 3.3.1).

Most relevant URLs, and other precise references

The EN 50491-11 is a published standard currently available from the TC 205 Work Programme at https://www.cenelec.eu/dyn/www/f?p=104:110:1686791285416701:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258281,42730,25 . The download requires credentials. The standard can be purchased from CENELEC’s National Committees and Affiliates for a fee.

Overall description

The EN 50491-11: 2015 standard specifies a data model to abstract the metering world towards a simple external consumer display. The data model, as described by means of functional blocks contained in EN 50491-11, lays down the format of metering data accessible by a simple external consumer display. This data interface would be typically part of the meter communication functions and be accessed by a simple external consumer display via the H1 interface of the CEN/CLC/ETSI TR 50572 between the display and the meter communication functions (however, note that the same data model can be used also on the H2 interface). The EN 50491-11 standard specifies neither the communication mechanisms used on the data interface, nor the applied data privacy and security mechanisms nor the ergonomics of the simple external consumer displays, where national

regulations may apply. It does also not specify the communication protocol used between the meters and the meter communication functions. However, it considers the existing European standards like the EN 13757 series (in particular EN 13757-3:2013 and its Annex O) and the EN 62056 series for the definition of the data model.

Description of the semantic coverage and main data elements

The main concepts addressed in EN 50491-11 are those of *Meter* (i.e., instrument for measuring, memorizing and displaying data related to the consumption of a commodity) and *Data Point* (i.e., container element, in which information is located related to a function of a product). Meters are characterized by metering functions. Each metering function is represented by a corresponding *Functional Block*, typically part of the metering communication function and accessed by a simple user display. Some meters may also provide metering data history values (e.g. monthly data). A functional block is specified for each typical metering function, grouping a number of in- and output data points. Most functional blocks of the data interface specified in the EN 50491-11 standard contain data that are intended as output data to a connected display.

Metering Functional Blocks:

- The Functional Block 'MDC Heat Meter' contains heat meter data.
- The Functional Block 'MDC Heat Cost Allocator' contains heat cost allocator data.
- The Functional Block 'MDC Water Meter' contains water meter data.
- The Functional Block 'MDC Generic Meter' is used if none of the other functional blocks cover the desired metering medium (e.g. oil, steam, or other).
- The Functional Block 'MDC Gas Meter' contains gas meter data.
- The Functional Block 'MDC Electricity Meter' contains electricity meter data.
- The Functional Block 'MDC Breaker' contains metering Breaker data.
- The Functional Block 'MDC Valve' contains Valve data.

Datapoints for the functional blocks mentioned above include: CurrentEnergyConsumption, TempFlowWater (Current flow temperature), TempReturnWater (Current Return temperature), TempDiffWater (Current Temperature difference), CurrentVolumeConsumption, CurrentPower, HistoryEnergyConsumption, HistoryMaxPower, HistoryMinPower, Metering DeviceType, Manufacturer, IdentificationNumber, VersionNumber, CurrentDate, MaxPowerDate, MaxPower, MinPowerDate, MinPower, Currency, Accumulated Cost, Current Credit.

Measurable quantities that can be represented in the data interface through the functional blocks mentioned above are the following: Oil, Electricity, Gas, Heat (outlet), Steam, Warm Water (30°C to 90°C), Water, Heat cost allocator, Cooling Load meter (outlet), Cooling Load meter (inlet), Heat (inlet), Heat and Cool, Breaker, Valve, Waste water meter.

Interface covered in the end-to-end DSF flow

H1, H2 (see Figure 3-1).

3.3.2.3 CENELEC EN 50631-1

Standard Acronym and Full Name

CENELEC prEN 50631-1 “Household appliances network and grid connectivity - Part 1: General Requirements, Generic Data Modelling and Neutral Messages” is part of the upcoming EN 50631 standard that will further comprise the following parts:

- prEN 50631-2-x: Household appliances network and grid connectivity - Product Specific Requirements and Specifications;
- prEN 50631-3: Household appliances network and grid connectivity - General Test-Requirements and Specifications;
- prEN 50631-4-x: Household appliances network and grid connectivity - Specific Implementation and Test Requirements.

Issuing Organisation/ Technical Committee/ Industry Alliance

CENELEC, European Committee for Electrotechnical Standardization, TC 59X Household appliances network and grid connectivity (see Section 3.3.1), WG7 Smart Household Appliances.

Most relevant URLs, and other precise references

The prEN 50631-1 is a published draft currently available from the TC 59X Work Programme at https://www.cenelec.eu/dyn/www/f?p=104:110:1438163728984601:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,47024,25. The download requires credentials. The standard can be purchased from CENELEC's National Committees and Affiliates for a fee. The prEN 50631-1 draft is currently in the 'Approval stage' status and its Date of Publication (DOP) is estimated for 2018-05-14.

The data model in the prEN 50631-1 draft is based on the “Smart Premises Interoperable Neutral-Message Exchange (SPINE)” specification published by the EEBUS and Energy@Home associations at <https://www.eebus.org/en/downloads/> (see Section 3.3.3 for the most relevant URLs and other precise references on SPINE, EEBUS and Energy@Home).

Overall description

The EN-50631 standard focuses on interoperability on information exchange among various appliances in the home. It describes the necessary control and monitoring, and defines a set of functions of household and similar electrical appliances. The functions in this standard cover, next to energy-management, main remote-control and monitoring use cases. The prEN 50631 Part 1 (draft) defines generic data modelling and generic neutral messages for interoperable connected household appliances, without relation to any specific communication technology or any product specific layout. Part 2 will list and specify product specific requirements and implementation guidance based on the generic data model and generic neutral messages. Part 3 will define Test-Requirements and Test-Specifications. Part 4 will define the mapping of neutral messages to examples of typical communication protocols like ZigBee, KNX, OIC, SHIP, Echonet light, Thread and so forth.

Description of the semantic coverage and main data elements

The prEN 50631-1 draft defines data models for Interoperable Connected Household Appliances. Household appliances designate equipment intended for housekeeping functions such as washing, cleaning, heating, cooling, cooking, etc. and appliances intended for use in the home environment such as shavers, hair care appliances, food preparation appliances, etc. Appliances for household use cover use by non-expert users in similar conditions as in households, for example, in shops, offices or other similar work environments; in farm houses; by clients in hotels, motels and other residential

type of environments; in bed and breakfast type environments, which are also considered as household appliances.

The data model in the prEN 50631-1 draft is based on the “Smart Premises Interoperable Neutral-Message Exchange (SPINE)” specification. The prEN 50631-1 draft standard provides normative schemas (expressed as XSDs) for the following SPINE classes: Actuator Switch, Binding Management, Command Common Definitions, Command Frame, Common Data Types, Datagram, Device Classification, Direct Control, Load Control, Measurement, Messaging, Network Management, Node Management, Operating Constraints, Power Sequences, Result, Sensing, Smart Energy Management Ps, Specific Device Entity Definitions, Subscription Management, Task Management, Threshold, Time Information, Time Table, Version (see dedicated description in Section 3.3.3 for details on SPINE).

Interface covered in the end-to-end DSF flow
S2, S1 (see Figure 3-1).

3.3.2.4 ETSI TS 103 264 (SAREF)

Standard Acronym and Full Name

ETSI SAREF TS 103 264 “SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping”.

Issuing Organisation/ Technical Committee/ Industry Alliance

ETSI, European Telecommunications Standards Institute, TC Smart Machine-to-Machine communications (SmartM2M) (see Section 3.3.1).

Most relevant URLs, and other precise references

The latest SAREF specification TS 103 264 V2.1.1 (2017-03) can be downloaded for free from http://www.etsi.org/deliver/etsi_ts/103200_103299/103264/02.01.01_60/ts_103264v020101p.pdf.

The ontology file is available from <https://w3id.org/saref>, which is a persistent URL¹¹ run by the W3C Permanent Identifier Community Group¹² that re-directs to <http://ontology.tno.nl/saref>.

Examples of how to create SAREF devices (i.e., data instances of actual devices compliant with the SAREF specification) are available at <http://ontology.tno.nl>.

Overall description

The first SAREF specification for smart appliances was published by ETSI SmartM2M TC in November 2015 as TS 103 264 V1.1.1 (2015-11)¹³. This specification was based on the Smart Appliance REFerence ontology (SAREF) that was originally created in the context of the SMART 2013/0077 study promoted by the European Commission (DG Connect) and conducted by TNO in collaboration with ETSI TC SmartM2M (<https://sites.google.com/site/smartappliancesproject>).

¹¹ A persistent URL acts as a permanent identifier in the face of a dynamic and changing Web infrastructure. The purpose is to provide a secure, permanent URL re-direction service for Web applications. This capability provides continuity of references to network resources that may migrate from machine to machine for business, social or technical reasons, ensuring that applications using persistent URLs will always be re-directed to a working website.

¹² <https://www.w3.org/community/perma-id/>

¹³ http://www.etsi.org/deliver/etsi_ts/103200_103299/103264/01.01.01_60/ts_103264v010101p.pdf

The study was motivated by the need of the market to reduce the energy utilization by managing and controlling smart appliances (for example, in a house or an office building) on a system level. The industry and the European Commission identified the need for a common architecture with standardized interfaces and a common data model to assure interoperability. Without these two components, the market would continue to be fragmented and powerless. Therefore, the development of a reference ontology was targeted as the main interoperability enabler for appliances relevant for energy efficiency, and ETSI accepted to cover the communication aspect and provide the necessary standardization process support. As a result, following a broad consultation with stakeholders to address clear market needs, the European Commission financially supported the SMART 2013/0077 study for the creation of SAREF, which was completed on April 1st 2015.

The outcomes of the study [4] were then transferred to ETSI TC SmartM2M to turn the SAREF ontology into an ETSI Technical Specification, published in November 2015 (TS 103 264 V1.1.1). This specification subsequently evolved in a new version published in March 2017 (TS 103 264 V2.1.1), which considers the feedback received from the industrial stakeholders since its first release in April 2015. The TS 103 264 V2.1.1 contains the specification of SAREF 2.0, including the changes compared to the previous version, and an updated mapping to the oneM2M Base Ontology developed in collaboration with oneM2M experts (see Section 3.3.2 for details on the oneM2M Base Ontology).

Description of the semantic coverage and main data elements

SAREF is based on the following main concepts (in alphabetical order):

- Command, which is a directive that a device shall support to perform a certain function (e.g. On Command, Off Command, Pause Command, Get Command, Notify Command, Set Level Command);
- Commodity, which is a marketable item for which there is demand, but which is supplied without qualitative differentiation across a market (e.g. Electricity, Gas, Water);
- Device, which is a tangible object designed to accomplish a task in households, common public buildings or offices (e.g. Switch, Meter, Sensor, Washing Machine);
- Function, which is the functionality necessary to accomplish the task for which a device is designed (i.e., Actuating Function, Event Function, Metering Function, Sensing Function);
- Measurement, which is the measured value made over a property. It is also linked to the unit of measure in which the value is expressed and to the timestamp of the measurement;
- Profile, which is a specification associated to a device to collect information about a certain property or commodity (e.g., Energy or Water) for optimizing its usage in the home/building in which the device is located;
- Property, which is anything that can be sensed, measured or controlled in households, common public buildings or offices (e.g., Energy, Humidity, Light, Motion, Occupancy, Power, Pressure, Price, Smoke, Temperature, Time);
- Service, which is a representation of a function to a network that makes the function discoverable, registerable and remotely controllable by other devices in the network (e.g., Switch On Service);
- State, which is the state in which a device can be found (e.g., On Off State, Open Close State, Start Stop State, Multi Level State);
- Task, which is the goal for which a device is designed, from a user perspective (e.g. Cleaning, Comfort, Lighting, Safety, Entertainment, Energy Efficiency); and

- UnitOfMeasure, which is a standard for measurement of a quantity, such as a Property. For example, Power is a property and Watt is a unit of power that represents a definite predetermined power (e.g. Currency, Energy Unit, Power Unit, Temperature Unit).

Interface covered in the end-to-end DSF flow

S2, S1 (see Figure 3-1).

3.3.2.5 ETSI TS 103 410-1 (SAREF4ENER)

Standard Acronym and Full Name

ETSI SAREF4ENER TS 103 410-1 “SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain”.

Issuing Organisation/ Technical Committee/ Industry Alliance

ETSI, European Telecommunications Standards Institute, TC Smart Machine-to-Machine communications (SmartM2M) (see Section 3.3.1).

Most relevant URLs, and other precise references

The SAREF4ENER specification V1.1.1 (2017-02) can be downloaded for free from http://www.etsi.org/deliver/etsi_ts/103400_103499/10341001/01.01.01_60/ts_10341001v010101p.pdf. The ontology file is available from <https://w3id.org/saref4ener> which is a persistent URL that redirects to <http://ontology.tno.nl/saref4ener>.

Overall description

TS 103 410-1 is a technical specification of SAREF4ENER, an extension of SAREF that was created in collaboration with Energy@Home¹⁴ and EEBUS¹⁵, the major Italy- and Germany-based industry associations, to enable the interconnection of their (different) data models. SAREF4ENER is meant to enable interoperability among various proprietary solutions developed by different consortia in the smart home domain. By using SAREF4ENER, smart appliances from manufacturers that support the EEBUS or Energy@home data models can easily communicate with each other using any energy management system at home or in the cloud. To that end, SAREF4ENER should be used to annotate (or generate) a neutral (protocol-independent) set of messages to be directly adopted by the various manufacturers, or mapped to their domain specific protocols of choice. SAREF4ENER is an OWL-DL ontology that extends SAREF with 63 classes, 17 object properties and 40 data type properties. SAREF4ENER focuses on demand response scenarios, in which customers can offer flexibility to the Smart Grid to manage their smart home devices by means of a Customer Energy Manager (CEM). The CEM is a logical function for optimizing energy consumption and/or production that can reside either in the home gateway or in the cloud. Moreover, the Smart Grid can influence the quantity or patterns of use of the energy consumed by customers when energy-supply systems are constrained, e.g. during peak hours. These scenarios involve the use cases described in TR 103 411 “SmartM2M; Smart Appliances; SAREF extension investigation” (see Section 3.3.3 for details on TR 103 411 and the use cases underlying SAREF4ENER).

Description of the semantic coverage and main data elements

¹⁴ <http://www.energy-home.it>

¹⁵ <https://www.eebus.org/?lang=en>

The main concepts covered by SAREF4ENER are *Device*, *Power Profile*, *Alternatives Group*, *Power Sequence* and *Slot*. A Power Profile in SAREF4ENER extends the more generic *Profile* class in SAREF with additional properties that are specific for smart energy management. The power profile in SAREF4ENER is used by a device to expose the power sequences (or plans) that are potentially relevant for the CEM. To that end, a power profile consists of one or more groups (each group modelled as an *AlternativesGroup* class) with alternative power sequences. Within one group, there can be one or more power sequences that are alternatives to each other, where at most one of these alternatives can be finally executed. Power sequences may have further options with regards to flexibility, for example, one of the alternatives may offer that the CEM can pause a power sequence, if the sequence completes before the latest time set by the user. Finally, a power sequence consists of one or more slots that represent different phases of consumption (or production) and their values. Power sequences of a heating system, for example, typically have a single slot each, while other devices such as washing machines, may have a power sequence with various slots for the different phases of washing, e.g., heating the water, washing and rinsing.

SAREF4ENER also defines how to model events used in, for example, a direct load management and power curtailing scenarios, as reaction to special requests from the Smart Grid, such as incentives to consume depending on current energy availability, or emergency situations that require temporary reduction of the power consumption (see TR 103 411 in Section 3.3.3 for further details on these scenarios). The classes of interest defined in SAREF4ENER for these scenarios are the following:

- *LoadControlEventData* is used to represent overload warning severity level and related load control commands to a device. It is characterized by an event ID and a timestamp that represents the time the event information instance was created or received, and the time period that denotes the period of validity of the event. For example, an event was received 5 minutes ago, notifying that the considered event shall take effect tomorrow from 2:00 p.m. to 3:30 p.m. (where the timestamp of this event is "5 minutes ago" and time period is "tomorrow 2:00 p.m. to 3:30 p.m.");
- *LoadControlEventAction* expresses the type of actions to be performed as a consequence of a load control event. These actions can be of type "consume" or "produce" to denote consumption or production of energy or power. Values that can be assumed by both consume and produce actions can be *emergency*, *increase*, *normal*, *pause*, *reduce*, *resume*;
- *LoadControlStateData* expresses the data about the state of an event and is characterized by an event ID (the same used for the corresponding event in the *LoadControlEventData* class) and a timestamp;
- *LoadControlEventState* is associated to *LoadControlState*, which expresses the possible states of a load control event. These states can be of type "consume" or "produce" (analogously to the load control actions mentioned above). Values that can be assumed by both consume and produce states can be *eventAccepted*, *eventStarted*, *eventStopped*, *eventRejected*, *eventCancelled*, or *eventError*.

*Interface covered in the end-to-end DSF flow
S2, S1 (see Figure 3-1).*

3.3.2.6 IEC 61970 CIM

Standard Acronym and Full Name

IEC 61970 Common Information Model (CIM)/Energy Management series of standards:

- IEC 61970-1 Part 1: Guidelines and general requirements;
- IEC 61970-2 Part 2: Glossary;
- IEC 61970-3XX Part 3XX: Common Information Model (CIM) → IEC 61970-301 (Core CIM);
IEC 61970-4XX Part 4XX: Component Interface Specification (CIS);
- IEC 61970-5XX Part 5XX: CIS Technology Mappings → IEC 61970-501 (CIM RDF Schema).

Issuing Organisation/ Technical Committee/ Industry Alliance

IEC, International Electrotechnical Commission, TC57 - Power systems management and associated information exchange (see Section 3.3.1).

Most relevant URLs, and other precise references

IEC 61970-301:2016 (Core CIM) is a published standard currently available at <https://webstore.iec.ch/publication/31356>. The standard is not available for free, but it has to be purchased from IEC.

Overall description

The IEC 61970-301 standard (Core CIM) lays down the common information model (CIM), which is an abstract model that represents all the major objects in an electric utility enterprise typically involved in utility operations. By providing a standard way of representing power system resources as object classes and attributes, along with their relationships, the CIM facilitates the integration of network applications developed independently by different vendors, between entire systems running network applications developed independently, or between a system running network applications and other systems concerned with different aspects of power system operations, such as generation or distribution management. The CIM facilitates integration by defining a common language (i.e. semantics) based on the CIM to enable these applications or systems to access public data and exchange information independent of how such information is represented internally.

Description of the semantic coverage and main data elements

The CIM standard is currently maintained as a UML class model. It defines a common vocabulary and basic ontology for aspects of the electric power system. It defines about 1500 different concepts (classes) and a multitude of properties divided over some 100 packages.

The metering profile in CIM contains core information classes representing metering, end-devices and other related concepts such as:

- UsagePoint: a specialised subclass of IdentifiedObject. A UsagePoint is a representation logical or physical point in the network to which readings may be attributed. Used at the place where a physical- or virtual meter may be located; however, it is not required that a meter device is present.
- UsagePointLocation: a specialised subclass of Location. The location of an individual usage point is modelled as a UsagePointLocation, which is a specific type of Location in CIM. A UsagePoint is the place, scene, or point of something (e.g., address-, electronic- or GPS-location are examples of locations). Example of a UsagePoint is the place where a physical or virtual meter is located in the power system. It can be defined with one or more position points (coordinates) in a given coordinate system.

- Meter: a specialised subclass of EndDevice. A Meter is defined as a physical asset that represents the physical attributes of a meter EndDevice and enables the implementation of MeterReading at a specific UsagePoint, used for measuring consumption and detection of EndDeviceEvent. A Meter specializes the concept of EndDevice, which is an AssetContainer that performs one or more end device functions. One specific type of EndDevice is a Meter which can perform metering and optional other EndDeviceFunction like, load management, connect/disconnect, accounting functions, etc. Other type of EndDevice, such as monitoring and controlling air conditioner, refrigerator and pool pumps may be connected to a Meter as well. All EndDevice may have communication capability defined by the associated communication function(s).
- MeterReading: Set of values obtained from a meter EndDevice. A MeterReading is a set of values obtained via the Meter.
- Reading: Specific value measured by a meter or other asset, or calculated by a system. Each Reading in the set of MeterReading is a specific value measured by a Meter, or calculated by a system. Each Reading is associated with a specific ReadingType. An example of a ReadingType is an individual- or regular 15-minutes interval reading.
- Channel: a single path for the collection or reporting of register values over a period;
- Register: a device that indicates or records units of the commodity or other quantity measured.

Interface covered in the end-to-end DSF flow

Interface G3 (see Figure 3-1).

3.3.2.7 IEC 61968-9 CIM for metering

Standard Acronym and Full Name

IEC 61968 “Application integration at electric utilities - System interfaces for distribution management” Parts 1 to14:

- IEC 61968-1 “Part 1: Interface architecture and general recommendations” [Published];
- IEC 61968-2 “Part 2: Glossary” [Published];
- IEC 61968-3 “Part 3: Interface for Network Operations” [Published];
- IEC 61968-4 “Part 4: Interfaces for Records and Asset management” [Published];
- IEC 61968-5 “Part 5: Interfaces for Operational planning and optimization” [Under Development];
- IEC 61968-6 “Part 6: Interfaces for Maintenance and Construction” [Published];
- IEC 61968-7 “Part 7: Interfaces for Network Extension Planning” [Under Development];
- IEC 61968-8 “Part 8: Interface Standard for customer Support” [Published];
- IEC 61968-9 “Part 9: Interfaces for meter reading and control” [Published];
- IEC 61968-10 “Part 10: Interfaces for Business functions external to distribution management” [Retired];
- IEC 61968-11 “Part 11: Common Information Model (CIM) Extensions for Distribution” [Published];
- IEC 61968-12 “Part 12: Common Information Model (CIM) Use Cases for 61968” [Retired];
- IEC 61968-13 “Part 13: Common Information Model (CIM) RDF Model exchange format for distribution” [Published];

- IEC 61968-14 “Part 14: MultiSpeak – CIM Harmonization” [Published].

Issuing Organisation/ Technical Committee/ Industry Alliance

IEC, International Electrotechnical Commission, TC57- Power systems management and associated information exchange, WG14- System interfaces for distribution management (SIDM) (see Section 3.3.1).

Most relevant URLs, and other precise references

The IEC 61968-2: 2011 (Glossary) is a published standard currently available at <https://webstore.iec.ch/publication/6201> . The IEC 61968-9: 2013 (CIM for metering) is a published standard currently available at <https://webstore.iec.ch/publication/6204>. These standards are not available for free, but they can be purchased from IEC.

Overall description

IEC 61968 is a series of standards under development for information exchanges between electrical distribution systems. These standards are being developed by Working Group 14 of Technical Committee 57 of the IEC. IEC 61968 is intended to support the inter-application integration of a utility enterprise that needs to collect data from different applications that are legacy or new and each has different interfaces and run-time environments. IEC 61968 defines interfaces for all the major elements of an interface architecture for Distribution Management Systems (DMS) and is intended to be implemented with middleware services that broker messages among applications.

The part of the IEC 61968 standard that is of interest in the scope of the DSF study to extract data elements is Part 9 (CIM for metering).

The IEC 61968-9 standard specifies the information content of a set of message types that can be used to support many of the business functions related to meter reading and control. Typical uses of the message types include meter reading, controls, events, customer data synchronization and customer switching. The purpose of IEC 61968-9 is to define a standard for the integration of metering systems (MS), which includes traditional manual systems, and (one or two-way) automated meter reading (AMR) systems, and meter data management (MDM) systems with other enterprise systems and business functions within the scope of IEC 61968. The scope of IEC 61968-9 is the exchange of information between metering systems, MDM systems and other systems within the utility enterprise.

Description of the semantic coverage and main data elements

A Meter is a specialization of an End Device in CIM. From the perspective of the IEC 61968-9 standard, a meter is an end device that has metrology capability, may have communications capability, may be a load control unit and may host a mixture of other different types of functionality. The following information about the meter is of interest for the IEC 61968-9 standard:

- has a unique identity (mRID and/or one or more instances of the Names class)
- is managed as a physical asset
- may issue events
- may receive control requests
- may collect and report measured values
- may participate in utility business processes

A meter records the data used for tariffing public networks, and data used for network balancing mechanisms. Readings captured by the metering system are collected by a system such as the Meter Data Management (MDM) before being presented for billing purposes. Billing entities may correct the data, or, in some regions, the energy supplier may perform validating, editing, and estimating (VEE) according to rules established by the appropriate supervising regulatory agency. In any case, those corrections are made available to the user who requests them.

Given that a meter has metrology capability, electricity meters measure kWh, but will possibly measure also demand, reactive energy and demand, time of use quantities, interval data, engineering quantities and more. Analogously, meters for other commodities such as gas and water may monitor analogous quantities.

Data exchanged via the interfaces for Meter Reading and Control specified in IEC 61968-9 include meter readings and status, outage detection and restoration verification data, power reliability and quality events, communication network health information for maintenance of the communications network, configuration and installation of meters (i.e., Meter Asset Management, or Asset Management in general), control and reconfiguration information (such as meter control commands, communicating payment system information, tariff units of measure and calendar, power quality measurement, meter event recording, load control signals, meter identity and security credentials), load control signals in order to control the load presented by the EndDevice(s) and pricing signals in order to affect the load presented by the EndDevice(s) (for both economic and emergency reasons). Functionality related to customer care and billing is a subject external to the IEC 61968-9 standard. The billing function is driven by readings, typically demand or time-of-use, obtained from the meter.

The information model relevant to meter reading and control consists of classes defined in the IEC 61968-9 standard. In particular, the IEC 61968-9 standard makes use of the following classes:

- Classes described as type "Asset", which are defined in the 61968/Assets package of the CIM
- Classes described as type "Customer", which are defined in the 61968/Customers package of the CIM.
- Classes described as type "Metering", which are defined in the 61968/Metering package of the CIM.
- Classes described as type "PaymentMetering", which are described in the 61968/PaymentMetering package of the CIM.
- Classes described as type "Profile", which are contextual profiles defined for 61968-9. These classes include, among others, the AuxiliaryAgreementConfig class (i.e., message profile for AuxiliaryAgreements), the ComModuleConfig class (i.e., profile for configuring communications modules), the EndDeviceControls class (i.e., message used to convey one or more EndDeviceControls), the MeterConfig class (i.e., message profile for Meter configuration messages), the CustomerAccountConfig class (i.e., message profile for CustomerAccount), the MeterReadings class (i.e., profile for conveying MeterReadings), the MeterServiceRequests class (i.e., requests that can be used for a variety of meter service related activities that include meter installation, meter change out, customer disconnect/reconnect, , etc.), the PricingStructureConfig class (i.e., profile for configuring pricing structures), the UsagePointLocationConfig and UsagePointConfig classes (i.e., messages used to establish associations to UsagePointLocations).

Interface covered in the end-to-end DSF flow
H1, H2 (see Figure 3-1).

3.3.2.8 IEC 62056 COSEM

Standard Acronym and Full Name

IEC 62056 DLMS/COSEM (Device Language Message Specification / Companion Specification for Energy Metering) suite:

- IEC 62056-6-1 “Electricity metering data exchange - The DLMS/COSEM suite - Part 6-1: Object Identification System (OBIS)”;
- IEC 62056-6-2 “Electricity metering data exchange - The DLMS/COSEM suite - Part 6-2: COSEM interface classes”;

Issuing Organisation/ Technical Committee/ Industry Alliance

IEC, International Electrotechnical Commission, TC13 - Electrical energy measurement and control, WG14 - Data exchange for meter reading, tariff and load control (see Section 3.3.1).

Most relevant URLs, and other precise references

IEC 62056-6-1:2017 (OBIS) is a published standard currently available at <https://webstore.iec.ch/publication/32782>. IEC 62056-6-2:2017 (COSEM interface classes) is a published standard currently available at <https://webstore.iec.ch/publication/34317>. These standards are not available for free and they have to be purchased from IEC.

Note that IEC 62056-6-2 matches the “Companion Specification for Energy Metering: COSEM interface classes and OBIS identification system” (also called “Blue Book” specifications) from DLMS User Association, 27 September 2014, available for members only at <http://dlms.com/documentation/index.html>.

Overall description

DLMS/COSEM (Device Language Message Specification / Companion Specification for Energy Metering) is a world-wide standard that specifies smart meter functionality. It is developed and maintained by the DLMS User Association¹⁶.

DLMS is a generalized concept for abstract modelling of communication entities. It is a middleware protocol that can be applied on various physical layer technologies, such as Zigbee, M-bus, but also Internet. It is designed to support messaging to and from (energy) distribution devices in a computer-integrated environment. Applications like remote meter reading, remote control and value added services for metering any kind of energy, like electricity, water, gas or heat are supported.

COSEM (Companion Specification for Energy Metering) sets the rules, based on existing standards, for data exchange with energy meters. It is designed for use with DLMS but can also be applied to other protocols. COSEM achieves this by using object modelling techniques to model all functions of the meter, without making any assumptions about which functions need to be supported, how those functions are implemented and how the data are transported. The formal specification of COSEM

¹⁶ www.dlms.org

interface classes forms a major part of COSEM. To process and manage the information it is necessary to uniquely identify all data items in a manufacturer-independent way. Therefore, the definition of OBIS (Object Identification System) is an essential part of COSEM. OBIS is standardized as IEC 62056-6-1, which specifies the overall structure of the Object Identification System and the mapping of all commonly used data items in metering equipment to their identification codes. COSEM is standardized as IEC 62056-6-2, which specifies a model of a meter as it is seen through its communication interface(s). Generic building blocks are defined using object-oriented methods, in the form of interface classes to model meters from simple up to very complex functionality.

Description of the semantic coverage and main data elements

A COSEM Physical device contains COSEM Logical Device(s) and must contain a Management Logical Device (mandatory). A Logical device must have a Logical Device Name (LDN), and contains two or more objects (Associations objects and Application objects), but also holding parameters and measurement values. The naming system is based on OBIS, the Object Identification System: each logical name is an OBIS code. There are OBIS values groups (A,B,C,D,E,F) and, for example, the group A specifies the media (energy type) to which the metering is related, and has the following values:

- 0: Abstract Object
- 1: Electrical Related Object
- 4: Heat Cost Allocator Related Object
- 5: Cooling Related Object
- 6: Heat Related Object
- 7: Gas Related Object
- 8: Cold Water Related Object
- 9: Hot Water Related Object

In particular, Electrical Related Objects (A= 1) include definitions of electricity related concepts such as active power, reactive power and apparent power. Heat Cost Allocator Related Object (A=4) or Cooling Related Object (A=5) include definitions such as Radiator surface temperature, Heating medium temperature, Flow (forward) temperature, Return temperature, Room temperature. Gas Related Objects (A= 1) include definitions of gas related concepts such as Forward undisturbed meter volume, Forward disturbed meter volume, Forward absolute meter volume, Reverse undisturbed meter volume, Reverse disturbed meter volume, Reverse absolute meter volume, Forward undisturbed converter volume, Forward undisturbed logger volume, Forward undisturbed Energy and so forth. Water related definitions (A= 8 or A=9) include concepts such as Accumulated volume, Flow rate and Forward temperature.

Interface covered in the end-to-end DSF flow

H2, H1 (see Figure 3-1).

3.3.2.9 KNX specification (CENELEC EN 50090)

Standard Acronym and Full Name

KNX standard for home and building control.

Issuing Organisation/ Technical Committee/ Industry Alliance

KNX Association¹⁷ is a non-profit-oriented group of companies active in many fields of home and building control that counts around 370 members. As common goal, these companies promote the development of building installation systems and KNX as a worldwide specification for home and building control, offering more than 7.000 KNX certified product groups in their catalogues, from different application domains. Worldwide, KNX Association has partnership agreements with more than 44.000 installer companies in 128 countries. KNX Association is the creator and owner of the KNX specification, resulting from the knowledge and experience also of the predecessor technologies to KNX, i.e. the European Installation Bus (EIB), the European Home System (EHS) and BatiBUS. The KNX specification is published as an European standard by CENELEC, TC 205 Home and Building Electronic Systems (HBES) (see Section 3.3.1).

Most relevant URLs, and other precise references

The KNX specifications, including the “KNX Handbook for Home and Building Control” (fifth edition) are available for free at <https://my.knx.org/en/shop/knx-specifications> after creating an account and going to the purchase process to accept the license terms. The purchase itself is provided for 0 euro. The Chapter “KNX System Specifications Interworking Datapoint Types, version 01.08.02” is the part of the KNX specification v2.1 that defines the KNX Datapoint Types for Interworking.

KNX is approved as:

- European Standard (CENELEC EN 50090 and CEN EN 13321-1):
 - CENELEC EN 50090 “Home and Building Electronic Systems (HBES) - Part 1: Standardization structure” by CLC/TC 205 is a published standard available at https://www.cenelec.eu/dyn/www/f?p=104:110:865087283504901:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258281,55668,25. The download requires credentials. The standard can be purchased from CENELEC’s National Committees and Affiliates for a fee.
 - CEN EN 13321-1:2012 “Open data communication in building automation, controls and building management - Home and building electronic system - Part 1: Product and system requirements” by CEN/TC 247 is a published standard available at https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT,FSP_ORG_ID:36019,6228&cs=1E7F5F12CB0D6E56F4BC6A9AAF5FC9DC9. The download requires credentials. The standard can be purchased from CEN National Standardization Bodies (NSBs) for a fee.
- International Standard (ISO/IEC 14543-3)
 - ISO/IEC 14543-3 “Information technology - Home electronic system (HES) architecture” is publicly available, but not for free, at <https://webstore.iec.ch/searchform&q=ISO/IEC%2014543-3>. The ISO/IEC 14543-3 standards can be purchased from the IEC webstore at <https://webstore.iec.ch/> or the ISO webstore at <https://www.iso.org/store.html>.

Overall description

The KNX standard is designed for the control of applications in industrial, commercial and residential buildings worldwide, ranging from lighting and shutter control to various security systems, heating,

¹⁷ www.knx.org

ventilation, air conditioning, monitoring, alarming, water control, energy management, metering as well as household appliances, audio and lots more. It can be used in new as well as in existing home and buildings. The Engineering Tool Software (ETS) is a manufacturer independent configuration software tool by KNX Association to design and configure intelligent home and building control installations with the KNX system. Recent efforts at KNX aim at investigating the benefits of associating a KNX IoT ontology to the model underlying the ETS tool and leverage semantic technologies, as enabler to add semantic information for advanced functional queries without pre-knowledge on the devices implementing the actual functions. The KNX IoT ontology is available at <https://knxiot.org> (access to the KNX ontology requires credentials that can be obtained contacting the KNX association).

Description of the semantic coverage and main data elements

KNX covers Lighting, Blinds & Shutters, Security Systems, Energy Management, Heating Ventilation and Air-Conditioning (HVAC) Systems, Monitoring Systems, Remote Control, Metering, Audio/Video Controls, and White Goods. The current KNX specifications define devices that can be configured at design-time using the ETS set up tool. At run-time, KNX is a data driven standard that defines commands. The parameters in those commands are called *Datapoints*. There are several types of Datapoints, namely *Datapoint Types for common use*, *Datapoint Types for HVAC*, *Datapoint Types for Load Management*, *Datapoint Types for Lighting*, *Datapoint Types for Systems*. Combinations of data point types into a device are called *Functional Blocks*. Examples of functional blocks are *Dimmer Actuator Basic* and *Sunblind Actuator Basic*:

- The *DimmerActuatorBasic* functional block combines the *DPT_ControlDimming*, *DPT_Scaling* and *DPT_Switch* data point types. This functional block can be in one of the 3 states “On”, “Off”, or “Dimming”, which are defined under the *DimmingActuatorBasicState* class. The change from one state to another is triggered by the so-called *Events* with one of the values listed under the *DimmingActuatorBasicEvent* class.
- The *SunblindActuatorBasic* functional block combines the *DPT_Step* and *DPT_UpDown* data point types. This functional block can be in one of the 4 states “Stopped”, “InMotion”, or “StepUp”, “StepDown”, which are defined under the *SunblindActuatorBasicState* class. The change from one state to another is triggered by events with one of the values listed under the *SunblindActuatorBasicEvent* class.

Interface covered in the end-to-end DSF flow

S2, S1 (see Figure 3-1).

3.3.2.10 oneM2M TS 0012 Base Ontology

Standard Acronym and Full Name

oneM2M TS 0012 “Base Ontology” and TS 0030 “Ontology based Interworking”

Issuing Organisation/ Technical Committee/ Industry Alliance

oneM2M (see Section 3.3.1).

Most relevant URLs, and other precise references

The latest versions of the Base Ontology specification, TS 0012 Release 3 “Base Ontology” and TS 0030 “Ontology based Interworking”, can be downloaded from <http://onem2m.org/technical/published-drafts>. The OWL representation of the oneM2M base ontology can be found at <https://git.onem2m.org/MAS/BaseOntology>.

Overall description

oneM2M specifies an interoperable framework for middleware functionality that can be virtually used for any M2M/IoT application, independently from the underlying communication networks. The semantics of such M2M/IoT application layer (devices, messages, data model) can be described with an ontology in a formal representation (e.g. OWL format). oneM2M represents entities in terms of data resources, which are handled by applications and the functions of the oneM2M system (see oneM2M TS-0001 “Functional Architecture” in Section 3.3.3). Therefore, entities of the application layer, described in the application layer ontology, need to be represented as resources in the oneM2M system. The oneM2M Base Ontology is an ‘upper’ ontology that facilitates that other, specialized, ‘lower’ application layer ontologies can be mapped into oneM2M resources. TS 0012 specifies the oneM2M Base Ontology. TS 0030 describes the mapping into oneM2M resources. The design concept outlined above, using ontologies to describe the application layer together with a specified mapping into resources of the global oneM2M standard, enables semantic interoperability between heterogeneous applications and interworking with existing non-oneM2M technologies.

Description of the semantic coverage and main data elements

The oneM2M Base Ontology has been designed with the intent to provide a minimal number of concepts, relations and restrictions that are necessary for semantic discovery of entities in the oneM2M System. The Base Ontology contains Classes and Properties (i.e., the schema), but not instances (i.e., the data), since it is meant to provide a semantic description for data handled in oneM2M. Instantiation of the data is done via oneM2M resources. The approach is that given a semantic description of instances according to the oneM2M Base Ontology, a structure for a oneM2M resource can be automatically created as follows: specified oneM2M resources (e.g., a oneM2M *Application Entity* resource) are created for representing devices (e.g., a washing machine). So-called *flexContainers* are used for storing dynamic data, e.g. the status of the washing machine. Other, more static aspects (e.g., the manufacturer) are stored in special *Semantic Descriptor* resources that can be attached to several types of oneM2M resources (e.g., a semantic descriptor resource attached to the oneM2M resource representing a device would contain semantic information, such as the manufacturer). Such a *semantic descriptor* resource also contains information concerning the relation to other resources, e.g. operations that can be executed.

The oneM2M Base ontology represents the following classes:

- A Thing in oneM2M (class: Thing) is an entity that can be identified in the oneM2M System. E.g., a room that is modelled in oneM2M would be a Thing that could have a room-temperature as a Thing Property (via hasThingProperty) and could have a hasThingRelation “isAdjacentTo” to another “room” Thing;
- Thing Property, denotes a property of a Thing. E.g., the indoor temperature of the room could be a Value of a Thing “room”, or the manufacturer could be a ThingProperty of a Thing “car”;

- Device, which is a Thing (a sub-class of class:Thing) that is able to interact electronically with its environment. E.g., a "lightswitch" would be a device, a combined fridge/freezer would be a device that consists of a sub-device fridge and a sub-device freezer;
 - An Interworked Device describes a Device which is not a oneM2M Device and can only be accessed from the oneM2M System through an interworking proxy;
- Function, which represents the functionality necessary to accomplish the task for which a Device is designed;
 - Controlling Function, which is a sub-class of Function that only controls/influences real world Aspects that the functionality relates to;
 - Measuring Function, which is a sub-class of Function that only measures/senses real world Aspects that the functionality relates to;
- Command, which denotes an action that can be performed to support the Function;
- Service, which is a representation of a Function to a network that makes the Function discoverable, registerable, remotely controllable in the network;
- Input Data Point, which is a Variable of a Service that is set by a RESTful Device in its environment and the Device reads out;
- Output Data Point, which is a Variable of a Service that is set by a RESTful Device in its environment and that provides state information about the Service.
- Operation, which is the means of a Service to communicate in a procedure-type manner over the network (i.e. transmit data to/from other devices). An Operation is a representation of a Command to a network;
 - Operation Input, which describes the type of input of an Operation to a service of the device;
 - Operation Output, which describes the type of output of an Operation from a service of the device.

Interface covered in the end-to-end DSF flow
S1, G3 (see Figure 3-1).

3.3.3 Non-selected standards and industry initiatives

The following additional standards and industry initiatives are also relevant in the scope of this study, but less suitable for our data elements alignment (see Section 3.4 for rationale of not inclusion in the short-list):

- CEN EN 13757-1
- CENELEC EN 50491-12
- EFI
- ETSI TR 103 411 (SAREF Extension Investigation)
- IEC TR 62746-2
- IEC TS 62913-2-3
- oneM2M TS 0001 (Functional Architecture)
- OpenADR
- SPINE specification

3.3.3.1 CEN EN 13757-1

Standard Acronym and Full Name

CEN EN 13757 “Communication systems for meters” Parts 1 to 6:

- CEN EN 13757-1 “Communication systems for meters - Part 1: Data exchange”.

Issuing Organisation/ Technical Committee/ Industry Alliance

CEN, the European Committee for Standardization, TC 294 Communication systems for meters (see Section 3.3.1).

Most relevant URLs, and other precise references

The EN 13757 Communication systems for meters, parts 1 and 2, are publicly available from the TC 294 Work Programme at :

- The EN 13757-1:2014 Part 1: Data exchange
https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT:34339&cs=1F7CC9409E1B873EB55054CACB08516CF.
- The EN 13757-2:2004 Part 2: Physical and link layer
https://standards.cen.eu/dyn/www/f?p=204:110:0:::FSP_PROJECT,FSP_ORG_ID:20602,6275&cs=162C0F529CCE8C55EDCB976C7A738EF82

The download requires credentials. The standard can be purchased from CEN's National Standardization Bodies (NSBs) for a fee.

Overall description

The EN 13757 standard on communication systems for meters comprises 6 parts, of which Part 1 is especially relevant for extracting data elements and therefore for our state of standardization analysis. The EN 13757-1:2014 standard specifies data exchange and communications for meters and remote reading of meters in a generic way. It establishes a protocol specification for the Application Layer for meters and establishes several protocols for meter communications which may be applied depending on the application being fulfilled. Note that Electricity meters are not covered by this standard, as the standardization of remote readout of electricity meters is a task for CENELEC. The EN 13757-2:2004 standard covers the physical and link layer parameters of baseband communication over twisted pair (M Bus) for meter communication systems. It is especially applicable to heat meters, heat cost allocators, water meters and gas meters. Note that it is usable also for other meters (like electricity meters) and for sensors and actuators. For generic descriptions concerning communication systems for meters and remote reading of meters, see EN 13757-1. The IEC 62056-7-3 standard, also known as DLMS UA Green Book, specifies a DLMS/COSEM M-Bus profile that allows running DLMS/COSEM applications over wired or wireless M-Bus.

Description of the semantic coverage and main data elements

The EN 13757-1 standard does not cover electricity meters and it references DLMS/COSEM for generic concepts that are related to meters and remote reading of meters. The IEC 62056-7-3 standard contains a normative Annex with Mapping from M-Bus (VIF/DIF) towards COSEM identifiers (OBIS) for core meter data elements. Therefore, we refer the reader to IEC 62056 COSEM in Section 3.3.2 for the core meter data elements that are also contained in EN 13757-1.

Interface covered in the end-to-end DSF flow

H2, H1 (see Figure 3-1).

3.3.3.2 CENELEC EN 50491-12

Standard Acronym and Full Name

CENELEC prEN 50491-12 “Smart grid - Application specification - Interface and framework for customer” is part of the EN 50491 series “General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS)”. The upcoming standard EN 50491-12 will comprise the following parts:

- prEN 50491-12-1 Part 1: Interface between the CEM and Home/Building Resource manager– General Requirements and Architecture;
- prEN 50491-12-2 Part 2: Interface between the Home/Building CEM and Resource manager(s)- Data model and messaging;
- prEN 50491-12-3 Part 3: Home/Building Customer Energy Manager (CEM);
- Part 12-4: Resource manager.

Issuing Organisation/ Technical Committee/ Industry Alliance

CENELEC, European Committee for Electrotechnical Standardization, TC 205 Home and Building Electronic Systems (HBES) (see Section 3.3.1).

Most relevant URLs, and other precise references

The prEN 50491-12-1 is a published draft currently available from the TC 205 Work Programme at https://www.cenelec.eu/dyn/www/f?p=104:110:115820593117301::::FSP_ORG_ID,FSP_PROJECT,FS P_LANG_ID:1258281,63376,25. The download requires credentials. The standard can be purchased from CENELEC's National Committees and Affiliates for a fee. The prEN 50491-12-1 draft is currently in the ‘Enquiry stage’ status and its Date of Publication (DOP) is estimated for 2019-10-04.

Overall description

Today renewable energy is not always available to meet demand. To increase efficiency, the energy request should be aligned with the available energy supply. To reach this goal, communication between the various equipment and systems of the stakeholders within the energy field is necessary. This grid, exchanging information and energy between producers, consumers, distributors and metering is known as the “Smart Grid”. The 50491-12 series describes aspects of this smart grid that relate specifically to home and building electronic systems and Building Automation and Control Systems (BACS) part of a smart grid premises side system, including the common interface between equipment in the premises and the smart grid.

Description of the semantic coverage and main data elements

The draft prEN 50491-12-1 applies to all Home and Building Electronic Systems (HBES) and Building Automation Control Systems (BACS) and specifies the general requirements and architecture of an application layer interface between the Customer Energy Manager (CEM) and Smart Devices (SD) operating within the smart grid premises side system (i.e. home or building, but not industrial premises). The semantic coverage further includes concepts and components such as Customer Energy Manager System (CEMS), Energy Management Gateway (EMG), Head End System (HES), Local Network Access Point (LNAP), Meter Data Management (MDM), Resource Manager, Neighborhood

Network Access Point (NNAP), Premises, Smart Appliances, Smart Grid Connection Point (SGCP) and Smart Meter Gateway (SMG).

Interface covered in the end-to-end DSF flow

S2 (see Figure 3-1).

3.3.3.3 EFI (input to CENELEC EN 50491-12-2)

Standard Acronym and Full Name

Energy Flexibility Interface (EFI)

Issuing Organisation/ Technical Committee/ Industry Alliance

The Flexiblepower Alliance Network (FAN)¹⁸ is an alliance of companies and institutions that jointly develop and manage a number of solutions (i.e., specifications, software platforms and underlying technology). The Flexiblepower Alliance Network¹⁹ contributes to a renewable energy future by promoting open-source standards for flexible energy demand, matching the variations in renewable energy, paving the way for a fully renewable energy future. Solutions offered by the alliance are Open Source, all interested parties are free to use FAN international specifications. Among these solutions, the Energy Flexibility Interface (EFI)²⁰ is a communications protocol to control multiple types of smart appliances (dish washers, heating, air conditioning, solar panels, car charging) and signal the smart grid its energy flexibility.

EFI is currently an input to the TC205 WG18 for the upcoming CENELEC prEN 50491-12-2 “Smart grid - Application specification - Interface and framework for customer. Part 12-2: Interface between the Home/Building CEM and Resource manager(s) - Data model and messaging” (see CENELEC prEN 50491-12 description in Section 3.3.3 for details).

Most relevant URLs, and other precise references

The latest specification of the FAN Energy Flexibility Interface (EFI 2.0) is available at <https://github.com/flexiblepower/efi> under an Apache License version 2.0 and provides:

- An XSD file that specifies the EFI schema
- Examples of data instances in XML that are compliant with the EFI schema in XSD

Overall description

The underlying assumption is that manufacturers that supports EFI in their products will be able to communicate with all Smart Grid technologies (such as Powermatcher, OpenADR, Triana) and developers of new Smart Grid technologies that support EFI will enable communication of their solution with other smart devices that support EFI. An important difference compared to other protocols is that EFI does not model a smart device, but only the available energy flexibility and the way it is utilized by the Smart Grid technology. By focusing only on energy flexibility, devices specific details and functions for other purposes than energy management can be omitted, interoperability is guaranteed and complexity is greatly reduced.

¹⁸ <http://flexible-energy.eu/>

¹⁹ Current partners of the alliance include Alliander (<https://www.alliander.com/en>), Dutch Heat Pump Association (<http://dhpa-online.nl/>) and Stedin (<https://www.stedin.net/>).

²⁰ <http://flexible-energy.eu/efi/>

Description of the semantic coverage and main data elements

The semantic coverage of FAN EFI consists of the following main concepts:

- A *Resource* represents a functional (hardware) component that consumes, produces, releases, or converts electricity or physical substances and that has some flexibility in its energy usage and can therefore be energy-managed. Resources represent devices within a household or a building that can provide flexibility regarding consumption, storage and production of energy;
- *Device manager*, or *resource manager*, describes the energy flexibility of a device in a generic and standardized way. A CEM is only interested in exploiting energetic flexibility and not in the specifics of a washing machine, for instance. The energetic flexibility is expressed in the following four energy flexibility categories that cover most appliances:
 - *Shiftable resources* are resources that can shift the generation or usage of energy over a specific period. Examples are washing machines with a possibility to postpone the start time. Parameters in the flexibility information of a shiftable resource are an energy profile and a period over which the start moment can be shifted. With the shiftable energy flexibility category it is also possible to send independently schedulable sub-profiles, and to provide multiple alternative energy profiles from which a CEM can choose;
 - *Storage resources* are resources that can temporarily consume (or produce) more energy so they will use (or generate) less energy at a later moment in time. In most cases these are thermic buffers such as heating devices or refrigerators, but can also be storage devices like electric vehicles or batteries. Examples of parameters for the storage category are: total buffer capacity, filling, minimal run times and cooldown times, leakage functions, usage forecasts and targets for charging or discharging the Storage resource;
 - *Adjustable resources* are resources that are resources that can be controlled to produce or consume energy, and don't have any storage constraints. Minimal run times and cooldown times can be described. A typical example would be a diesel generator;
 - *Inflexible resources* are type of Resources whose energy behavior cannot be controlled (e.g. solar panels, TV, computers, etc.). For this resources only a prediction can be made for the expected consumption or production of energy. These predictions can be used in the rest of the framework to make decisions on energy control. This category also supports curtailment.

A CEM receives the flexibility information and decides how to exploit the energetic flexibility. As a response to the flexibility inform, the CEM will send an instruction which contains the energy profile that a resource must follow. An instruction should always respect the constraints that were expressed in the flexibility information, although it is possible to violate flexibility constrains in the case of grid emergencies.

Interface covered in the end-to-end DSF flow

S2 (see Figure 3-1).

3.3.3.4 ETSI TR 103 411 (SAREF Extension Investigation)

Standard Acronym and Full Name

ETSI TR 103 411 “SmartM2M; Smart Appliances; SAREF extension investigation”.

Issuing Organisation/ Technical Committee/ Industry Alliance

ETSI, European Telecommunications Standards Institute, TC Smart Machine-to-Machine communications (SmartM2M) (see Section 3.3.1).

Most relevant URLs, and other precise references

The SAREF extension investigation TR 103 411 V1.1.1 (2017-02) can be downloaded for free from http://www.etsi.org/deliver/etsi_ts/103200_103299/103264/02.01.01_60/ts_103264v020101p.pdf

The TR 103 411 technical report further contains an example of how to instantiate a power profile using the SAREF4ENER extension of SAREF (see Section 3.3.2 for details on SAREF4ENER). The Turtle²¹ code for this example can be downloaded from <http://ontology.tno.nl/examples/saref4ener/heatingsystem.ttl>.

Overall description

Following the first SAREF study promoted by the European Commission (SMART 2013/0077), ETSI TC SmartM2M requested in 2016 a Specialist Task Force (STF) to provide input on the management of SAREF, identify possible SAREF extensions in specific domains and create these extensions. STF 513 was therefore established with the goal to develop 3 extensions for SAREF in the Energy, Environment and Building domains. The TR 103 411 “SmartM2M; Smart Appliances; SAREF extension investigation” describes the use cases covered by the three extensions SAREF4ENER, SAREF4ENVI and SAREF4BLDG, and the requirements that were used to build these extensions. TR 103 411 further proposes a strategy for the extension and maintenance of SAREF and its extensions. Furthermore, it provides examples of data based on SAREF and its extensions.

Description of the semantic coverage and main data elements

The TR 103 411 technical report describes, among others, the use cases covered by the extension SAREF4ENER for the energy domain, which are the following:

- Use case 1: configuration of devices that want to connect to each other in the home network, for example, to register a new dishwasher to the list of devices managed by the CEM;
- Use case 2: smart energy management/ (re-)scheduling of appliances in certain modes and preferred times using power profiles to optimize energy efficiency and accommodate the customer's preferences;
- Use case 3: monitoring and control of the start and status of the appliances;
- Use case 4: reaction to special requests from the Smart Grid; for example, incentives to consume depending on current energy availability, or emergency situations that require temporary reduction of the power consumption.

²¹ Turtle (file extension “.ttl”) is a serialization for ontologies and data expressed in RDF/OWL that offers a compact and easy to understand syntax also for humans. Turtle files can be opened as text files using any text editor such as Notepad, or can be inspected using ontology editors such as Protégé or TopBraid Composer.

These use cases are associated with user stories such as the following:

- User wants to do basic settings of his/her devices;
- User wants to know when the washing machine has finished working;
- User wants the washing done by 5:00 p.m. with least electrical power costs;
- User likes to limit his/her own energy consumption up to a defined limit;
- User allows the CEM to reduce the energy consumption of his/her freezer in a defined range for a specific time, if the grid recognizes (severe) stability issues;
- Grid related emergency situations (blackout prevention).

Concerning data elements, the TR 103 411 technical report includes an example of how to instantiate a Power Profile used by a heating system with hot water tank to communicate its energy flexibility to the CEM according to the consumer's preferences and needs. The power profile is used by the heating system device to expose the power sequences that are potentially relevant for the CEM, for example, regarding its expected energy consumption for a certain day. In particular, the power profile in the example consists of two groups with alternative plans (each group modelled as an *AlternativesGroup* class) that do not overlap in time and allow to model consecutive (and also rather independent) periods of action: 1) one group of alternatives for a task in the morning, and 2) a second group of alternatives for another task in the afternoon. Within one group, there can be one or more plans (or power sequences) that are alternatives to each other, i.e., at most one of these plans/power sequences can be finally executed. For example, in the afternoon alternative group, the heating system can offer the two following alternative plans to charge the hot water tank: 2.a) a "cheapest" plan in which the CEM should try to minimize the user's energy bill and permits the CEM to shift the start between e.g. 2:45 p.m. and 5:00 p.m.; and 2.b) a "greenest" plan in which the CEM should try to optimize the configuration towards the maximum availability of renewable energy (it can even announce the user's preference for "green energy"). In other words, the CEM can take a choice for the "cheap" or "green" plan for the afternoon. These plans may have further options with regards to their flexibility. For example, one of the plans may offer that the CEM can pause a sequence (as long as the sequence completes before the latest time set by the user). Finally, a plan/power sequence consists of one or more slots that represent different phases of consumption (or production) and their values. The power sequences of the heating system example have a single slot each. However, for other devices such as washing machines, a power sequence may have various slots for the different phases of washing, such as heating the water, washing and rinsing.

Interface covered in the end-to-end DSF flow
S2, S1 (see Figure 3-1).

3.3.3.5 IEC TR 62746-2

Standard Acronym and Full Name

IEC TR 62746-2 "Systems interface between customer energy management system and the power management system - Part 2: Use cases and requirements".

Issuing Organisation/ Technical Committee/ Industry Alliance

IEC, International Electrotechnical Commission, TC57 - Power systems management and associated information exchange, WG 21 - Interfaces and protocol profiles relevant to systems connected to the electrical grid (see Section 3.3.1).

Most relevant URLs, and other precise references

IEC TR 62746-2:2015(EN) is a published document currently available at <https://webstore.iec.ch/publication/22279>. This standard is not available for free, but it can be purchased from IEC.

Overall description

IEC TR 62746-2 describes the main pillars of interoperability to assist different Technical Committees in defining their interfaces and messages covering the whole chain between a smart grid and smart home/building/industrial (H/B/I) area. The main topics covered by this technical report are: architecture model from a logical point of view; set of user stories describing several situations related to energy flexibility and demand side management; set of use cases based on the user stories and architecture; details of the communication; identified in the use cases, by describing the requirements for messages and information to be exchanged.

Description of the semantic coverage and main data elements

As discussed in Section 2, the IEC TR 62746-2 document covers several use cases from which we could identify the following data elements:

- Use case 2, Flexible start of Smart Device (SD)
 - Control parameters, e.g. profile selection
 - Preferred time slot of operation per SD
 - Flex start enabled
 - Energy consumption
 - Energy Profile
 - Start time/ time slot of operation
 - New tariff information
 - Recalculated start time / time slot
 - Operation commands
- Use case 3 Response of Smart Home to Emergency
 - Emergency signal
 - Emergency load command
- Use case 4, Control of non-smart Device by CEM, based on pre-set tariff threshold (set by user) and actual tariff
 - Tariff threshold
 - Real Time Tariff
 - operation commands (increase or decrease power and turn off/on)
- Use case 5, Direct Load Control of Smart Device via CEM
 - Id of participating devices
 - Power thresholds
 - Load management signal
 - Load adjustment command
 - Feedback about adjustment
 - Expected change in consumption
- Use case 6, Demand-supply adjustment by cooperation between supplier and customer
 - Price information of electrical energy based on time of use (TOU)

- Planned load profile (expected consumption in time)
- Use case 7, Exchanging information on (partial) consumption
 - Actual Individual Appliances (= partial) consumption/generation
 - Forecasted partial consumption/generation
 - Actual total house consumption
 - Forecasted total house consumption
- Use case 8, External Actor Retrieves status of smart devices
 - Device Status Request
 - Device Status
 - Status is displayed to consumer
- Use case 9, CEM requests time from Smart Meter GW and Smart Meter GW synchronizes time of CEM
 - Actual time request
 - Actual time
- Use case 10, Smart Meter GW notifies actual tariff to CEM
 - Active tariff notification

Interface covered in the end-to-end DSF flow
S2, S1, G3, H2, H1 (see Figure 3-1).

3.3.3.6 IEC TS 62913-2-3

Standard Acronym and Full Name

IEC TS 62913-2-3 Ed.1 “Generic Smart Grid Requirements - Part 2-3: Domains - Resources connected to the grid related domains, these include Bulk Generation, Distributed Energy Resources, Smart Home / Commercial / Industrial / DR-Customer Energy Management, and Energy Storage”

Issuing Organisation/ Technical Committee/ Industry Alliance

IEC, International Electrotechnical Commission TC8 - Systems aspects for electrical energy supply, WG6 SyC Smart Energy (see Section 3.3.1).

Most relevant URLs, and other precise references

IEC TS 62913-2-3 ED1 is available at http://www.iec.ch/dyn/www/f?p=103:38:7354931541404:::FSP_ORG_ID,FSP_APEX_PAGE,FSP_PROJECT_ID:11825,23,22240. This standard is not available for free, but it can be purchased from IEC.

Overall description

The IEC TS 62913-2-3 document defines the Generic Smart Grid Requirements of resources connected to the grid related domains. Chapter 4 provides a business analysis of Smart Home / Commercial / Industrial / DR-Customer and Energy Management. It presents a list of ‘Business Use cases’ for Smart Homes, as well as ‘System Use Cases’.

Description of the semantic coverage and main data elements

As discussed in Section 2, the IEC TS 62913-2-3 document covers several use cases from which we could identify the following data elements:

- Use case 1, Device Registration & Configuration

- Device Identifier
- Device capabilities

The original specification refers to “Smart Devices” and since this Use Cases should also cover CEM identifier and capabilities, we use the word “Device”.

- Use case 2, Flexible start of Smart Device (SD)
 - Control parameters, e.g. profile selection
 - Preferred time slot of operation per SD
 - Flex start enabled
 - Energy consumption
 - Energy Profile
 - Start time/ time slot of operation
 - New tariff information
 - Recalculated start time / time slot
 - Operation commands
- Use case 3 Response of Smart Home to Emergency
 - Emergency signal
 - Emergency load command
- Use case 5, Direct Load Control of Smart Device via CEM
 - Id of participating devices
 - Power thresholds
 - Load management signal
 - Load adjustment command
 - Feedback about adjustment
 - Expected change in consumption
- Use case 6, Demand-supply adjustment by cooperation between supplier and customer
 - Price information of electrical energy based on time of use (TOU)
 - Planned load profile (expected consumption in time)

Interface covered in the end-to-end DSF flow
S2, S1, G3, H2 (see Figure 3-1).

3.3.3.7 oneM2M TS 0001 (Functional Architecture)

Standard Acronym and Full Name

oneM2M TS 0001 Functional Architecture

Issuing Organisation/ Technical Committee/ Industry Alliance

oneM2M (see Section 3.3.1).

Most relevant URLs, and other precise references

The latest version of the oneM2M Functional Architecture specification can be downloaded from <http://onem2m.org/technical/published-drafts>. In this study we consider TS 0001 V2.10.0 Release 2 “Functional Architecture”.

Overall description

oneM2M defines a Layered Model for supporting end-to-end (E2E) M2M Services that comprises three layers: Application Layer, Common Services Layer and the underlying Network Services Layer. The TS 0001 specification describes the end-to-end oneM2M functional architecture across this oneM2M Layered Model and comprises the following three main entities: 1) Application Entity (AE), which is an entity in the Application Layer that implements an M2M application service logic. Examples of the AEs include an instance of a fleet tracking application, a remote blood sugar monitoring application, a power metering application, or a controlling application; 2) Common Services Entity (CSE), which represents an instantiation of a set of "common service functions" of the M2M environments. Such service functions are exposed to other entities through reference points (interfaces) called "Mca" and "Mcc". Another reference point, called "Mcn", is used for accessing underlying Network Service Entities. Examples of service functions offered by CSE include: Data Management, Device Management, M2M Service Subscription Management, and Location Services; and 3) Underlying Network Services Entity (NSE), which provides services from the underlying network to the CSEs. Examples of such services include device management, location services and device triggering.

Description of the semantic coverage and main data elements

The semantic coverage of the Functional Architecture specification includes the following concepts:

- Application Layer: comprises oneM2M Applications and related business and operational logic;
- Application Entity: represents an instantiation of Application logic for end-to-end M2M solutions;
- Common Services Entity (CSE): represents an instantiation of a set of Common Service Functions of the M2M environments. Such service functions are exposed to other entities through reference points;
- Common Services Layer: consists of oneM2M service functions that enable oneM2M Applications (e.g. management, discovery and policy enforcement);
- Common Services Function (CSF): architectural construct which conceptually groups together several sub-functions;
- M2M Application: applications that run the service logic and use M2M Common Services accessible via a set of oneM2M specified open interfaces;
- M2M Application Infrastructure: equipment (e.g. a set of physical servers of the M2M Application Service Provider) that manages data and executes coordination functions of M2M Application Services;
- M2M Application Service: realized through the service logic of an M2M Application and is operated by the User or an M2M Application Service Provider;
- M2M Application Service Provider: entity (e.g. a company) that provides M2M Application Services to the User;
- M2M Area Network: form of an Underlying Network that minimally provides data transport services among M2M Gateway(s), M2M Device(s), and Sensing&Actuation Equipment;
- M2M Device: physical equipment with communication capabilities, providing computing and/or sensing and/or actuation services;
- M2M Common Services: set of oneM2M specified functionalities that are widely applicable to different application domains made available through the set of oneM2M specified interfaces;

- M2M Gateway: physical equipment that includes, at minimum, the entities and APIs of a Middle Node;
- M2M Service: consists of one or more M2M Application Services and one or more M2M Common Services;
- M2M Service Infrastructure: physical equipment (e.g. a set of physical servers) that provides management of data and coordination capabilities for the M2M Service Provider and communicates with M2M Devices;
- M2M Service Provider: entity (e.g. a company) that provides M2M Common Services to a M2M Application Service Provider or to the User;
- Managed Entity: may be either an M2M Device, M2M Gateway, or a device in the M2M Area Network or the M2M Application Layer or M2M Service Layer software components;
- Network Services Layer: provides transport, connectivity and service functions;
- Node: logical entity that is identifiable in the oneM2M System;
- non-oneM2M Node: node that does not contain oneM2M Entities;
- oneM2M System: system developed by the oneM2M global initiative that enables deployable M2M Solutions;
- Reference Point: A reference point consists of one or more interfaces of any kind. The following reference points are supported by the Common Services Entity (CSE): Mca Reference Point, Mcc Reference Point, Mcn Reference Point and Mcc' Reference Point;
- Resource: uniquely addressable entity in oneM2M architecture;
- Thing: element which is individually identifiable in the oneM2M system;
- Virtual Device: logical device (implemented as software) that acts similar to physical M2M Device and provides derived data. EXAMPLE: Average temperature of a room, number of vehicles that passed during the last minute.

Interface covered in the end-to-end DSF flow
S1, G3 (see Figure 3-1).

3.3.3.8 OpenADR

Standard Acronym and Full Name

OpenADR (Automated Demand Response) Profile Specification.

Issuing Organisation/ Technical Committee/ Industry Alliance

The OpenADR Alliance (<http://www.openadr.org>) was formed in 2010 by industry stakeholders to foster the development, adoption and compliance of the Open Automated Demand Response (OpenADR) Smart Grid standard. The mission of the OpenADR Alliance is to foster the development, adoption, and compliance of the Open Automated Demand Response (OpenADR) standards through collaboration, education, training, testing and certification.

Most relevant URLs, and other precise references

OpenADR 2.0a Profile Specification_v1.0

OpenADR 2.0b Profile Specification_v1.1

Based on the OASIS Energy Interoperation Standard, the OpenADR Alliance created several product profile specifications. The OpenADR 2.0a and OpenADR 2.0b Profile Specifications provide specific implementation related information to build an OpenADR enabled device or system.

The OpenADR 2.0 Specifications can be downloaded from <http://www.openadr.org/specification> after registration.

Overall description

Demand Response (DR) plays a vital role in grid stabilization during hot Summers, easing severely constrained electrical grids from coast-to-coast. Future energy crises caused by electricity demand exceeding system capacity can be postponed or even averted through Demand Response. Automated Demand Response (ADR) helps system operators reduce the operating costs of DR programs while increasing DR resource reliability. For customers, ADR reduces the resources and effort required to achieve successful results from these DR programs. Automation is what also makes it possible to translate changes in wholesale markets to corresponding changes in retail rates, enabling customers to respond to DR signals in real-time to reduce demand.

Successful implementation of ADR requires standardization allowing wholesale producers to communicate with utilities and aggregators, who in turn communicate with their customers, who can then reduce demand during peak periods. Without an ADR standard, automated DR would be difficult and costly to implement. System development, integration and installation costs could grow to prohibitive levels, and these proprietary and expensive assets could eventually become stranded. Open Automated Demand Response (OpenADR) is an open and standardized way for electricity providers and system operators to communicate DR signals with each other and with their customers using a common language over any existing IP-based communications network, such as the Internet. OpenADR has achieved widespread support throughout the industry.

Description of the semantic coverage and main data elements

The OpenADR 2.0 profile specification is a flexible data model to facilitate common information exchange between electricity service providers, aggregators, and end users. The concept of an open specification is intended to allow anyone to implement the two-way signalling systems, providing the servers, which publish information (Virtual Top Nodes or VTNs) to the automated clients, which subscribe the information (Virtual End Nodes, or VENS). This OpenADR 2.0 profile specification covers the signalling data models between VTN and VEN (or VTN/VEN pairs) and does include information related to specific DR electric reduction or shifting strategies, which are taken at the facility.

OpenADR 2.0 supports the following services from OASIS EI Version 1.0 standard or subset thereof. Extensions to these services are included to meet the DR stakeholder and market requirements:

- Registration (EiRegisterParty): Register is used to identify entities such as VEN's and parties. This is necessary in advance of an actor interacting with other parties in various roles such as VEN, VTN, tenderer, and so forth.
- Enrollment (EiEnroll): Used to enroll a Resource for participation in DR programs. This establishes a relationship between two actors as a basis for further interactions. (Planned for future releases)

- Market Contexts (EiMarketContext): Used to discover program rules, standard reports, etc. Market contexts are used to express market information that rarely changes, and thereafter need not be communicated with each message. (Planned for future releases)
- Event (EiEvent): The core DR event functions and information models for price responsive DR. This service is used to call for performance under a transaction. The service parameters and event information distinguish different types of events. Event types include reliability events, emergency events, and more – and events MAY be defined for other actions under a transaction.
- Quote or Dynamic Prices (EiQuote): EiDistributeQuote for distributing complex dynamic prices such as block and tier tariff communication. These are sometimes referred to as price signals; such signals are indications of a possible tender price - they are not themselves actionable.
- Reporting or Feedback (EiReport): The ability to set periodic or one-time information on the state of a Resource (response).
- Availability (EiAvail): Constraints on the availability of Resources. This information is set by the end node and indicates when an event may or may not be accepted and executed by the VEN with respect to a Market Context. Knowing the Availability and Opt information for its VENs improves the ability of the VTN to estimate response to an event or request. (Planned for future releases)
- Opt or Override (EiOpt): Overrides the EiAvail; addresses short-term changes in availability to create and communicate Opt-in and Opt-out schedules from the VEN to the VTN.

Interface covered in the end-to-end DSF flow G3 (see Figure 3-1).

3.3.3.9 SPINE

Standard Acronym and Full Name

SPINE (Smart Premises Interoperable Neutral-Message Exchange) specification.

Issuing Organisation/ Technical Committee/ Industry Alliance

The SPINE specification is created and maintained by the EEBUS initiative in collaboration with the Energy@home association. Nota that the SPINE specification is standardized by TC 59 WG 7 in CENELEC (see Section 3.3.1) in the prEN 50631-1 specification (see CENELEC EN 50631-1 description in Section 3.3.2).

EEBUS is a non-profit organization for interoperability in the area of the Internet of Things with a strong focus on standardisation. The EEBUS initiative focuses on domains such as smart energy, smart home and building, connected devices (domestic appliances, heating and air conditioning), connected car and, more in general, smart connectivity. Originated in Germany, the EEBUS initiative counts now global partnerships with various associations in Europe, Asia and the USA. EEBUS is active in several standardisation bodies, such as the VDE standardisation organisation DKE in Germany, and relevant organisations at European (CENELEC and ETSI) and international level (IEC). The benefit of standardisation is used by the EEBUS initiative to open up a future market which could not be realized through closed systems.

Energy@home is a non-profit organization founded in 2012 from the results of a collaborative project among Electrolux, Enel Distribuzione, Indesit Company and Telecom Italia. The Energy@home association includes now various European members with the mission of developing technologies and services for energy efficiency in smart homes, based on the interaction between user devices and the energy infrastructure. The goal of Energy@home association is to promote products and services based on the interoperability of various appliances within the household. Energy@home has established a Standardisation Committee to maintain its technical specifications leveraging on collaborations with other standard organisations and alliances, such as the EEBUS initiative and the ZigBee Alliance (Energy@home is an acknowledged contributor to the ZigBee Home Automation 1.2 standard).

Most relevant URLs, and other precise references

The SPINE Specification 1.0 (2016-04-29) consists of the following documents:

- SPINE Technical Report Introduction “Intro duction” Version 1.0.0
- SPINE Technical Specification “Protocol Specification” Version 1.0.0
- SPINE Technical Specification “Resource Specification” Version 1.0.0
- SPINE_V1.0.0_XSDs

The SPINE specification can be downloaded from <https://www.eebus.org/en/downloads/> after registration.

Overall description

SPINE defines a neutral layer to connect different technologies to build a smart home/ smart grid system. SPINE defines messages and procedures on application level and is independent from the used transport protocol. Any technology that supports the bi-directional exchange of arbitrary data can be used directly, e.g., SmartHome IP (SHIP), which is also created by the EEBUS Initiative, or Thread, which is very much used by the Energy@home association. For other communications technologies, a mapping is needed. SPINE covers use cases concerning control and monitoring of smart appliances like White Goods, HVAC systems and adjacent devices like batteries, e-cars, etc. with a focus on the sectors of smart energy, smart home and building, connected devices and E-Mobility. Domains like Ambient Assisted Living (AAL), home entertainment, etc. are currently not in the focus of SPINE, although some use cases from these domains can be realised with the existing data model. The SPINE data model evolves continuously. Hence, further domains will be added in the future. The SPINE data model is specified in XML Schema Definition (XSD), therefore the file extension ".xsd".

The SPINE data model is divided into classes, functions and elements as follows:

- Classes, such as the *Measurement*, *Sensing*, and *Time Information* classes, define sets of functions that can be used for communication. For example, the *Measurement* class defines all functions related to measurement;
- Functions are the resources that are used for communication. For example, *measurementListData* and *measurementConstraintsListData* are functions for the *Measurement* class;
- Elements are function specific datapoints that represent a single piece of information, such as a value, a timestamp, a unit, etc. A function defines a set of elements. For example, the

measurementListData element of the corresponding *measurementListData* function contains the actual value of a measurement.

Description of the semantic coverage and main data elements

The SPINE data model covers Device Types, Entity Types and Feature Types/Classes, as follows:

- Device Types (i.e., physical devices such as a “Fridge Freezer” or “Heat Pump”): Dishwasher, Dryer, Environment Sensor, Heat Generation System, Heat Sink System, Heat Storage System, HVAC Controller, Sub Meter, Washer.
- Entity Types (i.e., logical devices such as a “Freezer” that is one logical part of a physical device “FridgeFreezer”): Battery, Compressor, Domestic Hot Water (DHW) Circuit, DHW Storage, Dishwasher, Dryer, Electrical Immersion Heater, Fan, Gas Heating Appliance, Heating Buffer Storage, Heating Circuit, Heating Object, Heating Zone, Heat Pump Appliance, Heat Sink Circuit, Heat Source Circuit, Heat Source Unit, HVAC Controller, HVAC Room, Household, Instant DHW Heater, Inverter, Oil Heating Appliance, Pump, Refrigerant Circuit, Smart Energy Appliance, Solar DHW Storage, Solar Thermal Circuit, Sub Meter Electricity, Temperature Sensor, Washer.
- Feature Types (i.e., specific usage of a function defined by a Class) and corresponding Classes: Actuator Level, Actuator Switch, Alarm, Data Tunneling, Device Classification, Device Diagnosis, Direct Control, Electrical Connection, HVAC, Load Control, Measurement, Messaging, Network Management, Node Management, Operating Constraints, Power Sequences, Sensing, Setpoint, Smart Energy Management Ps, Subscription Management, Supply Condition, Task Management, Threshold, Time Information, Time Table, Version.

Interface covered in the end-to-end DSF flow

S2 (see Figure 3-1).

3.4 Results

The objective of this task was to identify a short list of standards to be used as a basis to further proceed with alignments and to assess if the use cases and data elements in scope are sufficiently covered by these standards, using SAREF and SAREF4ENER as common mapping tool.

3.4.1 Short list of standards

The short-listed standards are used as a basis to further proceed with data alignments in the study. The short list is presented in the table below.

Table 3-2: Short list of standards identified in the DSF study

#	Reference/ Issued by	URL
2	CEN EN 16836 (TC 294) / ZigBee SEP2 (ZigBee Alliance) Communication systems for meters - Wireless mesh networking for meter data exchange	https://standards.cen.eu/dyn/www/f?p=204:32:0:::FSP_ORG_ID,FSP_LANG_ID:6275,25&cs=1A1D2A71837AB4AB1532B872DBD554033 OR http://www.zigbee.org/about/centc294

#	Reference/ Issued by	URL
3	CENELEC EN 50491-11 (TC 205) General requirements for Home and Building Electronic Systems (HBES) and Building Automation and Control Systems (BACS) - Part 11: Smart Metering - Application Specifications - Simple External Consumer Display	https://www.cenelec.eu/dyn/www/f?p=104:110:1686791285416701:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1258281,42730,25
5	CENELEC prEN 50631-1 (TC59 WG7) / SPINE (EEBUS and E@h) Household appliances network and grid connectivity - Part 1: General Requirements, Generic Data Modelling and Neutral Messages	https://www.cenelec.eu/dyn/www/f?p=104:110:1438163728984601:::FSP_ORG_ID,FSP_PROJECT,FSP_LANG_ID:1257245,47024,25 OR https://www.eebus.org/en/downloads/
7	ETSI SAREF TS 103 264 (SmartM2M TC) SmartM2M; Smart Appliances; Reference Ontology and oneM2M Mapping	http://www.etsi.org/deliver/etsi_ts/103200_103299/103264/02.01.01_60/ts_103264v020101p.pdf
8	ETSI SAREF4ENER TS 103 410-1 (SmartM2M TC) SmartM2M; Smart Appliances Extension to SAREF; Part 1: Energy Domain	http://www.etsi.org/deliver/etsi_ts/103400_103499/10341001/01.01.01_60/ts_10341001v010101p.pdf
10	IEC 61968-9 CIM for Metering (TC 57 WG14) Common Information Model (CIM)/ Distribution Management	http://www.iec.ch/smartgrid/standards/
11	IEC 61970-301 CIM Core (TC 57) Common information model (CIM)/Energy Management	http://www.iec.ch/smartgrid/standards/
12	IEC/ CENELEC 62056 COSEM (TC 13 WG 14) Electricity metering - Data exchange for meter reading, tariff and load control	https://webstore.iec.ch/publication/24231 OR http://dlms.com/PASSWORD/Books/Blue_Book_1_1th_edition.pdf
15	CENELEC EN 50090 for home building and control (TC 205)/ KNX specification for home building and control (KNX Association)	https://my.knx.org/en/shop/knx-specifications
17	oneM2M Base Ontology TS 0012 (oneM2M)	http://onem2m.org/technical/published-drafts

Note that this short list is not an endorsement by DNV-GL, TNO, ESMIG or the European Commission, it only provides a means to further proceed with alignments and investigate a possible solution for interoperability in this study. Standards that are not included in the short list can be used by the interested stakeholders to generate new interoperability solutions using the alignment approach proposed in Section 4.2.

3.4.2 Non-selected standards

Nine standards from the long list have been discarded from further proceeding with alignments, as they did not satisfy one or more of the Short List (SL) criteria presented in Section 3.2. Note that the complete state of standardisation for DSF in the scope of this study is provided by both the short-listed and the non-selected standards. The non-selected standards are:

- CEN EN 13757-1
- CENELEC EN 50491-12
- EFI (input to CENELEC EN 50491-12-2)
- ETSI TR 103 411 (SAREF Extension Investigation)

- IEC TR 62746-2
- IEC TS 62913-2-3
- oneM2M TS 0001 (Functional Architecture)
- OpenADR
- SPINE specification (referenced in CENELEC EN 50631-1)

These standards and industry specifications are not considered for further data elements alignment in this study for the following reasons:

- CEN EN 13757-1 references COSEM identifiers (OBIS) for core meter data elements, and IEC 62056 COSEM was already selected to be part of our short list. Therefore, it is not necessary to consider also CEN EN 13757-1.
- CENELEC EN 50491-12-1 specifies the general requirements and architecture between the Customer Energy Manager (CEM) and Smart Devices. Therefore, it does not contain data definitions that allow us to extract data elements, as required by criterion SL1 in Section 3.2. In contrast, CENELEC EN 50491-12-2 would be suitable for data alignments, but it is an ongoing work in TC 205 WG18 and there is no draft specification that can be referenced. Therefore it cannot be considered as input for our study.
- EFI is one of the inputs currently used for discussion for the upcoming CENELEC EN 50491-12-2. It is suitable for data alignments, but it is not recognised yet by any official standardization body nor is a de-facto widely-adopted international industry standard, therefore it cannot be further considered in this study.
- ETSI TR 103 411 (SAREF Extension Investigation) mainly describes the use cases on which SAREF4ENER is based, rather than data elements. Therefore, it does not satisfy the criterion SL1 in Section 3.2. Note that although TR 103 411 presents a useful instantiation of SAREF4ENER, this instantiation does not add information in terms of semantic coverage compared to the SAREF4ENER specification that is already part of the short list.
- IEC TR 62746-2 and IEC TS 62913-2-3 are relevant for this study and the interfaces of interest, but they describe use cases and provide limited input to the identification of data elements for alignments. Therefore, they do not satisfy the criterion SL1 in Section 3.2.
- oneM2M TS 0001 describes the oneM2M Functional Architecture, therefore it does not contain data definitions that allow us to extract data elements, as required by criterion SL1 in Section 3.2. Note that, however, the oneM2M TS 0012 specification is included in the short list, as it specifies the oneM2M Base Ontology, which is suitable for data alignments.
- The OpenADR specification has a similar semantic coverage to the IEC CIM standard. A mapping effort is currently being performed between OpenADR and IEC CIM. As it is out of scope to duplicate efforts already being done elsewhere, openADR is not in the short list.
- SPINE is an industry specification that has been used in CENELEC as a basis to the EN 50631-1 standard, and by ETSI as a basis to create SAREF4ENER. Therefore, the relevant data elements from SPINE are fully covered by EN 50631-1 and SAREF4ENER, which are part of the short list.

3.4.3 Positioning of standards

Figure 3-1 positions the short-list standards with respect to the corresponding interfaces in the scope of our study (i.e., S1, S2, G3, H2 and H1).

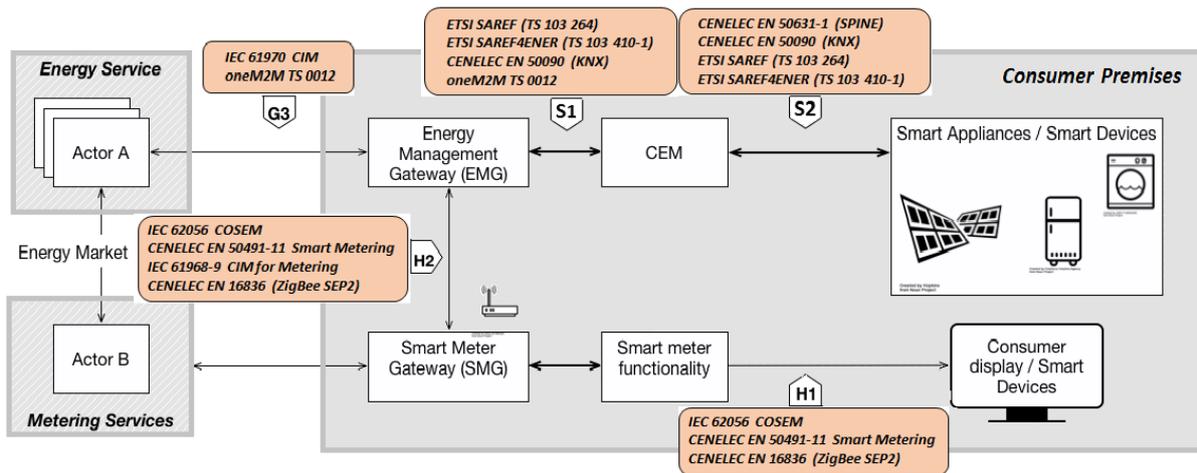


Figure 3-1: Short-list standards considered in the DSF study, positioned with respect to their corresponding interfaces in the DSF flow

3.4.4 Mapping of use cases, interfaces and standards

As shown in Table 3-3, it can be concluded that SAREF and SAREF4ENER classes sufficiently cover the identified use cases and the associated data elements from task 1 (see Section 2). This means that SAREF and SAREF4ENER provide a good basis as a “common mapping tool” to the other short-listed standards selected in this study to create interoperability within Demand Side Flexibility. The alignment of the short-list standards via SAREF and SAREF4ENER as a common mapping tool is elaborated in Section 4.

This conclusion has been drawn from an assessment that compared 1) the data elements associated with the main use cases (see Section 2.3.3); and 2) the ‘Description of semantic coverage and main data elements’ of SAREF and SAREF4ENER (see Section 3.3.2). The result of the assessment is shown in Table 3-3, which provides an initial mapping of use cases, corresponding data elements and interfaces onto SAREF and SAREF4ENER classes. This table is used as basis for further alignments to the other short-listed standards in Section 4.

Table 3-3: Mapping of use cases, corresponding data elements and interfaces with SAREF and SAREF4ENER classes

Involved interfaces	Use cases	Data elements	SAREF and SAREF4ENER classes
S2	# 1: Device Registration & Configuration	Device (ID and capabilities)	saref:Device saref:hasManufacturer saref:hasModel saref:hasFunction saref:controlsProperty saref:measuresProperty saref:Actuator saref:Appliance saref:HVAC saref:LightingDevice saref:Meter saref:Sensor etc. s4ener:Device s4ener:deviceName s4ener:deviceCode

			s4ener:serialNumber s4ener:softwareRevision s4ener:hardwareRevision s4ener:vendorName
S1, S2, H2, G3	# 2: Flexible start of Smart Device	Control parameters, e.g. profile selection Energy Profile Preferred time slot of operation per device Energy consumption Flex start enabled Start time/ time slot of operation; Recalculated start time/ time slot New tariff info Operation commands	s4ener:AlternativesGroup s4ener:PowerSequence s4ener:PowerProfile s4ener:Slot s4ener:Energy s4ener:Power s4ener:StartTime s4ener:EndTime s4ener:EarliestStartTime s4ener:LatestEndTime, etc. saref:Price saref:Command
S1, S2, H2	# 3: Home response to Emergency	Emergency signal Emergency load command	s4ener:LoadControlEventAction s4ener:EventActionConsume s4ener:EventActionProduce s4ener:pause, resume, reduce, increase, emergency, normal
S1, S2, G3	# 4: Control of non-smart Device by CEM (user settings)	Tariff threshold Real Time Tariff Operation commands (increase or decrease power, turn off/on)	saref:Price saref:Currency saref:Time saref:Command
S1, S2, G3	# 5: Direct Load Control of Smart Device via CEM	ID of participating devices Power thresholds Load management signal Load adjustment command Feedback about adjustment Expected change in consumption	s4ener:Device s4ener:deviceName s4ener:deviceCode s4ener:Power s4ener:LoadControlEventAction s4ener:EventActionConsume s4ener:EventActionProduce s4ener:pause, resume, reduce, increase, emergency, normal s4ener:PowerExpected s4ener:EnergyExpected
S1, S2, G3	# 6: Demand/ Supply adjustment	Price information of electrical energy based on time of use Planned load profile (expected consumption in time)	saref:Price saref:Currency s4ener:PowerExpected s4ener:EnergyExpected

S1, S2, H1, H2, G3	# 7: Exchange information on (partial) consumption	Consumption/Generation <ul style="list-style-type: none"> Actual Individual Appliances (= partial) consumption/generation Forecasted partial consumption/generation Actual total house consumption Forecasted total house consumption 	saref:Measurement s4ener:Power saref:PowerUnit s4ener:Energy saref:EnergyUnit
S1, S2, G3	# 8: Smart device status retrieval	Device Status	saref:Device saref:State
S1, H2	# 9: Time info CEM & Smart Meter Gateway	Actual time	saref:Meter saref:Time time:TemporalEntity time:DurationDescription
S1, H2	# 10: Smart Meter Gateway notifies actual tariff to CEM	Active tariff notification	saref:Meter saref:EventFunction saref:NotifyCommand saref:Price

4. Alignments and Actions

4.1 Objective

This study enables semantic interoperability between DSF standards by aligning them on some so-called *core data elements (or core concepts)*. Core data elements are defined here as recurring, common concepts in the DSF domain that define the meaning (or *semantics*) of the data exchanged between standards. For instance, a core data element is *Power* from which more detailed data elements and attributes can be derived, such as *Cumulative Power* or *Instantaneous Power*. A gap occurs when one or more core data elements in the DSF domain are missing in one of the standards under consideration or have a different meaning in different standards.

The goal of task 3 (alignments) was to establish the level of alignment of the short-listed standards, identify gaps among them and define actions to reach alignment.

4.2 Approach

Starting point

The SAREF and SAREF4ENER ontologies have been used in this study as a “common mapping tool” to align short-listed standards to create semantic interoperability, or, in other words, as the overarching ontologies to enable semantic interoperability between DSF standards. SAREF was created in a previous study for the European Commission [4] with a bottom-up approach using 23 so-called “semantic assets” (i.e., standards, data models, protocols, ontologies, specifications) relevant for smart appliances, which provided the core concepts to make SAREF interoperable by design. The underlying assumption in this study was that if the standards in our short-list are aligned with the core concepts in SAREF/SAREF4ENER, then these standards are also aligned with each other on the same core concepts.

Comparing standards

In order to facilitate the task of the alignment of standards, there are various ontology matching algorithms²² can support the comparison automatically [8]. These algorithms take as input files expressed in the OWL format²³, which is typically used to represent ontologies. However, the short-listed standards selected in this study not always provide OWL files nor suitable files (such as XSD and UML) that can be translated to OWL, meaning that for these standards a manual comparison was required.

- **Automatic approach:** For the automatic comparison, TNO has created an alignment-application that creates an alignment based on the similarity between class names in SAREF/SAREF4ENER and data element names in the short-listed standards. The class-name-similarity is calculated by the Python-module *FuzzyWuzzy*²⁴ that comes with out-of-the-box string-comparison algorithms that are based on the *Levenshtein-distance*²⁵. The Levenshtein-distance is defined as the number of single-character edits to convert one input in the other [9]. We used the algorithms *fuzz.ratio*, which takes a full class name and uses the Levenshtein-distance in order to calculate a similarity score), and *fuzz.partial_ratio*, which performs the same similarity function also on substrings. In order for two classes to be

²² <http://www.mkbergman.com/1769/50-ontology-mapping-and-alignment-tools/>

²³ <http://www.w3.org/TR/owl-features/>

²⁴ <https://github.com/seatgeek/fuzzywuzzy>

²⁵ <https://xlinux.nist.gov/dads/HTML/Levenshtein.html>

matched, one of these two algorithms has to return a similarity score greater than 70. Note that this approach is only used to find similar classes in both standards. However, this approach does not consider properties, class relationships or similar (i.e., we compared only data elements to each other, but NOT attributes of these data elements). The results of the alignment-application were manually filtered by the study team (i.e., domain experts with specific knowledge about the standards) and clustered into high-level concepts. Clustering was based on similar terms like “Device”, “Energy”, “Power” and “Time”, which we refer to as *core concepts*.

- **Manual approach:** When the automatic approach was not possible, we inspected manually the PDF specifications of the short-listed standards, extracted the DSF core data elements and compared them to SAREF/SAREF4ENER using a table format.

Alignment

This study considered that the alignment on a certain data element was reached when a) the two standards under comparison both covered that data element; and b) the meaning of that data element was the same in both standards. In some cases the alignment was not straightforward (i.e., it was not a one to one mapping from one standard to the other), but it could still be reached by extending an existing class in SAREF. For instance, the concept of “Volume” does not exist explicitly in SAREF, but the class “Property” does exist, which is the upper class for concepts like “Power”, “Energy” and “Temperature”. One can therefore create a new class “Volume” as subclass of the existing “Property” class.

A gap occurred when the mapping was not possible at all, because the data element under consideration did not exist in SAREF or in one of the considered standards, or the meaning was different. For instance, SAREF does not define the “Status” of the meter reading, therefore, it could be considered to extend SAREF with a new property to express this additional information.

Maturity level of alignments

The standards considered in this study are heterogeneous in the way they express semantics and only some of these standards provide a suitable format that can be used straightforward as input for an automated alignment. A suitable format for automated alignment, and used in this study, is the OWL format, which enables to formally capture the semantics of a specification.

- Four standards explicitly provide executable semantics by means of an ontology expressed in the OWL format, these are: SAREF and SAREF4ENER ontologies, the KNX ontology (EN 50090) and the oneM2M ontology.
- Three standards provide a format that can be automatically translated to OWL, such as XML schema (XSD) or UML, these are: EN 50631-1 (SPINE), whose data model is expressed as XSDs, and IEC 61970 CIM and 61968-9 CIM for Metering, whose semantics is expressed in UML.
- The remaining three standards, i.e., CEN 16836 (ZigBee SEP2), CENELEC EN 50491-11 Smart Metering and IEC/CENELEC 62056 COSEM, currently do not explicitly capture the semantics of their data elements, which remains hidden in the data model and needed to be manually extracted from the PDF specifications.

This heterogeneity has led to a different maturity level of the alignments proposed in this study, and as a result, a different way of presenting and visualizing the alignments. For some alignments, an automated tool could be used for ontology alignment and generating a complete visualization of the results accordingly, while other alignments needed to be performed manually and are visualised by means of a (less sophisticated) mapping table.

4.3 Technical analysis

4.3.1 Alignment and Actions for CEN EN 16836 (ZigBee SEP2)

Input for Alignment

The EN 16836 series of standards is specified by CEN TC 294 (Communication systems for meters) that not only has a technical liaison agreement with The ZigBee Alliance in order to exchange documents, share knowledge and report on meetings, but is also allowed to reference published ZigBee documents due to a Memorandum of Understanding (MOU) in place between the organisations under the Consortium Bridge procedure within CEN/CENELEC. One of the referenced documents by EN 16836 is the “ZigBee Smart Energy Profile Specification Standard – 07-5356 Rev 19, December 3, 2014”, which is also the document used in this study as input for the alignment (available in PDF format at <http://www.zigbee.org/about/centc294>).

Earlier alignments

The earlier “Smart Energy Profile 2 (SEP2) Application Protocol Standard, ZigBee Public Document 13-0200-00, April 2013”²⁶ document has been used as basis to create SAREF in the previous study for the European Commission on “Semantic Assets for Smart Appliances Interoperability” [4]. Therefore, an alignment of the CEN EN 16836 series with SAREF already exists via the mapping of the “SEP2 Application Protocol Standard (2013)” onto SAREF performed in [4], which was based on the following SEP2 data elements:

- Commodity Type (e.g., Electricity, Air, Natural Gas, Potable Water, Waste Water, Heating Fluid)
- Device Category (e.g., Thermostat, Water Heater, Pool Pump, Smart Appliance, Irrigation Pump, Exterior Lighting, Interior Lighting, Electric Vehicle)
- Service Kind (e.g., Electricity, Gas, Heat)
- Device Status (e.g., Operating, Starting up, Shutting down)
- Device Information (e.g., Manufacturer, Model Number, Serial Number, Software Version)
- Unit of Measure Type (e.g., kWh, kW, Watts, Cubic Meters, Kelvin, Celsius)

Analysis

A further alignment is performed in this study to determine correspondences and/or gaps between the CEN EN 16836 (ZigBee SEP2) and SAREF/ SAREF4ENER²⁷ data elements described in Section 3.3.2. We performed this mapping manually (see approach in Section 4.2) using as basis the ZigBee SEP2 specification available in PDF format at <http://www.zigbee.org/about/centc294>. We have manually extracted the semantic coverage and main data elements from the ZigBee SEP2 specification (see

²⁶ Note that the “Smart Energy Profile 2 Application Protocol Standard, ZigBee Public Document 13-0200-00, April 2013” is an earlier version than the “ZigBee Smart Energy Profile Specification Standard – 07-5356 Rev 19, December 3, 2014” used for alignment in this study

²⁷ Note that the alignment performed in [4] was between ZigBee SEP2 and SAREF, while the current alignment considers a new version of ZigBee SEP2 specification and also SAREF4ENER (which did not exist yet at the time of the first study in [4]).

Section 3.3.2 for details on these data elements) and compared it to the core concepts for DSF in SAREF/ SAREF4ENER, using Table 3-3 as a mapping tool. The resulting alignment is shown in Table 4-1.

Table 4-1: Alignment of CEN EN 16836 (ZigBee SEP2) with SAREF/SAREF4ENER

SAREF/SAREF4ENER	Common data elements	EN 16836 (ZigBee SEP2)
saref:Device saref:hasManufacturer saref:hasModel saref:hasFunction saref:controlsProperty saref:measuresProperty saref:Actuator saref:Appliance saref:HVAC saref:LightingDevice saref:Meter saref:Sensor etc. s4ener:Device s4ener:deviceName s4ener:deviceCode s4ener:serialNumber s4ener:softwareRevision s4ener:hardwareRevision s4ener:vendorName	Device (ID and capabilities)	Device types: Load Control Device, Smart Appliance Device, Programmable Communicating Thermostat (PCT) Device, Metering Device
s4ener:AlternativesGroup s4ener:PowerSequence s4ener:PowerProfile s4ener:Slot	Control parameters, e.g. profile selection Energy Profile Preferred time slot of operation per device	! ! !
s4ener:Energy s4ener:Power s4ener:StartTime s4ener:EndTime s4ener:EarliestStartTime s4ener:LatestEndTime etc. saref:Price saref:Command	Energy consumption Flex start enabled Start time/ time slot of operation Recalculated start time/ time slot New tariff info Operation commands	Consumption Start and end times to avoid spikes Generated (delivered) prices Control methods for Demand Response/Load Control
s4ener:LoadControlEventAction s4ener:EventActionConsume s4ener:EventActionProduce	Emergency signal Emergency load	Events for Demand Response/Load Control Criticality levels: Green, Emergency, Planned Outage, Service Disconnect, Utility Defined

s4ener:pause, resume, reduce, increase, emergency, normal	command	Control methods for Demand Response/Load Control
saref:Price saref:Currency saref:Time saref:Command	Tariff threshold Real Time Tariff Operation commands (increase or decrease power, turn off/on)	Price, Multiple currencies for international support (using ISO 4217), Time Demand response or pricing events for Smart Appliance device informing customers via in-home displays
s4ener:Device s4ener:deviceName s4ener:deviceCode s4ener:Power s4ener:LoadControlEventAction s4ener:EventActionConsume s4ener:EventActionProduce s4ener:pause, resume, reduce, increase, emergency, normal s4ener:PowerExpected s4ener:EnergyExpected	ID of participating devices Power thresholds Load management signal Load adjustment command Feedback about adjustment Expected change in consumption	Generation (delivered) and consumption (received), Units of measure Events for Demand Response/Load Control Control methods for Demand Response/Load Control
saref:Price saref:Currency s4ener:PowerExpected s4ener:EnergyExpected	Price information of electrical energy based on time of use Planned load profile (expected consumption in time)	Generated (delivered) and consumed (received) prices Multiple currencies for international support (using ISO 4217) Time; Generation (delivered) and consumption (received); Measurement types (such as load profile), Units of measure
saref:Measurement s4ener:Power saref:PowerUnit s4ener:Energy saref:EnergyUnit	Consumption/Generation <ul style="list-style-type: none"> Actual Individual Appliances (= partial) consumption/generation Forecasted partial consumption/generation Actual total house consumption Forecasted total 	Measurement types for Load Control Device, Smart Appliance Device and Metering Device; Units of measure; Generation (delivered) and consumption (received); Real-time information

	house consumption	
saref:Device saref:State	Device Status	Status indicators (e.g. battery low, tamper detected)
saref:Meter saref:Time time:TemporalEntity time:DurationDescription	Actual time	Metering Device; Time; Real-time information
saref:Meter saref:EventFunction saref:NotifyCommand saref:Price	Active tariff notification	Metering Device; Price, Multiple currencies for international support (using ISO 4217); Real-time information

As is shown in Table 4-1, the main data elements from the CEN EN 16836 standard (ZigBee SEP2) provide an exhaustive coverage to the SAREF/ SAREF4ENER classes that are relevant for the DSF use cases (data elements in green in the table). The type of devices of interest for the DSF study are well covered by CEN EN 16836 (ZigBee SEP2), such as *Metering Device*, *Programmable Communicating Thermostat (PCT) Device*, which can control the premises heating and cooling systems, *Load Control Device*, which can receive Demand Response and Load Control events to manage consumption on a range of devices, and *Smart Appliance Device*, which can participate in energy management activities. Measurements, consumption and generation of e.g., energy and power are also covered in CEN EN 16836 (ZigBee SEP2), together with the possibility to express price and time information when, for example, Utilities initiate a demand response or pricing event.

Gaps

The data elements highlighted in red in Table 4-1 show that a gap exist in CEN EN 16836 (ZigBee SEP2) concerning the possibility for *Smart Appliance Devices* participating in energy management activities to express complex power profiles and optimal time slots for operation, also based on user preferences. As it is shown in Table 4-1, concepts related to Energy/Power Profile, such as “s4ener:AlternativesGroup”, “s4ener:PowerProfile”, “s4ener:PowerSequence” and “s4ener:Slot”, which are essential for the *Use case# 2: Flexible start of Smart Device* considered in this study, do not find corresponding data elements in the CEN EN 16836 (ZigBee SEP2) standard.

Actions

	Action owners	Action
A-1	CLC/TC 294	Include <i>Power Profile</i> and associated concepts (i.e., <i>Power Profile Alternatives Group</i> , <i>Power Sequence</i> , <i>Slot</i> and corresponding attributes) in CEN EN 16836 (ZigBee SEP2). Or, explicitly acknowledge if these concepts are out of scope of CEN EN 16836 (ZigBee SEP2) and provide explicit indication of which other international standard should be used to cover these missing concepts.

An additional observation is that the EN 16836 (ZigBee SEP2) standard defines detailed data elements also for other type of meters other than electricity meters (e.g., gas, water and heat meters). In contrast, SAREF explicitly defines only electricity meters, but provides the capability to derive other type of meters from existing classes. For example, the two new subclasses “saref:GasMeter” and “saref:WaterMeter” can be created from the existing “saref:Meter” class, and associated with the already existing commodity types “saref:Gas” and “saref:Water”.

	Action owner	Action
A-2	ETSI SmartM2M TC	Consider the possibility to explicitly extend SAREF to cover additional type of meters and related measurements (e.g., gas, water, heat, etc.) other than electricity meters, if relevant.

The CEN EN 16836 (ZigBee SEP2) standard defines various types of metering, measurements types, real-time readings, historical information, status indicators, etc., analogously to other standards on the same interface (H1 and H2), such a IEC 62056 COSEM and CENELEC EN 50491-11 Smart Metering. It is unclear to which extent these standards express overlapping and/or complementary information. Therefore, an action is necessary to clarify this, provide mappings where needed and reduce duplication of work and efforts in different Technical Committees that specify standards with similar scope on the same interface.

	Action owners	Action
A-3	CLC/TC 294, CLC/TC 205 and IEC/CLC/TC 13 WG 14	There are various smart meter standards used for the same interface (H1/H2), i.e., CEN EN 16836 (ZigBee SEP2), CENELEC EN 50491-11 Smart Metering, and IEC 62056 COSEM. Investigate overlapping between these standards, provide mappings and reduce duplication of work and efforts in different Technical Committees.

4.3.2 Alignment and Actions for IEC 62056 COSEM

Input for Alignment

Companion Specification for Energy Metering to IEC 62056-6-2 from DLMS User Association, Blue Book, 12th edition “COSEM Identification System and Interface Classes” (free excerpt available at <http://dlms.com/documentation/index.html>).

Earlier alignments

The companion specification to IEC 62056-6-2 from DLMS titled “Companion Specification for Energy Metering: COSEM interface classes and OBIS identification system”, 11th edition (also called the “Blue Book” specification), has been analysed as part of the long list of standards relevant to create SAREF in the earlier study for the European Commission on “Semantic Assets for Smart Appliances Interoperability” [4]. However, it was not included in the short-list that was directly mapped onto SAREF.

Analysis

An alignment was performed in this study to determine precise correspondences and eventual gaps between IEC 62056 COSEM and SAREF/ SAREF4ENER²⁸. Unfortunately, it was not possible to exploit the ontology alignment algorithm described in Section 4.2 to make this alignment in an automated way²⁹. Therefore, we performed the alignment manually. Given the extension and complexity of the COSEM data model and OBIS identification system, we compared with corresponding concepts from SAREF/ SAREF4ENER only the OBIS codes relevant to this study, i.e., those that define the media (energy type) to which the metering is related (OBIS codes from group A in the Blue Book). The resulting alignment is shown in Table 4-2.

Table 4-2: Alignment of IEC 62056 COSEM with SAREF/SAREF4ENER

SAREF/SAREF4ENER	Common data elements	OBIS codes/COSEM object	
saref:Power, s4ener:PowerExpected, s4ener:PowerMax, s4ener:PowerMin, s4ener:PowerSkewness, s4ener:PowerStandardDeviation	Power	Electrical Related Objects (A= 1) ³⁰	Value group C codes A=1: Active power, Reactive power, Apparent power, etc.
saref:Energy, s4ener: Energy Expected, s4ener: Energy Max, s4ener: Energy Min, s4ener: Energy Skewness, s4ener: EnergyStandardDeviation, s4ener: ResumeEnergyEstimated	Energy		General purpose codes A=1: Active energy, Reactive energy, Apparent energy, etc.
saref:Electricity, saref:Power, s4ener:PowerMax, s4ener:PowerMin, saref:Energy, s4ener: Energy Max, s4ener: Energy Min	Value type (for Electricity)		Value group D codes A=1: Minimum, Maximum, Cumulative, Average, Instantaneous, Threshold, etc.
saref:Time, time:DurationDescription, time:TemporalEntity (Instant or Interval), saref:Measurement hasTimestamp	Time		General purpose codes A=1: Timestamp billing period, Measurement period, Recording interval, etc.

²⁸ Note that this alignment also considers SAREF4ENER, which did not exist yet at the time of the first study on SAREF in [4] was performed.

²⁹ The reason is that COSEM has an extensive and complex data model based on the Object Identification System (OBIS). The semantics of the COSEM data elements and OBIS codes is not explicitly formalized in a machine readable format (such as OWL). Therefore, we had to extract the semantics manually from the corresponding PDF document (making it impossible to use the ontology alignment tool, which is not able to analyse an input in PDF format).

³⁰ For the complete list of data elements in COSEM related to Electricity, see section 5.5 of the Blue Book (Table 20 to Table 27).

xsd:dateTime			
<p>! No Status (as quality of the measurement), but only State (of the device) in SAREF.</p> <p>Action: create a new property “Status” to be added to the saref:Measurement class in SAREF</p>	Status (quality of the measurement)		General purpose codes A=1: Status info missing voltage, Status info missing current, Status info current without voltage, Status info auxiliary power supply
saref:State	State (of the device)	Abstract Object (A=0)	Internal Operation Status
saref:Temperature	Heat (Temperature)	Heat Cost Allocator Related Object (A=4) ³¹	Value group C codes A=4: Radiator surface temperature, Heating medium temperature, Flow (forward) temperature, Return temperature, Room temperature, etc.
<p>! there is no saref:Volume, (but it can be created as subclass of saref:Property)</p>	Heat/Cooling (Volume)	Heat/Cooling Related Object (A=5 or A=6) ³²	Value group C codes A=5 or A=6: Accounted volume, Flow volume, Return volume, etc.
<p>saref:Gas, saref:Temperature, saref:Pressure</p> <p>! there is no saref:Volume (but it can be created as subclass of saref:Property)</p>	Gas (Volume, Temperature, Pressure)	Gas Related Objects (A= 7) ³³	Value group C codes A=7: Forward undisturbed meter volume, Forward disturbed meter volume, Forward absolute meter volume, Reverse undisturbed meter volume, Reverse disturbed meter volume, Reverse absolute meter volume, Forward undisturbed converter volume, Forward undisturbed logger volume, Forward undisturbed Energy, Absolute temperature, Absolute pressure, etc.
saref:Water, saref:Temperature	Water	Cold Water Related Object (A=8) and	Value group C codes A=8 and A=9:

³¹ For the complete list of data elements in COSEM related to Heat Cost Allocator (HCA), see section 5.6 (Table 32) of the Blue Book.

³² For the complete list of data elements in COSEM related to Heat/Cooling, see section 5.7 (Table 38 to Table 40) of the Blue Book.

³³ For the complete list of data elements in COSEM related to Gas, see section 5.8 (Table 44 to Table 46) of the Blue Book.

! there is no saref:Volume		Hot Water Related Object (A=9) ³⁴	Accumulated volume, Flow rate, Forward temperature, etc.
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As it is shown in Table 4-2, there is a fair level of alignment (see common data elements coloured in green in the table, such as *Power*, *Energy*, *Value Types*, *Time*, *State* and *Temperature*) between IEC 62056 COSEM and SAREF/ SAREF4ENER. Green alignment should be intended as interoperability is currently possible, since SAREF/ SAREF4ENER provides the facility (i.e., an upper class and a text field) to express that concept. However, some ad-hoc adjustments may still need to be done. For example, consider the core concepts “Power” and “Value type (for Electricity)” in Table 4-2. On the one hand (see left side in the table), SAREF defines “saref:Power” and SAREF4ENER specific power value types, such as “s4ener:PowerMax” and “s4ener:PowerMin”. On the other hand (see right side in the table), COSEM needs additional value types for power, such as “Cumulative Power” and “Instantaneous Power”, for which there is not an explicit class in SAREF/ SAREF4ENER. The ad-hoc adjustment consists, in this case, of creating an instance of “saref:Power” called “saref:CumulativePower” and indicate in the corresponding text field description that this is cumulative power.

Note that the alignment between SAREF/SAREF4ENER and COSEM using this type of adjustments has been successfully implemented in the demonstrator of interoperability for DSF resulting from this study (see “Appendix C - Detailed description of the demonstrations”). In this demonstrator, an Energy Gateway uses SAREF/ SAREF4ENER as overarching ontology to combine data metering readings represented by COSEM objects and OBIS addresses (on interface H2), with data represented by oneM2M resources (on interface G3).

Gaps

The alignment in Table 4-2 further shows that there are some gaps in SAREF/SAREF4ENER (see common data elements coloured in red in the table) when it comes to the following data elements:

- Status of the meter reading (intended not as device status, but as the status/quality of the measurement provided by the device, i.e., “Status info missing voltage”, “Status info missing current”, “Status info current without voltage”, “Status info auxiliary power supply”, etc.). As this concept does not currently exist in SAREF (therefore the gap), it can be considered to create it by extending SAREF with e.g. a new property called “saref:hasMeterReadingStatus” to be added to the existing saref:Measurement class.
- Specific parameters related to Gas, Water and Heat meters, such as *Volume*. As the concept of “Volume” does not explicitly exist in SAREF (therefore the gap), it can be considered to create it. This can be done using the class “saref:Property”, which is the upper class for already existing concepts like “saref:Power”, “saref:Energy” and “saref:Temperature”. Next to the classes, a new class “saref:Volume” could be created as subclass of the existing “saref:Property” class.

Actions

Action owner	Action
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³⁴ For the complete list of data elements in COSEM related to Water, see section 5.9 (Table 50 to Table 52) of the Blue Book

A-4	ETSI SmartM2M TC	Consider to extend SAREF to fill the identified gaps with IEC 62056 COSEM (see red elements in Table 4-2), if relevant. These gaps concern the status of the meter reading (intended as quality of the reading), and specific parameters related to Gas, Water and Heat meters, such as <i>Volume</i> .
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As already observed for EN 16836 (ZigBee SEP2), also IEC 62056 COSEM defines detailed data elements for other type of meters other than electricity meters (e.g., gas, water and heat meters), while SAREF explicitly defines only electricity meters.

	Action owner	Action
A-5³⁵	ETSI SmartM2M TC	Consider to explicitly extend SAREF to cover additional type of meters and related measurements (e.g., gas, water, heat, etc.) other than electricity meters. SAREF already provides the capability to derive other type of meters from existing classes. For example, new subclasses such as “Gas Meter” and “Water Meter” can be created from the existing “saref:Meter” class and associated with the already existing commodity types “saref:Gas” and “saref:Water”. The suggested classes could be created either as part of the SAREF core ontology or the already existing SAREF4ENER. Another option could be to start a new extension of SAREF explicitly dedicated to the Smart Metering domain, if relevant.

An additional action concerns the green alignments in Table 4-2. It was mentioned for these alignments that interoperability is currently possible, since SAREF/ SAREF4ENER provides the facility (i.e., an upper class and a text field) to express that concept. However, some ad-hoc adjustments may still need to be done, such as create an instance of “saref:Power” called “Cumulative Power” or “Reactive Power” and indicate in the corresponding text field description that this is cumulative power or reactive power.

	Action owner	Action
A-6	IEC/ CENELEC TC 13 WG 14, but also SAREF users in general	When ad-hoc adjustments on SAREF/SAREF4ENER need to be done on a regular basis in different projects (recurrent adjustments), consider to submit a request to ETSI SmartM2M TC, so that an updated version of SAREF that incorporates these adjustments could possibly be released. For example, if one has to define recurrently in their own projects a “myproject:ReactivePower”

³⁵ Note that A-5 is an extension of the action A-2 already defined in Section 4.3.1

instance from the existing “saref:Power” class, it would be beneficial to provide feedback to ETSI SmartM2M TC³⁶, requesting to create a class “saref:ReactivePower” (instead of having to define a “myproject:ReactivePower” instance over and over in different projects).

4.3.3 Alignment and Actions for IEC 61968-9 CIM for metering

Input for Alignment

IEC TS 62056-6-9:2016 - The DLMS/COSEM suite - Part 6-9: Mapping between the Common Information Model message profiles (IEC 61968-9) and DLMS/COSEM (IEC 62056) data models and protocols, available at <https://webstore.iec.ch/publication/24736> to be purchased from IEC.

Earlier alignments

The “DLMS/COSEM/CIM Study Report” of June 2010 and the subsequent IEC 62056-6-9:2016 Technical Specification from the joint effort of IEC TC 13 and IEC TC 57 address the alignment of DLMS/COSEM (IEC 62056) to CIM for metering (IEC 61968-9). In particular, the IEC 62056-6-9 Technical Specification covers the mapping between information interchange messages of a CIM-based ERP or third party system and a DLMS/COSEM-based metering system.

Analysis

Figure 4-1 shows the application domain and the need for integration motivating the mapping between DSLM/COSEM and CIM for metering resulting by the joint effort of IEC TC 13 and IEC TC 57.

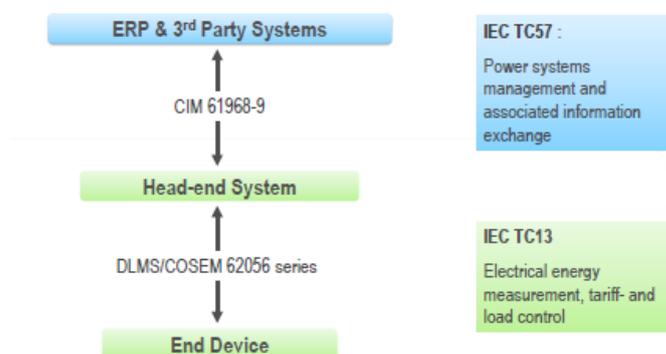


Figure 4-1: Integration of DLMS/COSEM with CIM (D.Taylor and M.Kozole, TC13/57 JWG16)

In the “DLMS/COSEM/CIM Study Report” of June 2010, message profiles are provided as XSD schemas to be exchanged between the ERP system, metering system head-end and the end device, where the integration is realized at the metering system head-end. The advantage of these message profiles is that they are based on the CIM for metering, but also maintain the contextual relationship between physical device, logical device, object, attribute and method exactly as is defined in the

³⁶ All ETSI members can participate to SmartM2M TC meetings (usually held four times per year) and ad-hoc calls on SAREF related topics, to provide feedback on the use and evolution of SAREF. Contacts of the SmartM2M TC Officials and the schedule of the meetings can be found at <https://portal.etsi.org/home.aspx>

DLMS/COSEM standards. Figure 4-2 shows the mapping approach of the CIM messages in the CIM for metering (IEC 61968-9) into DLMS services, OBIS codes and COSEM objects.

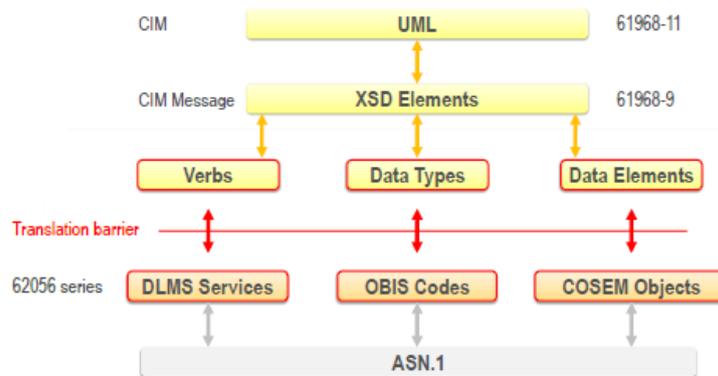


Figure 4-2: Mapping of CIM for metering message elements into DLMS/COSEM (D.Taylor and M.Kozole, TC13/57 JWG16)

To enable the mapping, the “DLMS/COSEM/CIM Study Report” of June 2010 extends the CIM UML model to accommodate the COSEM concepts of physical device, logical device and associated objects. To that end, new classes in the CIM metering are created, such as the *PhysicalDevice* class that is an aggregation of one or more logical devices (*LogicalDevice* class), which in turn are aggregations of COSEM objects (*CosemObject* class). Other classes such as *CosemAttribute*, *CosemMethod*, *CosemData*, and *CosemResult* are also part of this extension. In particular, a COSEM physical device is created as subclass of the *EndDeviceAsset* class of the CIM. *EndDeviceAsset* is a child class in the inheritance hierarchy of asset classes modelled in the CIM. End devices are conceptually those devices physically located at or near to (but associated with) the *ServiceDeliveryPoint* at the end of the distribution network. In this context, a billing meter is an *EndDeviceAsset* typically connected to the *ServiceDelivery* point. Thus, *MeterAsset* is a child class of *EndDeviceAsset*. Note that the COSEM physical device is modelled as a subclass of *EndDeviceAsset* (rather than a *MeterAsset*) because COSEM objects may locate in devices other than meters.

Gaps

The mapping between information interchange messages of a CIM-based ERP and a DLMS/COSEM-based metering system is already taken care of by the joint initiative of IEC TC13 and IEC TC 57, which resulted in the IEC TS 62056-6-9:2016. As it is out of scope to duplicate efforts already being done elsewhere, we did not identify the immediate need of an additional mapping of CIM for metering to SAREF/ SAREF4ENER (the mapping can be realized at the moment via DLMS/COSEM, which is aligned to both CIM for metering and SAREF/SAREF4ENER).

Actions

CIM for metering is already aligned to DLMS/COSEM via ongoing initiatives. This is sufficient for the scope of this study. However, it may be worthwhile in the future to further look at the direct mapping of CIM for metering and SAREF/SAREF4ENER.

	Action owner	Action
A-7	IEC TC 13 and IEC TC	CIM for metering is aligned with SAREF/SAREF4ENER through COSEM, meaning that interoperability is possible. IEC TC 13 and IEC

TC 57 should consider if interoperability through COSEM is sufficiently practicable. Otherwise, direct alignment with SAREF/SAREF4ENER could be explored.

4.3.4 Alignment and Actions for IEC 61970 CIM

Input for Alignment

The IEC CIM is specified as UML class diagram and an official version of the entire CIM in the OWL format published by IEC TC 57 does not exist. Therefore, we have performed our own, ad-hoc transformation of the CIM from UML to OWL³⁷. The generated OWL version of the CIM for this study is available at <http://ontology.tno.nl/DSFstudy/cim4alignment.ttl>.

Earlier alignments

No earlier alignments have been explored.

Analysis

The alignment with SAREF/SAREF4ENER is a cumbersome task due to the complexity of the CIM, which defines about 1500 different concepts (classes) and a multitude of properties divided over some 100 packages. To that end, we performed a transformation of the CIM from UML to OWL (see above), so that we could then perform the alignment automatically with our algorithm for ontology matching (see approach in Section 4.2) using as input the OWL version of the CIM and the SAREF/SAREF4ENER ontologies (available at <http://ontology.tno.nl>). The resulting alignment is shown in Figure 4-3, where the core data elements in the middle are coloured in green to show sufficient overlapping or in red when there is a possible gap and a consequent need for further action.

³⁷ We have applied several methods for this transformation, including 1) the UML to OWL transformation that comes prepackaged with TopBraid Composer, 2) the Sparkx Enterprise Architect schema composer export to RDFS, as well as 3) the same export function to XSD in combination with the import functionality for XSD in TopBraid Composer. The XSD (option 3) was the most fruitful. Using this method, UML classes were transformed to OWL classes and associations, specialization/generalization, attributes and cardinality were transformed as expected.



Figure 4-3: Alignment of IEC 61970 CIM with SAREF/ SAREF4ENER using the algorithm for ontology matching

The initial results obtained with the ontology matching tool show that there is a certain degree of overlapping with SAREF/ SAREF4ENER (see core concepts in green in Figure 4-3), although the CIM covers a much broader scope than DSF. This suggests that SAREF/SAREF4ENER is suitable to be used as the overarching ontology for DSF and could eventually be extended with missing concepts from the CIM.

Gaps

The alignment shown in Figure 4-3 is only an initial step towards the harmonization of the CIM and SAREF/ SAREF4ENER. However, further investigation to explore potential gaps, i.e., missing data elements or differences in meaning, is needed (see core concepts in red in the figure). For example, it has to be clarified whether the “State” concept in SAREF has the same meaning of the “Status” concept in CIM. The automatic alignment also suggests a matching in SAREF/ SAREF4ENER and CIM on the Load and Switch core concepts, but it has to be checked whether the meaning is the same and if the detailed data elements in CIM related to these core concepts are sufficiently covered by SAREF/ SAREF4ENER. Although there is an exact linguistic match between saref:Profile and CIM:Profile, further investigation is necessary to clarify whether the meaning of “Profile” in the two standards is equivalent. Moreover, the concepts of “Property” and “Service” seem to have a different meaning in

the two standards. Finally, SAREF/SAREF4ENER appear to be underspecified when it comes to the concepts of “Generator”.

Actions

The IEC CIM model is specified as UML class diagram, whereas more and more information models nowadays are published in the OWL format, which provides a formal representation of the semantics underlying the model and allows automated reasoning with dedicated software. An official IEC TC 57 ontology of the entire IEC CIM model published in the OWL format does not exist, or it should be created using the CIM tool (<http://wiki.cimtool.org/index.html>), which appears not to be maintained anymore by the CIM community. As a result, the burden of the translation from UML to OWL is currently left to the CIM users, who generate different OWL versions of the CIM, depending on how the translation UML to OWL is implemented by different individuals. An example of a CIM profile generated from UML to OWL using the CIM tool in the context of the CERISE project³⁸ is available at <http://ontology.tno.nl/cerise/cim-profile/>.

	Action owner	Action
A-8	IEC TC 57	Publish an official, standard OWL version of the CIM, as at the moment the burden of the translation from UML to OWL is left to the users (e.g., using the CIM tool), who generate different versions depending on how the translation is implemented. This also hinders the task to provide a standard alignment with other standards for DSF, like SAREF/SAREF4ENER.

It is important for IEC TC 57 to be aware of the European effort in developing, maintaining and evolving the SAREF series of ontologies.

	Action owner	Action
A-9	IEC TC 57	When an official OWL version of CIM is developed for the purpose of DSF, IEC TC 57 should use the SAREF series of ontologies (especially SAREF4ENER) as input. The alignment proposed in this study (see Figure 4-3), together with the domain expertise coming from IEC TC 57 (for CIM) and ETSI SmartM2M TC (for SAREF4ENER) could be beneficial for the suggested task.

4.3.5 Alignment and Actions for CENELEC EN 50491-11 Smart Metering

Input for Alignment

The EN 50491-11 standard specifies a data model to abstract the metering world towards a simple external consumer display. The data model, as described by means of functional blocks contained in EN 50491-11, lays down the format of metering data accessible by a simple external consumer display. The EN 50491-11 standard does not specify the communication protocol used between the

³⁸ CERISE project: Combining Energy and Spatial Information Standards as Enabler for Smart Grids (<http://www.cerise-project.nl>).

meters and the meter communication functions, but considers the EN 62056 COSEM series for the definition of the data model.

Earlier alignments

We acknowledge that current work within CLC/TC 205 aims at extending the EN 50491-11 Smart Metering standard with the mapping to COSEM.

Analysis

The mapping between the EN 50491-11 Smart Metering standard and IEC 62056 COSEM is already taken care of by an ongoing initiative. As it is out of scope to duplicate efforts already being done elsewhere, we did not identify the immediate need of an additional mapping of the EN 50491-11 Smart Metering to SAREF/ SAREF4ENER (the mapping can be realized at the moment via DLMS/COSEM, which is aligned to both the EN 50491-11 Smart Metering and SAREF/SAREF4ENER).

Gaps

There are no gaps identified.

Actions

For the scope of this study, it is sufficient that there are ongoing efforts addressing the mapping between the EN 50491-11 Smart Metering standard and IEC 62056 COSEM. We observe that it may be worthwhile in the future to further look at the direct mapping of EN 50491-11 Smart Metering standard with SAREF/SAREF4ENER.

	Action owners	Action
A-10	CLC/TC 205	EN 50491-11 is aligned with SAREF/SAREF4ENER through COSEM, meaning that interoperability is possible. CLC/TC 205 should consider if interoperability through COSEM is sufficiently practicable. Otherwise, direct alignment with SAREF/SAREF4ENER could be explored.

Please note that **Action A-3** specified in Section 4.3.1 also applies to EN 50491-11 Smart Metering.

4.3.6 Alignment and Actions for CENELEC EN 50631-1 (SPINE)

Input for Alignment

The data model in the prEN 50631-1 draft standardized by CLC TC59 WG7 is based on the “Smart Premises Interoperable Neutral-Message Exchange (SPINE)” specification created and maintained by EEBUS in collaboration with Energy@home. For the alignment, we used the SPINE specification available for download at <https://www.eebus.org/en/downloads/>.

Earlier alignments

As explained in ETSI TS 103 410-1 SAREF4ENER V1.1.1 (available at http://www.etsi.org/deliver/etsi_ts/103400_103499/10341001/01.01.01_60/ts_10341001v010101p).

[pdf](#)), SAREF4ENER is an extension of SAREF that was created in collaboration with EEBUS and Energy@home to enable the interconnection of their (different) data models. By design, SAREF4ENER is fully aligned with SPINE. Therefore, also the CENELEC EN 50631-1 that is based on SPINE is fully aligned with SAREF4ENER. The main concepts aligned in both the SAREF4ENER and CENELEC EN 50631-1/SPINE specifications are the following:

- Device (e.g., appliance, meter, sensor, actuator, switch), Energy (e.g., EnergyMax, EnergyMin),
- Power (e.g., PowerMax, PowerMin),
- Time (e.g., StartTime, EndTime),
- Duration (e.g., SlotTimeDurationDescription),
- Power Profile,
- Alternatives Group,
- Power Sequence and
- Slot
- Load Control information (i.e., LoadControlEventData, LoadControlEventActionConsume, LoadControlEventActionProduce, LoadControlStateData, LoadControlStateConsume, LoadControlStateProduce).

Analysis

For details on the approach followed to reach alignment of SAREF4ENER and SPINE by design, see Annex A of ETSI TS 103 410-1 SAREF4ENER V1.1.1.

Gaps

There are currently no gaps.

Actions

Since SAREF4ENER is already aligned by design to SPINE, no further action is suggested. The following observation could be however taken into account for the evolution of the alignment between SPINE and SAREF4ENER. Currently, SAREF4ENER defines static information on classes and properties, and axioms that constrain the usage of these classes and properties. A behavioural part that specifies assertions and inferences that can be used in more sophisticated reasoning mechanisms (e.g., in terms of rules, *if this, then that*) has not been formalized yet. In SPINE, this behavioural part is only textually specified in the document, but no formal specification is provided. Future work could aim to add such a behavioural part/rules, possibly at the level of SAREF using e.g., an associated (standard) rule language like the W3C SHACL³⁹ (from the same family of the RDF/OWL language commonly used for modelling ontologies).

4.3.7 Alignment and Actions for CENELEC EN 50090 (KNX)

Input for Alignment

KNX IoT Ontology available at <https://knxiot.org> (access to the KNX ontology requires credentials that can be obtained contacting the KNX association). KNX Demand Side Management white paper,

³⁹ W3C SHACL

version 2, November 2013, available at <https://www.knx.org/media/docs/Flyers/KNX-Demand-Side-Management-White-Paper/KNX-Demand-Side-Management-White-Paper.pdf>.

Earlier alignments

The “KNX System Specifications Interworking Datapoint Types, Version 01.09.01, 18 September 2014” document has been used as basis to create SAREF in the previous study for the European Commission on “Semantic Assets for Smart Appliances Interoperability” [4]. Therefore, an alignment of the CEN EN 50090 series with SAREF already exists via the mapping of the KNX onto SAREF performed in [4], which was based on the following KNX data elements:

- Devices that can be configured in KNX at design-time. Type of devices include Lighting, Blinds & Shutters, Security Systems, Energy Management, Heating Ventilation and Air-Conditioning (HVAC) Systems, Monitoring Systems, Remote Control, Metering, Audio/Video Controls, and White Goods.
- Datapoints are parameters that can be used at run-time in KNX to define commands. Several types of Datapoints were considered as basis to create SAREF (e.g., Datapoint Types for common use, Datapoint Types for HVAC, Datapoint Types for Load Management, Datapoint Types for Lighting, Datapoint Types for Systems).
- Functional Blocks are combinations of Datapoint types into a device. Functional blocks used as basis to create SAREF were Dimmer Actuator Basic and Sunblind Actuator Basic. For example, Dimmer Actuator Basic combines the DPT_ControlDimming, DPT_Scaling and DPT_Switch data point types. This functional block can be in one of the 3 states “On”, “Off”, or “Dimming”, which are defined under the DimmingActuatorBasicState class. The change from one state to another is triggered by the so-called Events with one of the values listed under the DimmingActuatorBasicEvent class.

Analysis

A further alignment was performed in this study to determine correspondences and/or gaps between the CEN EN 50090 series (KNX) and SAREF/ SAREF4ENER⁴⁰ data elements, especially regarding DSF and use cases for demand response. We performed the alignment automatically (see approach in Section 4.2) with our algorithm for ontology matching using as basis the KNX IoT Ontology available at <https://knxiot.org> (access to the KNX ontology requires credentials that can be obtained contacting the KNX association) and the SAREF/ SAREF4ENER ontologies available at <http://ontology.tno.nl>. The resulting alignment is shown in Figure 4-4, where the core data elements in the middle are coloured in green to show sufficient overlapping, or in red when there is a possible gap and a consequent need for further action.

As is shown in Figure 4-4, there is a potential level of alignment (see common data elements in green) on the following concepts:

- *Building*. A class to describe in which part of the building a device is located. Covered by both the KNX ontology and SAREF. In particular, KNX specifies concepts such as knx:Building and knx:BuildingPart, which are subclasses of knx:Space and can be related to knx:SpaceUsage

⁴⁰ Note that the alignment performed in [4] was between KNX and SAREF, while the current alignment considers also SAREF4ENER for demand response use cases, which did not exist yet at the time of the first study in [4].

(e.g., Bedroom, Diningroom, Office, Garage, etc.). Note that the building spatial concepts are not covered by SAREF itself (and therefore they do not appear in Figure 4-4), but are covered by the extension SAREF for building (called SAREF4BLDG)⁴¹, which defines concepts such as s4bldg:Building, s4bldg:BuildingSpace and s4bldg:BuildingObject which are in line with the KNX concepts for building.

- *Temperature*. Both KNX ontology and SAREF provide classes to express temperature and setpoint temperature with their value and corresponding unit of measure.
- *Time*. KNX provides several Datapoints (DPT) to express Time. Covered also by SAREF (saref:Time class) which refers to the external W3C Time ontology (<https://www.w3.org/TR/owl-time/>) to further specifies time related concepts, such as time:TemporalEntity, time:Instant and time:Interval.
- *Pressure*. Both KNX ontology and SAREF provide data elements to express pressure with its value and corresponding unit of measure (KNX in terms of datapoints and SAREF in terms of classes).
- *Switch*. Both KNX ontology and SAREF provide data elements to define switch (whether it is a device or an action).
- *Actuator*. Actuator data points in KNX ontology can be expressed with the Actuator class in SAREF.
- *Energy, Electricity*. Covered both in KNX and SAREF, although KNX is more expressive concerning the Electrical-related data elements. Further investigation could address whether these elements need to have corresponding elements in SAREF.
- *HVAC*. KNX has a large number of datapoints associated with HVAC. It may be worthwhile to further explore if SAREF is expressive enough to represent the KNX-information about HVAC.
- *Load, Control*. These core concepts are covered both in KNX and SAREF, although with a different level of detail.
- *Occupancy, Humidity*. These data elements are covered in KNX and SAREF in a similar way.

⁴¹ SAREF4BLDG is specified in ETSI TS 103 410-3 V1.1.1 (2017-01) and is available at http://www.etsi.org/deliver/etsi_ts/103400_103499/10341003/01.01.01_60/ts_10341003v010101p.pdf

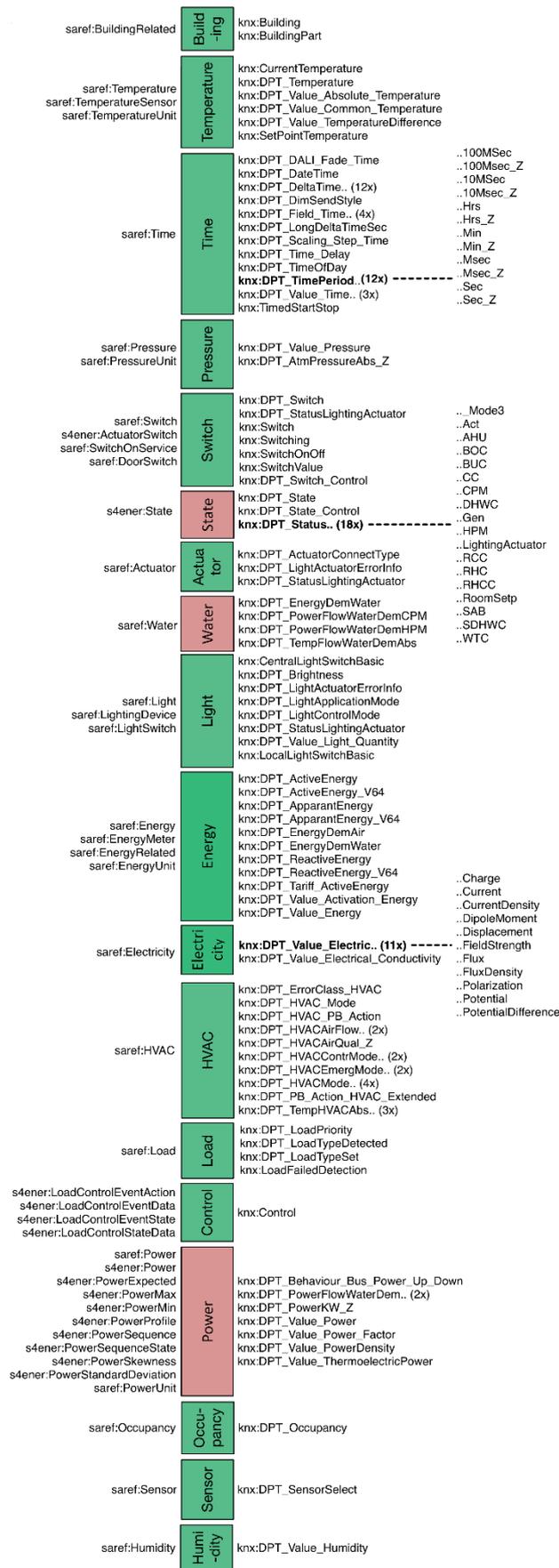


Figure 4-4: Alignment of CEN EN 50090 (KNX) with SAREF/ SAREF4ENER using the algorithm for ontology matching

Gaps

Figure 4-4 further shows that there are some potential gaps (see common data elements in red) when it comes to the following concepts:

- *State*. KNX ontology presents a few datapoints to express “State” and many datapoints to express “Status” (18 types of different datapoints containing the string “Status” in their name). Further investigation is needed to explore whether the Status datapoints in KNX are semantically equivalent to the State of a device existing in SAREF and/or whether SAREF is missing the concept of “Status” as intended by KNX.
- *Water*. KNX presents some datapoints to express energy, power and temperature for water meters, while SAREF is underspecified when it comes to water meters. A possible action could be needed to extend SAREF for water meters.
- *Power*. Both KNX and SAREF provide means to express power usage and consumption. However, it seems difficult to represent the important SAREF4ENER concepts of *Power Profiles*, *Power Sequences* and *Slots* using the existing KNX datapoints for Power.

Actions

	Action owner	Action
A-11	CLC/TC 205	Align the KNX ontology with SAREF/SAREF4ENER for the purpose of having only one ontology for interoperability (see elements in red in Figure 4-4).
A-12	CLC/TC 205	Since CENELEC EN 50090/KNX and CENELEC EN 50631-1/SPINE are both covered by CLC/TC 205 Home and Building Electronic Systems (HBES) and are both used for DSF, we suggest TC 205 to align these standards that cover the same interface (S2) to avoid confusion.

As additional observation that involves CENELEC EN 50090/KNX, we acknowledge that TC 205 WG18 is planning to use SPINE, KNX and EFI as input for their EN 50491-12-2 standard regarding the S2 interface (see section 3.3.3). However, this is work in progress and at the time of writing we cannot provide any official alignment of EN 50491-12-2 in relation to SAREF and SAREF4ENER.

4.3.8 Alignment and Actions for oneM2M Base Ontology

Input for Alignment

The latest versions of the Base Ontology specification, TS 0012 Release 3 “Base Ontology” and TS-0030 “Ontology based Interworking”, can be downloaded from <http://onem2m.org/technical/latest-drafts>. The OWL representation of the oneM2M base ontology can be found at <https://git.onem2m.org/MAS/BaseOntology>.

Earlier alignments

The ETSI TS 103 264 V2.1.1 contains the specification of SAREF 2.0 and a mapping to the oneM2M Base Ontology developed in collaboration with oneM2M experts. Figure 4-5 shows this mapping. Relationships based on owl:equivalentClass and owl:equivalentProperty are considered to link the

key classes and object properties of SAREF and the oneM2M Base Ontology. These are needed to be able to apply the oneM2M instantiation rules to the semantic description of entities that are described according to SAREF.

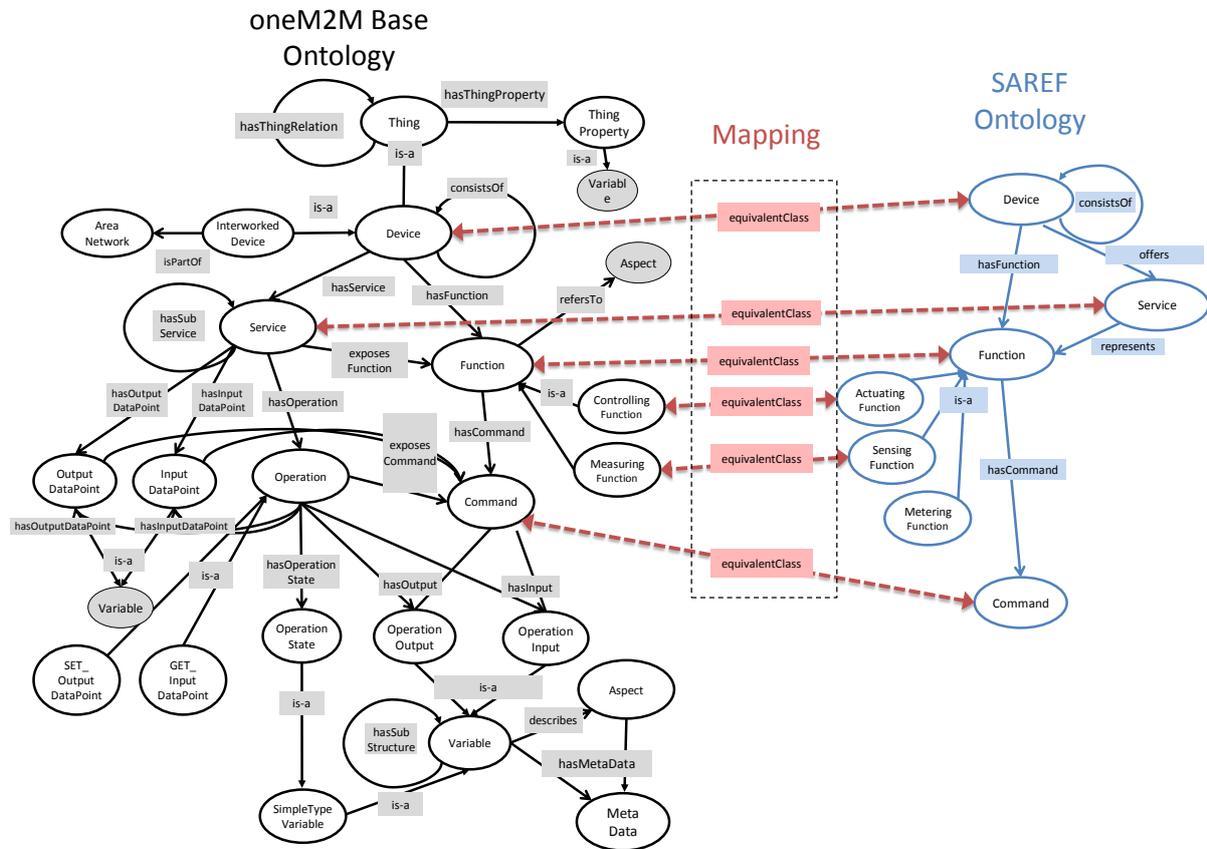


Figure 4-5: Alignment of oneM2M Base Ontology with SAREF

Table 4-2 shows which SAREF class is mapped to which oneM2M class (and vice-versa). As a result, all oneM2M instantiation rules defined for the oneM2M class can also be applied to the instance of the respective SAREF class, and oneM2M instances can be discovered from SAREF when querying for devices, functions, commands and services.

Table 4-3: Alignment of oneM2M Base Ontology classes with SAREF classes

SAREF	Mapping	oneM2M
saref:Device	owl:equivalentClass	oneM2M:Device
saref:Service	owl:equivalentClass	oneM2M:Service
saref:Function	owl:equivalentClass	oneM2M:Function
saref:SensingFunction	owl:equivalentClass	oneM2M:MeasuringFunction
saref:ActuatingFunction	owl:equivalentClass	oneM2M:ControllingFunction
saref:Command	owl:equivalentClass	oneM2M:Command

Table 4-3 shows which SAREF object property is mapped to which oneM2M object property.

Table 4-4: Alignment of oneM2M Base Ontology properties with SAREF properties

SAREF	Mapping	oneM2M
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saref:offers	owl:equivalentProperty	oneM2M:hasService
saref:hasFunction	owl:equivalentProperty	oneM2M:hasFunction
saref:represents	owl:equivalentProperty	oneM2M:exposesFunction
saref:hasCommand	owl:equivalentProperty	oneM2M:hasCommand
saref:consistsOf	owl:equivalentProperty	oneM2M:consistsOf

Analysis

A further alignment was performed in this study to validate the existing mapping between oneM2M Base Ontology and SAREF using our algorithm for ontology matching. We performed this mapping automatically (see approach in Section 4.2) using as basis the oneM2M Base Ontology in Turtle format available at <https://git.onem2m.org/MAS/BaseOntology> and the SAREF ontology available at <https://w3id.org/saref>. The resulting alignment is shown in Figure 4-6 and can be summarized as follows:

- *Function*. Covered by both SAREF and oneM2M Base Ontology (saref:Function and oneM2M:Function are equivalent classes). SAREF goes into a higher level of detail, defining also examples of functions, such as saref:OnOffFunction and saref:OpenCloseFunction. SAREF defines four types of Functions (i.e., saref:ActuatingFunction, saref:EventFunction, saref:MeteringFunction, saref:SensingFunction), while oneM2M Base Ontology defines two types of functions (i.e., oneM2M:MeasuringFunction and oneM2M:ControllingFunction). There is an equivalence between 1) saref:SensingFunction and oneM2M:MeasuringFunction; and saref:ActuatingFunction 2) and oneM2M:ControllingFunction. No equivalent in oneM2M for saref:EventFunction and saref:MeteringFunction.
- *Command*. Covered by both SAREF and oneM2M Base Ontology (saref:Command and oneM2M:Command are equivalent classes). SAREF goes into a higher level of detail, defining examples of commands, such as saref:OnCommand and saref:OffCommand, but also commands related to saref:MeteringFunction (which is missing in oneM2M), such as saref:GetCurrentMeterValueCommand.
- *Device*. Covered by both SAREF and oneM2M Base Ontology (saref:Device and oneM2M:Device are equivalent classes). SAREF goes into a higher level of detail, defining examples of devices, such as saref:LighthingDevice. SAREF defines also other type of devices such saref:Meter, saref:Sensor, saref:Actuator etc. that do not appear in the alignment because of a limitation of the algorithm we have used, which is a string-comparison algorithm⁴².
- *Service*. Covered by both SAREF and oneM2M Base Ontology (saref:Device and oneM2M:Device are equivalent classes).
- *State*. Valid match based on string comparison, but discarded by domain expert because saref:State and oneM2M:OperationState are not semantically equivalent, their meaning is different.
- *Network*. Valid match based on string comparison, but discarded by domain expert because saref:Network and oneM2M:AreaNetwork are not semantically equivalent, their meaning is different.

⁴²The class-name-similarity is calculated by the Python-module FuzzyWuzzy that comes with an out-of-the-box string-comparison algorithm. This algorithm does not detect the string “device” in terms such as saref:Meter, saref:Sensor, saref:Actuator etc. and therefore those devices do not appear in the alignment. We made use of a manual step performed by domain experts to overcome this limitation and make sure that we did not overlook important matches. Future work aims at improving the alignment-application to detect semantically related terms, not merely string-based similarity.

- *Property*. Valid match based on string comparison, but discarded by domain expert because `saref:Property` and `oneM2M:ThingProperty` are not semantically equivalent, their meaning is different.

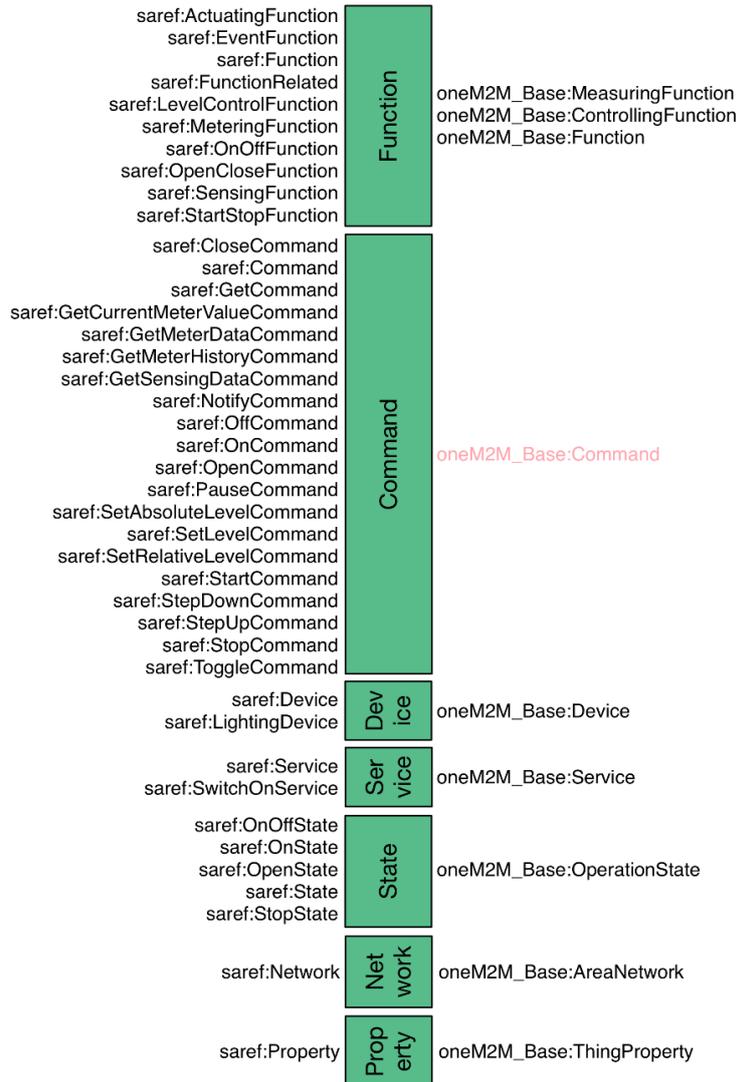


Figure 4-6: Alignment of oneM2M Base Ontology with SAREF using the algorithm for ontology matching

Gaps

There are no gaps identified between the oneM2M ontology and SAREF. However, in order to better understand the use of SAREF/SAREF4ENER in combination with oneM2M resources, it is beneficial to show an example of the tree structure for a oneM2M resource that can be automatically generated given a semantic description according to of SAREF/SAREF4ENER⁴³. The following tree structure shows a oneM2M resource representing a smart meter device, its status and measurements using SAREF/SAREF4ENER:

- **<oneM2M Application Entity Resource>** e.g., `saref:Meter`
 - **<oneM2M Container1>** for dynamic data, e.g. the ON/OFF Status of the meter

⁴³ The example belongs to the demonstrator implemented in this study and described in Appendix C “Detailed description of the demonstrations” of this document.

- **<Content Instance1.1>** for the data content, e.g., the value ON
- **<Content Instance1.2>** for the data content, e.g., the value OFF
- **<Content Instance1.3>** for the data content, e.g., the value ON
- ...
- **<Semantic Descriptor1>** static data according to the oneM2M Base Ontology or other external ontologies, e.g., the following excerpt of SAREF/SAREF4ENER from the DSF demo at EUW2017:

```
euw17demo:SmartMeter
rdf:type s4ener:Device ;
rdfs:label "Smart Meter"^^xsd:string ;
saref:hasManufacturer "Kamstrup"^^xsd:string ;
saref:hasModel "SM-AZ123456"^^xsd:string ;
saref:hasDescription "Kamstrup Smart Power Meter"^^xsd:string ; .
```

- **<Ontology Ref1>** the reference to the ontology used in the semantic descriptor, e.g., the following URLs of SAREF and SAREF4ENER used in the excerpt above:

```
saref: <https://w3id.org/saref>
s4ener: <https://w3id.org/saref4ener>
```

- **<oneM2M Container2>** for storing dynamic data, e.g. Power measurement
 - **<Content Instance2.1>** for the data content, e.g., the value 0.2
 - **<Content Instance2.2>** for the data content, e.g., the value 0.5
 - ...
 - **<Semantic Descriptor2>** static data according to the oneM2M Base Ontology or other external ontologies, e.g., the following SAREF/SAREF4ENER excerpt from the DSF demo at EUW2017:

```
euw17demo:Measurement_1
rdf:type saref:Measurement ;
saref:isMeasuredIn <http://www.wurvoc.org/vocabularies/om-1.8/kilowatt> ;
saref:relatesToProperty euw17demo:Power_1 ; .
```

```
euw17demo:Power_1
rdf:type s4ener:Power ;
saref:isMeasuredByDevice euw17demo:SmartMeter;
saref:relatesToMeasurement euw17demo:Measurement_1 ; .
```

- **<Ontology Ref2>** the reference to the ontology used in the descriptor, e.g., the following URLs of SAREF and SAREF4ENER used in the excerpt above:

```
saref: <https://w3id.org/saref>
s4ener: <https://w3id.org/saref4ener>
```

Actions

No further actions are needed at a semantic level, as considerable work has already been done to align SAREF and the oneM2M Base Ontology by the corresponding Technical Committees in ETSI and oneM2M (the resulting alignment of data elements is shown in Table 4-2 and Table 4-3). However, we noticed a lack of guidelines and practical examples on how to implement oneM2M resources in the oneM2M Service Layer using semantic descriptions according to SAREF and its extensions. In other words, an action is needed to create reproducible proof-of-concept solutions for stakeholders interested to use SAREF and its extensions (at a semantic level) in combination with oneM2M resources (at an architectural and protocol level). An example solution is presented in the “Appendix C - Detailed description of the demonstrations” of this report, where a Sierra Wireless M2M platform

serves as a Flexibility Control System for an Energy Services company, combining data represented by oneM2M resources (on the WAN side) with data represented by SPINE resources (on the Smart Home side) using SAREF/ SAREF4ENER as overarching ontology.

	Action owner	Action
A-13	oneM2M and ETSI SmartM2M	Create and document reproducible examples/guidelines for semantic interoperability to be used by stakeholders interested to combine SAREF and its extensions (at a semantic level) with oneM2M resources (at an architectural and protocol level).

4.4 Results

The objective of task 4 was to analyse the current semantic interoperability between the short-listed standards and define actions for alignment. The result of the analysis is shown in the table below.

Table 4-5: Level of alignment

STANDARD	LEVEL OF ALIGNMENT
EN 50631-1 (SPINE)	Fully aligned with SAREF4ENER
oneM2M Base ontology	Fully aligned with SAREF
IEC/CENELEC 62056 COSEM and	Fair alignment with SAREF/SAREF4ENER
CEN 16836 (ZigBee SEP2)	Fair alignment with SAREF/SAREF4ENER
CENELEC EN 50090 (KNX)	Potential alignment with SAREF/SAREF4ENER
IEC 61970 CIM	Potential alignment with SAREF/SAREF4ENER
CENELEC EN 50491-11 Smart Metering	Aligned with IEC/CENELEC 62056 COSEM
IEC 61968-9 CIM for Metering	Aligned with IEC/CENELEC 62056 COSEM

Full alignment between the selected standards can be achieved, executing the actions as defined in the table below.

	Action owners	Action
A-1	CLC/TC 294	Include <i>Power Profile</i> and associated concepts (i.e., <i>Power Profile Alternatives Group</i> , <i>Power Sequence</i> , <i>Slot</i> and corresponding attributes) in CEN EN 16836 (ZigBee SEP2). Or, explicitly acknowledge if these concepts are out of scope of CEN EN 16836 (ZigBee SEP2) and provide explicit indication of which other international standard should be used to cover these missing concepts.

A-2	ETSI SmartM2M TC	Consider the possibility to explicitly extend SAREF to cover additional type of meters and related measurements (e.g., gas, water, heat, etc.) other than electricity meters, if relevant.
A-3	CLC/TC 294, CLC/TC 205 and IEC/CLC/TC 13 WG 14	There are various smart meter standards used for the same interface (H1/H2), i.e., CEN EN 16836 (ZigBee SEP2), CENELEC EN 50491-11 Smart Metering, and IEC 62056 COSEM. Investigate overlapping between these standards, provide mappings and reduce duplication of work and efforts in different Technical Committees.
A-4	ETSI SmartM2M TC	Consider to extend SAREF to fill the identified gaps with IEC 62056 COSEM (see red elements in Table 4-2), if relevant. These gaps concern the status of the meter reading (intended as quality of the reading), and specific parameters related to Gas, Water and Heat meters, such as <i>Volume</i> .
A-5	ETSI SmartM2M TC	Consider to explicitly extend SAREF to cover additional type of meters and related measurements (e.g., gas, water, heat, etc.) other than electricity meters. SAREF already provides the capability to derive other type of meters from existing classes. For example, new subclasses such as “Gas Meter” and “Water Meter” can be created from the existing “saref:Meter” class and associated with the already existing commodity types “saref:Gas” and “saref:Water”. The suggested classes could be created either as part of the SAREF core ontology or the already existing SAREF4ENER. Another option could be to start a new extension of SAREF explicitly dedicated to the Smart Metering domain, if relevant.
A-6	IEC/ CENELEC TC 13 WG 14, but also SAREF users in general	When ad-hoc adjustments on SAREF/SAREF4ENER need to be done on a regular basis in different projects (recurrent adjustments), consider to submit a request to ETSI SmartM2M TC, so that an updated version of SAREF that incorporates these adjustments could possibly be released. For example, if one has to define recurrently in their own projects a “myproject:ReactivePower” instance from the existing “saref:Power” class, it would be beneficial to provide feedback to ETSI SmartM2M TC ⁴⁴ , requesting to create a class “saref:ReactivePower” (instead of having to define a “myproject:ReactivePower” instance over and over in different projects).
A-7	IEC TC 13 and IEC TC	CIM for metering is aligned with SAREF/SAREF4ENER through COSEM, meaning that interoperability is possible. IEC TC 13 and IEC

⁴⁴ All ETSI members can participate to SmartM2M TC meetings (usually held four times per year) and ad-hoc calls on SAREF related topics, to provide feedback on the use and evolution of SAREF. Contacts of the SmartM2M TC Officials and the schedule of the meetings can be found at <https://portal.etsi.org/home.aspx>

57		TC 57 should consider if interoperability through COSEM is sufficiently practicable. Otherwise, direct alignment with SAREF/SAREF4ENER could be explored.
A-8	IEC TC 57	Publish an official, standard OWL version of the CIM, as at the moment the burden of the translation from UML to OWL is left to the users (e.g., using the CIM tool), who generate different versions depending on how the translation is implemented. This also hinders the task to provide a standard alignment with other standards for DSF, like SAREF/SAREF4ENER.
A-9	IEC TC 57	When an official OWL version of CIM is developed for the purpose of DSF, IEC TC 57 should use the SAREF series of ontologies (especially SAREF4ENER) as input. The alignment proposed in this study (see Figure 4-3), together with the domain expertise coming from IEC TC 57 (for CIM) and SmartM2M TC (for SAREF4ENER) could be beneficial for the suggested task.
A-10	CLC/TC 205	EN 50491-11 is aligned with SAREF/SAREF4ENER through COSEM, meaning that interoperability is possible. CLC/TC 205 should consider if interoperability through COSEM is sufficiently practicable. Otherwise, direct alignment with SAREF/SAREF4ENER could be explored.
A-11	CLC/TC 205	Align the KNX ontology with SAREF/SAREF4ENER for the purpose of having only one ontology for interoperability (see elements in red in Figure 4-4).
A-12	CLC/TC 205	Since CENELEC EN 50090/KNX and CENELEC EN 50631-1/SPINE are both covered by CLC/TC 205 Home and Building Electronic Systems (HBES) and are both used for DSF, we suggest TC 205 to align these standards that cover the same interface (S2) in order to avoid confusion.
A-13	oneM2M and ETSI SmartM2M	Create and document reproducible examples/guidelines for semantic interoperability to be used by stakeholders interested to combine SAREF (at a semantic level) with oneM2M resources (at an architectural and protocol level).

5. Conclusions and recommendations

The main conclusion is that interoperability between the selected standards can be achieved, however, action is required to achieve it.

An important conclusion is that the SAREF and SAREF4ENER ontologies can be used as the overarching ontologies to make alignments between standards. If all standards can be aligned with SAREF/SAREF4ENER on the core data elements in the DSF domain, then all standards are also semantically interoperable with each other.

A certain level of alignment already exists. Out of the eight standards that have been analysed on alignment with SAREF/SAREF4ENER, two standards are fully aligned and do not need any further action for alignment. The first one is SPINE, which is aligned with SAREF/SAREF4ENER by design. The other one is oneM2M, for which good work has already been done by the Technical Committees in ETSI and oneM2M.

Four standards need further alignment, for which actions are defined, these standards are: IEC/CENELEC 62056 COSEM, CEN 16836 (ZigBee SEP2), CENELEC EN 50090 (KNX) and IEC 61970 CIM. For the specific actions, we refer to the results section of chapter four.

The remaining two standards, CENELEC EN 50491-11 and IEC IEC 61968-9 CIM for Metering, do not have a direct alignment with SAREF/SAREF4ENER, but are aligned through the COSEM standard, as they all cover the same interface. Therefore, these standards are considered to be aligned, however, in the future it might be more practical when these standards have a direct alignment with SAREF/SAREF4ENER.

The demonstrations that have been performed in this study (Amsterdam, Brussels and Sophia Antipolis) have shown that for a subset of standards (oneM2M, COSEM and SPINE) interoperability is achieved using SAREF/SAREF4ENER. For more detailed and practical conclusions we refer to the detailed descriptions in Appendix C.

Additional to the actions that have been defined to reach alignment between standards, we have defined several recommendations that smooth the road to interoperability:

- I. The study has shown that SAREF/SAREF4ENER can be used to reach interoperability on data level. We therefore recommend that SAREF4ENER is used as the ontology for the interfaces that are relevant for DSF applications as indicated in this report (H1, H2, S1, S2, G3).
- II. Since the development of ontologies is taking place in several organisations and even in several committees within the same SDO, we recommend that SAREF4 ENER is promoted as the ontology for Demand Side Flexibility system components, in order to prevent the development of competing solutions.
- III. We recommend the European SDO's to join forces and upgrade SAREF (or elements of it) to a "Three logo Standard" (i.e., a CEN, CENELEC and ETSI standard).
- IV. It is recommended that a 'power limitation' use case is developed in which the following data elements are incorporated: power limit and actual power consumption. Analyses the DSF use cases in task 1 showed that no use case was identified that covered the case in which the

Smart Meter informs the CEM about the programmed power limit and the actual total power that is consumed. A common Smart Meter use case is 'power limitation'.

- V. A common format of presenting use cases in documents published by the SDO's is recommended. Although this format is existing (i.e., IEC 62559), many Use Cases identified in this project do not use that format.

Overall, we conclude that alignment between standards is needed and that SAREF/SAREF4ENER can be used as the overarching ontology to facilitate alignments. Several actions and recommendations for various stakeholders, such as the Standards Development Organisations, have been identified and are listed in the report. The next step to be taken is scaling up the proof of concept that we demonstrated. The SAREF ontology needs to be implemented in more use cases for Demand Side Flexibility, in more smart devices and at real consumer sites.

References

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Appendix A - Longlist of Use Cases

Use cases presented in IEC62746-2:2015

Section in IEC62746-2:2015	Use case name:	Selected:	Comment:
A.3.2	Flexible start of a SD. (JWG1100)	Yes: UC2	The use cases A3.2-A3.6 are important because they relate to Smart Devices that have flex capabilities that can be used by Actor A via the CEM. Not all individual use cases cover multiple interfaces, however, several use cases can be combined to a more sophisticated one that covers multiple interfaces in the architecture.
A.3.3	SD informs CEM about flexible start (JWG1101)	Yes: UC2	
A.3.4	CEM informs SD about starting time. (JWG-SPUC1102)	Yes: UC2	
A.3.5	CEM informs SD about slot shift. (JWG1103)	Yes: UC2	
A.3.6	Control of Smart home appliances based on price information by time slot. (JWG1110)	Yes: UC2	
A.3.7	Fuel Cell Operation with Fixed Tariff Profile (JWG1111)	Yes: UC4	
A.3.8	Manage Mixed Energy System like heat pumps with PV, Storage Battery. (JWG1124)	Yes: UC4	Describes how non-smart controller can be operated smart. Involves multiple interfaces & data elements
A.3.9	Log Mixed Energy System events of heat pumps with PV, Storage Battery. (JWG113x)	No.	No smart device involved, focuses on local generation.
A.3.10	Provide local power managing capabilities. (JWG120x)	No.	No smart appliances involved, focusses on load/generation.
A.3.11	Provide local power managing capabilities. (JWG121x)	No.	No smart appliances involved, focusses on load/generation.

A.3.12	Demand Supply Adjustment by cooperation between supplier and customer. (JWG2000)	Yes: UC6	In this use case, multiple interfaces are covered and smart devices exchange information with actor A via the CEM. It's an essential use case.
A.3.13	Cascaded CEM (JWG2001)	No.	Special case for buildings, not important for this study. Study focuses on smart homes.
A.3.14	District Energy Management (JWG2002)	No.	Special case about multiple building in district, not important for this study.
A.3.15	Information exchange on distributed power systems with RES (JWG2010)	No.	Less important for this study, is about grid management instead of DSF
A.3.16	Peak Shift Contribution by Battery Aggregation (JWG202x)	No.	Less important for this study, is about grid management instead of DSF.
A.3.17	Power Adjustment Normal Conditions (JWG2041)	No.	Less important for this study, is about grid management instead of DSF.
A.3.18	Energy Accommodation for Buildings Under Disaster Conditions (JWG2042)	No.	Not important for this study, special case.
A.3.19	Tariff-Consumption Information Exchange (WGSP2111) (WGSP2114)	Yes: UC7 (Price, consumption) Yes: UC8 (Status, warnings)	Covers total infra and relevant data is exchanged over multiple interfaces.
A.3.20	Exchanging information on consumption, price, device status and warnings with external actors and within the home (WGSP2111) (WGSP2114)	Yes: UC7 (Price, consumption) Yes: UC8 (Price, consumption)	Refers to the same set of WGSP's as A3.19

A.3.21	Direct Load-Generation Management (International)	Yes: UC3	Involves Smart Devices, covers total infrastructure.
A.3.22	Direct load / generation management (European) (WG 2122, scenario 1)	Yes: UC3	Refers to the same set of JWG's as A3.21.
A.3.23	Tariff synchronization (WG2141) – via time (WG2143) – via tariff change notification.	Yes: UC9 Yes: UC10	Covers multiple interfaces. Important use case about keeping time synchronicity between smart meter and CEM.
A.3.24	Energy Flexibility Management	No.	This use case gives a very broad description and details are missing.
A.3.25	Energy production/storage integration	No.	No Smart Devices in the home involved. Use case is not about DSF.
A.3.26	Power loss notification and analysis	No.	Special case, CEM with UPS capabilities. Use case is not about DSF.
A.3.27	Historical data visualization (external data processing & storage)	No.	Use case is about export of historical data from CEM to external, private server. Interface is not in scope of this study.

Use Cases Presented in prEN 50631-1

Section in: prEN50631	Description:	Selected:	Comment:
5.3.4	Flexible Start	Yes: UC2	Use case description is limited to the interface between CEM and SD. Description of use case is very limited, but it can be derived that it belongs to 'Flexible start', UC2.
5.3.5	Direct Load control	Yes: UC5	Use case description is limited to the interface between CEM and SD. Direct control of load via CEM, so belongs to UC5.

5.3.6	Emergency Blackout prevention	Yes: UC3	Use case description is limited to the interface between CEM and SD. Emergency signal is send from CEM to Smart Device, so belongs to UC3.
5.3.7	Remote Programming	Yes: UC1	Use case description is limited to the interface between CEM and SD. Belongs to configuration of the system, so related to UC1.
5.3.8	Remote Monitoring	Yes: UC8	Use case description is limited to the interface between CEM and SD. Monitoring of status belongs to UC9.
5.3.9	Manual Operation	No.	No interfaces involved if smart device is in manual mode.
5.3.10	Install Smart Appliance	Yes: UC1	Belongs to installation / configuration of the smart devices, so related to UC1.
5.3.11	Remove smart Appliance	No.	Removal of Smart Device from CEM. No identification data elements exchanged over the interface, so not relevant for this study.

Use Cases presented in ETSI TR 103 411 V1.1.1 (2017-02)

Use case in ETSI TR 103 411 V1.1.1 (2017-02), section 5.1.1.	Description:	Selected:	Comment:
Use case 1.	<p>Configuration of devices.</p> <p>Configuration of devices that want to connect to each other in the home network, for example, to register a new dishwasher to the list of devices managed by the CEM;</p>	Yes: UC1	From the description, it can be derived that this use case relates to UC1 (Installation and configuration). Use case gives high level description, without explicit mentioning the data elements between the actors.
Use case 2a.	<p>Appliance scheduling.</p> <p>CEM receives the input from the appliance that it is ready to start and in remote control OR that was manually planned to start. On UI the user can see tariffs for the day and areas of incentives for consuming /non consuming energy. User can plan when to start the appliance in remote control and see what other products are already running or planned to start.</p>	Yes: UC2	From the description, it can be derived that this use case relates to UC2 (Flexible Start). Use case gives high level description, without explicit mentioning the data elements between the actors.
Use case 2b.	<p>Automatic re-scheduling.</p> <p>CEM receives the input from Utility/Aggregator that a more convenient time to run the appliance is available. On UI, user can see the new timing for the start of the dishwasher. Case can be played also with rescheduling to avoid peak hours.</p>	Yes: UC2	From the description, it can be derived that this use case relates to UC2 (Flexible Start). Use case gives high level description, without explicit mentioning the data elements between the actors.
Use case 3:	<p>Monitoring and Control</p> <p>monitoring and control of</p>	Yes: UC5	From the description, it can be derived that this use case relates to UC5 (Direct Load control). Use case gives high level

	<p>the start and status of the appliances;</p> <p>CEM receives the input from Utility/Aggregator that a more convenient time to run the appliance is available.</p> <p>On UI, user can see the new timing for the start of the dishwasher.</p> <p>Case can be played also with rescheduling to avoid peak hours.</p>		<p>description, without explicit mentioning the data elements between the actors.</p>
Use case 4a	<p>Reaction to the Grid:</p> <p>CEM receives the input from Utility about incentive to consume more energy or reduce total consumption below a defined level. Some products that are not cycle based (Air Cond., Water Heater, etc.) can modify their settings to fulfil the request.</p> <p>Appliances can increase or reduce power based on their capability and what they are doing. Notification is provided to the user through the UI.</p>	Yes: UC2	<p>From the description, it can be derived that this use case relates to UC2 (Flexible start): SD offers flexibility, and Utility utilizes this via CEM. Use case gives high level description, without explicit mentioning the data elements between the actors.</p>
Use case 4b.	<p>Reaction to the Grid:</p> <p>CEM receives the input from Utility or smart meter that there is an emergency and that products are requested to reduce consumption for few minutes.</p> <p>Appliances reduce power based on their capability and what they are doing. Notification is provided to the user through the UI.</p> <p>Appliances that are planned to start a cycle during the critical time will be rescheduled.</p>	Yes: UC3	<p>From the description, it can be derived that this use case relates to UC3 (Emergency). Use case gives high level description, without explicit mentioning the data elements between the actors.</p>

Use Cases presented in IEC62913-2-3 CD: 2016

Reference to IEC62913-2-3/CD: 2016 Table 13	Description:	Selected:	Comment:
System UC-1	Configure the Smart Home to enable the interoperability with the Smart Grid.	Yes: UC1	From the description, it is derived that this use case relates to UC1 (Installation and Configuration). Data elements are not mentioned.
System UC-2	Manage the flexibility of the Smart Home on electricity demand and generation from prices incentives.	Yes: UC2	From the description, it is derived that this use case relates to UC2 (Flexible start of device). Data elements not explicitly mentioned.
System UC-3	Manage the flexibility of the Smart Home on electricity demand and generation from DR requests.	Yes: UC5	From the description, it is derived that this use case relates to UC5 (Direct Load control). Data elements are not explicitly mentioned.
System UC-4	Manage the flexibility of the Smart Home on electricity demand and generation from emergency signals	Yes: UC3	From the description, it is derived that this use case relates to UC3 (Response to Emergency). Data elements not explicitly mentioned.
System UC-5	Manage opt-outs to automatic responses (only prices incentives and DR requests, emergency excluding) including manual actions	No.	Special case, not included.
System UC-6	Provide a third party with enriched Smart Home electricity data	No.	It is not defined what is exchanged over the interfaces and how this use case relates to DSF. It is a too high level description. No definition of information exchange.
System UC-7	Provide alarms related to the smart home electricity behaviour to the client or resident	No.	No definition of information exchange. No direct relation with DSF indicated.
System UC-8	Customise automatic responses of the Smart Home (price incentives, DR requests, or emergency signals) of the Smart Home	UC-1	Relates to configuration of the Smart Devices in the Smart home. To high level description to derive data elements.
System UC-9	Process metering data to invoice electricity supply of the Smart Home	No.	This use case is about metering data, so it is not included.

System UC-10	Process data related to the Smart Home behaviour to aggregate (forecasting, real-time), value and certify flexibilities	Y: UC6	From the description, it can be derived that this use case relates to UC6.
System UC-11	Process metering data to remunerate electricity feed in by the Smart Home	No.	This use case is about metering data, so it is not included.

Appendix B - Workshop on interim results

Objectives

On June 19th 2017 a workshop was organized in Brussels. This event has been jointly organized by the European Commission and the consortium conducting the study on "Demand Side Flexibility (DSF) Interoperability" (SMART 2016/0082) by request of the European Commission as part of the tender specifications. The objectives of the workshop were:

- introduce the DSF study to the interested stakeholders and present its intermediate results;
- discuss relevant developments in the field of ontology and data format standardisation related to DSF;
- collect feedback from stakeholders on the identified use cases and standards, the proposed approach and the expected outcomes.

Participants

There were 43 registered participants and 39 physical participants. The participants were coming from a variety of backgrounds (EU Commission, Industry, SDOs, Research and consumer organisations). In addition, a remote connection has been organized and 3 Participants have been following the workshop electronically (Hartwig Ziegler, Francisco da Silva, Enrico Scarrone).

Contributions of the DSF Interoperability Team

The whole DSF Interoperability study team has participated in preparing and conducting the workshop: Willem Strabbing (ESMIG), Arjan Aalberts (DNV GL, project leader), Laura Daniele (TNO), Paul Stapersma (TNO), Bas Roelofsen (DNV GL) and Hans de Heer (DNV GL).

The morning session was fully dedicated to the presentation of the scope, objectives, approach and (intermediate) results of the DSF study, based on the work carried out in Tasks 1, 2 and 3.

The afternoon session was devoted to the introduction by four key experts from EEBUS, CLC TC 205, ETSI SmartM2M TC and OneM2M to their current standardization activities, followed by an interactive Q&A session that involved most of the stakeholders in the audience.

The presentations made during the Workshop are available on the DNV GL web site at:

<https://www.dnvgl.com/events/interoperability-for-demand-side-flexibility-93109>.

Morning session

The morning session was fully dedicated to present the scope, objectives, approach and (intermediate) results of the DSF study, based on the work carried out in Tasks 1, 2 and 3. After presenting each task a short discussion/Q&A session took place. Below the highlights of those discussions.

Task 1:

During the discussion, a recommendation for Distribution System Operators (DSOs) was agreed on the use of the IEC template for use cases. In addition, it will be worth examining

the use cases that have been developed within H2020 / FP7 projects, by the smart appliances industry (EEbUS, energy@home) and the French National Committee. The team has decided to consider only the use cases That contain new data elements, not yet found in the formal Use Cases from the official Standard Development Organisations.

During the discussion, it was observed that the interface between the consumer, and either the CEM or the appliances, is not part of the scope. The project focusses on data definitions for M2M communication and it is expected that information provided by the consumer will result in M2M information flows from the appliance or CEM to other components of the infrastructure.

Further, use cases targeting Electric Vehicles (EV) have not been considered, this may however be relevant with respect to local storage facilities. The project team has considered EV use cases as suggested by the participants of the workshop. However, the team has only considered use cases that cover data exchange over multiple interfaces of the infrastructure, and not just communication with the CEM for example.. Several EV use cases are still under development (eg in the EEbUS consortium).

Task 2 and 3:

An in-depth discussion took place on the follow-up on how to ensure that the recommendations of the project are being implemented by the SDOs. Moreover, it was discussed how the (modified) standards could be used in practice by the industry. Some thoughts on the required level of detail are shared, i.e., whether the data elements and their alignment should be done at a higher level of abstraction or at a very deep technical level, making very detailed alignments for all considered standards requires considerable resources which will not be possible in this project, but we will provide alignments on the most important data structures so that SDOs will be able follow up on the suggested actions.

Afternoon session

In the afternoon four experts from key standardization bodies were invited by the project team to share their views on the topic of DSF interoperability, focusing on the developments within their technical Committees and Working Groups:

Presenter 1: Josef Baumeister;

Josef discussed the EEBUS initiative for smart energy management. The main discussion was on the costs associated with using smart appliances based on EEBUS standards (i.e., SPINE), as well as on energy labels that could indicate whether appliances comply to specific requirements such as DSF standards (a.o. SAREF and SPINE).

Presenter 2: Lee Gould;

Lee discussed the development within CLC TC205. The main discussion was on the use of the SGAM model (Smart Grid Architectural Model, developed by the CEN/CENELEC/ETSI Smart Grid Coordination Group under Mandate 490), which provides a useful method to position standards within the DSF domain, and may help identifying missing or overlapping standards.

Presenter 3: Enrico Scarrone;

Enrico presented the activities related to smart appliances and IoT standardization in the SmartM2M TC in ETSI. These activities mainly relate to the ontology framework for multiple domains based on SAREF, specified in 2015 and updated in 2016, integrated with the oneM2M based ontology. The main discussion was on the plans with respect to SmartM2M standardization.

Presenter 4: Joerg Swetina;

Joerg presented the oneM2M standard, a software/middleware layer, sitting between applications and underlying communication networking HW/SW, which exposes common set of functions to applications via REST API and is integrated into devices gateways & servers. The main discussion is on the relation of oneM2M to ISO work, especially on security aspects. Everybody agreed that the ISO work should not be neglected, especially with respect to security.

Q&A session;

After a summary of the main discussions and questions raised throughout the day, a Q&A session took place to further discuss the points that needed elaboration, and new questions could be raised. The main topics covered during the Q&A session were:

- How will the recommendations be followed-up by the SDOs such as IEC, CEN, CENELEC, ETSI and oneM2M?
- What can we do to move the (buying) industry to use/require the existing standards?
- Ecodesign and labelling for “demand response ready” devices and appliances.

Conclusions

The participants have been very active in the presentations, as well as during the feedback and the Q&A session with many questions and points of view expressed. The project team perceived a consensus between the attendants on the proposed method for reaching semantic interoperability. The need to reach alignment between different standards was acknowledged several times during the day by the stakeholders. Specific input received:

- The use of existing standards should be mandated on European or at least national level;
- To give a good overview of existing standards, they should be linked with the interoperability levels on SGAM: to what level do they apply. The standards covered in this project apply to the information and function layers.

Appendix C - Detailed description of the demonstrations

C1. General description of the demonstrations

In total, there have been three demonstrations related to this project. The objective of these demonstrations is to show applications for Demand Side Flexibility (DSF) in practise and in an open and standards based infrastructure as shown in figures 1-1 and 2-1.

SAREF was used in the demonstrations to facilitate the data integration that is originally modelled in standards produced by the metering industry in CENELEC TC13 (DLMS/COSEM) and the Home Automation industry EEBUS (SPINE). The communication with IoT platforms has been implemented through a combination of the SAREF ontology and oneM2M communication services. More details about the technical set-up can be found in section B2.

The first demonstration took place at the European Utility Week conference and exhibition 3-5 October 2017, where also the project itself was presented by ESMIG and TNO. In this demo the full scope of the DSF architecture as shown in figure 2-1. It comprised the following components:

- An IoT platform for the DSO, connected to a Head End System (HES) and Data Analytics application
- The HES connected to two smart meters
- An IoT platform for the ESCO, connected to a Home Energy Gateway
- A smart meter connected to an In-Home Display and light bulb
- A smart meter connected to an In-Home Display and Home Energy Gateway
- Smart Appliances connected to the Home Energy Gateway through a CEM functionality.
- The smart appliances: a washing machine, a dryer, heat pump and EV charging station.

The picture below shows the set-up.

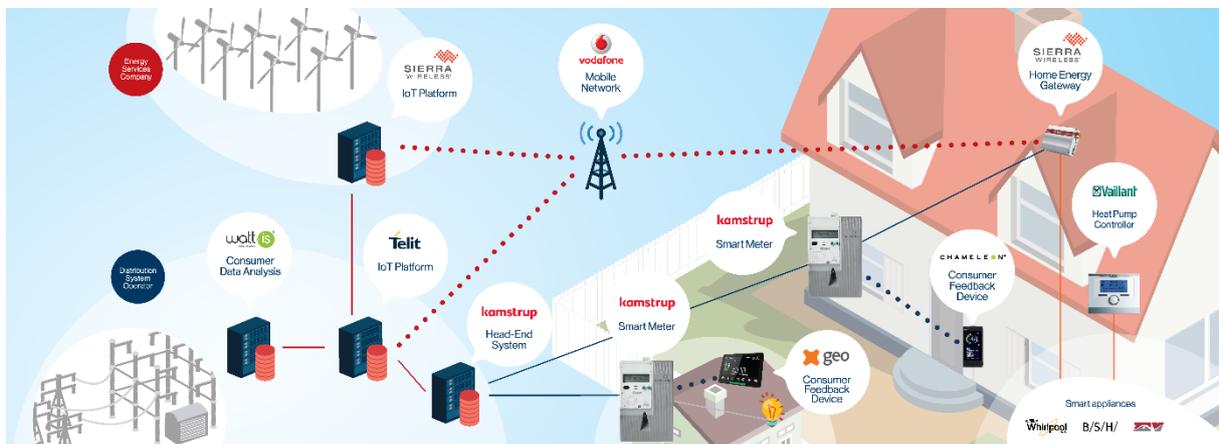


Figure 0-1: European Utility Week demonstration setup

Please note that the CEM functionality is not separately shown in this picture, it is supposed to be included in the “bubble” Smart Appliances.

Not all systems were physically present at the exhibition. The M2M-IoT platforms, HES and Data Analytics applications are reached through an internet connection to remote servers.

The demonstration covered two main functions:

1. Collection and analysis of meter data
2. Management of consumption

Function 1.

The meter data that is collected is provided by smart meters through two different interfaces on the meter. One (upstream) interface is used by the meter/grid operator for billing and grid management. This data is fed into the Head End system. Another interface provides real-time data for energy management. This data is fed into a Home Energy Gateway.

Historic meter data can be retrieved from the Head-End system and this is done by the Telit IoT platform. Real-time data is retrieved by the Telit M2M platform from the Energy Gateway.

The Watt-IS Data Analytics application analyses (real-time) consumer data to give insight in consumer behaviour and recommendations for energy efficiency.

So, the Telit M2M platform serves as a Data Hub for a Metering Services company.

Function 2.

Basically, there are two ways for managing energy consumption.

One is through the switch in the Smart Meter. This is an action that can be taken by a Grid Operator in case there is a risk that a black-out can occur caused by for example high consumption and low power generation capacity. This action will cause complete homes to be switched off. This is demonstrated by the meter connected with a light bulb.

Another, more sophisticated way, to manage energy consumption is through control of individual smart appliances. An energy services company can, for example on request of a grid operator, issue a command to reduce energy consumption. The motivation for such a command can also be an economical one: use less energy when prices are high. The Consumer Energy Management system (CEM) decides what appliances will be switched or activated at what moment based on the status of appliances. A second smart meter is connected to the Home Energy Gateway providing real-time information for the CEM.

The EMG and CEM can receive commands to increase consumption (for example when prices are low) or decrease consumption from the Sierra M2M platform.

So, the Sierra M2M platform serves as a Flexibility Control System for an Energy Services company.

A second demonstration took place in Sophia Antipolis during the ETSI IoT week 23-26 October 2017.

Due to limited space, the physical set-up was limited as compared to the EUW demo, but the implementation of the combination of data standards (COSEM, SPINE), the ontology (SAREF) and oneM2M communication services was the same. The demonstration set-up is shown in the picture below.

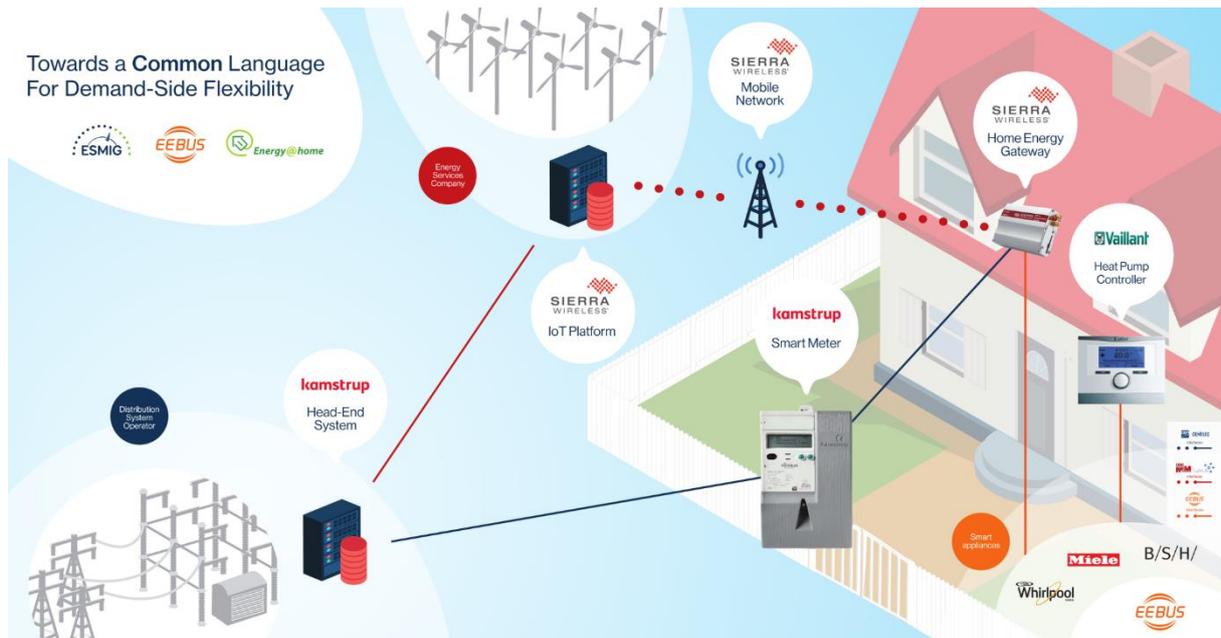


Figure 0-2: Sophia demonstration setup

As can be seen there was only one IoT platform and one Smart Meter in this demonstration. Since there was no space to install large small appliances, a washing machine was connected remotely and could be followed through a video connection.

Also at the ETSI conference ESMIG and TNO presented the project.

A third demonstration took place at DG-Connect's premises in Brussels on 27, 28 and 29 November 2017. This was again a full implementation of the DSF architecture like the EUW version. The number of smart appliances was however extended with a dish washer, tumble dryer and Solar power convertor station. The picture below shows the setup.



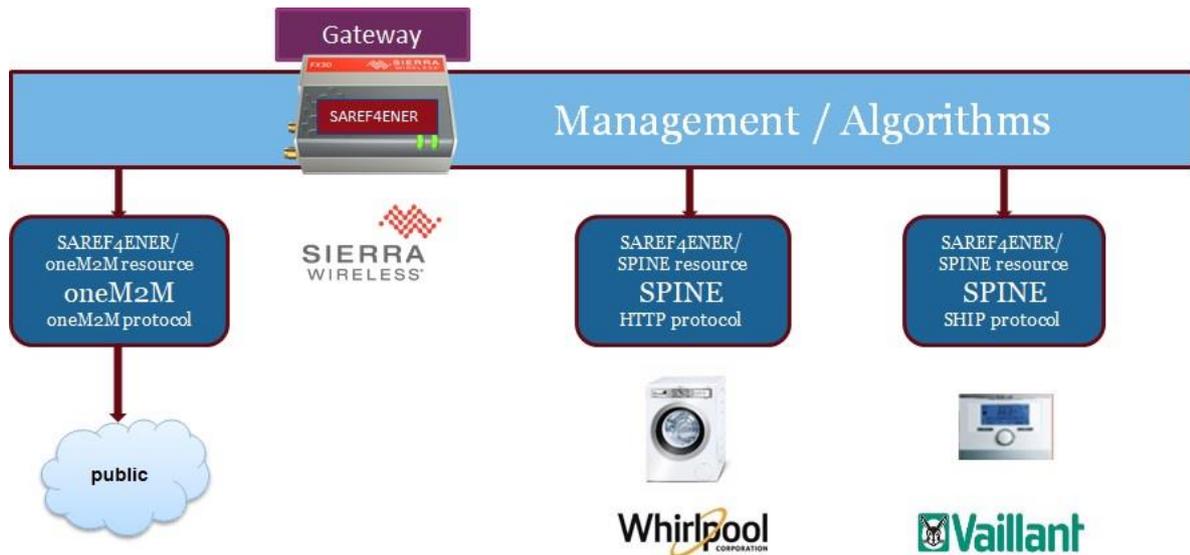
Figure 0-3: DG Connect demonstration setup

The 27th of November was politically focussed with C-level representatives of the European Commission, European Associations, Standardisation Development Organisations and Members of Parliament. There were discussions on standards for data models and ontologies, how SDO's should work together towards common standards. CEN/CENELEC clearly stated that they are committed to work together on ontologies such as SAREF and that the time needed to create a European standard ontology doesn't need to be long. There were questions about the introduction and price of Smart Appliances, and the industry representatives responded that the smartness would be "state of the art" within a few years. The European Commission is discussing the possibility of a label that could be used to indicate the "smartness" of appliances.

The 28th and 29th were more technology focussed and discussed the details of standards and further steps to be taken. It was explained that this project will result in recommendations for the Coordination Groups of CEN, CENELEC and ETSI, to take the work on alignment of standards on board and continue with this work.

C2. Technical description of the demonstrations

This section describes the technical implementation of most of the data standards that were selected in chapter 3. As described above, the Sierra Gateway implements the oneM2M communication layer and the SPINE communication layer to connect to the IoT platforms on one side and the CEM on the other side. SAREF4ENER is used as a common language to translate data from SPINE to COSEM and oneM2M resources. The diagram below shows this linking of data models



Smart appliances can have their own solution for a communication protocol such as HTTP, CoAP and SHIP (see documentation on www.eebus.org : <https://www.eebus.org/technologie/kommunikationswege/>). On the Smart Home side the data resources used are SPINE. On the WAN side the data is represented by oneM2M resources. The overarching ontology however is SAREF4ENER.

Below you find the details of data and data transactions.

Data Elements Definition

Data Element	Protocol	Format	Payload
MeterDataRequest.1	IP/Kamstrup	Kamstrup	getData
MeterDataRequest.2	HTTP/Kamstrup	OBIS	getOBIScode
MeterDataRequest.3	RS485	OBIS	
MeterReadings.1	IP/Kamstrup	Kamstrup	Various consump. data, incl. A+/A-/R+/R-
MeterReadings.2	HTTP/Kamstrup	OBIS	
MeterReadings.3	RS485	OBIS	Depends on OBIS code in request
MeterReadingsPush.1	oneM2M/HTTP	JSON	
MeterReadingsPush.2	ZigBee/SEP		Fixed set of consumption data for display
MeterReadingsResp.1	oneM2M/HTTP	JSON	
MeterReadingsResp.2	ZigBee/SEP		
MeterCmdRequest.1	HTTP/Kamstrup	OBIS	

MeterCmdRequest.2	IP/Kamstrup	Kamstrup	
MeterCmdReply.1	HTTP/Kamstrup		
MeterCmdReply.2	IP/Kamstrup	Kamstrup	
SAStatusRequest.1	oneM2M/HTTP	JSON	
SAStatusRequest.2	HTTP/SPINE		
SAConsumRequest.1	oneM2M/HTTP	JSON	
SAConsumRequest.2	HTTP/SPINE		
SAControlRequest.1a	oneM2M/HTTP	JSON	Decrease Consumption command
SAControlRequest.1b	oneM2M/HTTP	JSON	Increase Consumption command
SAControlRequest.2a	HTTP/SPINE		Decrease Consumption command
SAControlRequest.2b	HTTP/SPINE		Increase Consumption command
SAConsumData.1	oneM2M/HTTP	JSON	
SAConsumData.2	HTTP/SPINE		
SAStatusData.1	oneM2M/HTTP	JSON	
SAStatusData.2	HTTP/SPINE		
SAControlResponse.1	oneM2M/HTTP	JSON	OK or not OK
SAControlResponse.2	HTTP/SPINE		OK or not OK

Use Cases

Cluster 1: Reading and Presenting Meter Data

UC name		Displaying current consumption 1		
Interface		H1		
Systems involved		IHD	SM	
UC trigger		Smart Meter internal clock		
UC steps				
Step	Sender	Receiver	Data Element(s)	

1	SM	IHD	MeterReadingsPush.2	
2	IHD	"Consumer"		

UC name		Reading Meter Data 3 (over H2)		
Interface		H2		
Systems involved		EMG	SM	
UC trigger		EMG internal clock		
UC steps				
Step	Sender	Receiver	Data Element(s)	
1	EMG	SM	MeterDataRequest.3	
2	SM	EMG	MeterReadings.3	

UC name		Reading Meter Data 4 (current)		
Interface		G3		
Systems involved		IoTP1 / IoTP2	EMG	
UC trigger		EMG internal clock		
UC steps				
Step	Sender	Receiver	Data Element(s)	
1	EMG	IoTP1 + IoTP2	MeterReadingsPush.1	
2	IoTP1/2	EMG	MeterReadingsResp.1	

MeterReadingsPush.1 Request (HTTP):

The parts in red are susceptible to depend on the intent/situation

```
POST ~/IoTPX/ESMIGDemo/SWIR-21/meter-978/1_1_1_7_0_255?rcn=0 HTTP/1.1
Host: 52.28.68.95
X-M2M-Origin: //52.28.68.95/SWIR-21/Meter-978
X-M2M-RI: 123456789a
Content-Type: application/vnd.onem2m-res+json;ty=4
```

```
{
  "m2m:cin": {
    "cnf": "application/json:0",
```

```

    "con": "{\"timestamp\": 1478177480, \"value\": 1045}"
  }
}

```

MeterReadingsResp.1Response (HTTP):

The parts in red are susceptible to depend on the intent/situation

```

HTTP/1.1 201 Created
X-M2M-RSC: 2001
X-M2M-RI: 123456789a
Content-Location: /IoTPX/ESMIGDemo/cin-abcdef

```

Note : careful, the format of the oneM2M exchange has changed, it used to be the following in 2016:

Request (HTTP) – the parts in red are susceptible to depend on the intent/situation:

```

POST /IoTPX/ESMIGDemo/SWIR-21/meter-978/1_1_1_7_0_255?ty=contentInstance HTTP/1.1
Host: 52.28.68.95
X-M2M-Origin: //52.28.68.95/SWIR-21/Meter-278
X-M2M-RI: 123456789a
Content-Type: application/vnd.onem2m-res+json;charset=UTF-8

```

```

{
  "cnf": "application/json:0",
  "con": "{\"timestamp\": 1478177480, \"value\": 1045}"
}

```

Response (HTTP) – the parts in red are susceptible to depend on the intent/situation:

```

HTTP/1.1 200 OK
Content-Type: application/vnd.onem2m-res+json
Content-Length: 199
X-M2M-RI: 123456789a
<
{"ri":"1478177521ri","rn":"proxy","ct":"20161103T125201","et":"20161103T125201","lt":"20161103T125201","st":0,"cs":40,"cnf":"application\/json:0","con":{"timestamp": 1478177480, \"value\": 1045}"}* Connection #0 to host 52.28.68.95 left intact

```

Note: removed the use case reading current meter data real-time from IoT to HES to SM and back.

Cluster 2: Reading and presenting status of Smart Appliance(s)

UC name	Reading status of Smart Appliance (actual)		
Interface	G3		
Systems involved	IoTP1	EMG	CEM
UC trigger	Manual Request in IoTP1 User Interface		

UC steps				
Step	Sender	Receiver	Data Element(s)	
1	IoTP1	EMG	SAStatusRequest.1	
2	EMG	CEM	SAStatusRequest.2	
3	CEM	EMG	SAStatusData.2	
4	EMG	IoTP1	SAStatusData.1	

UC name		Reading consumption from Smart Appliance (actual)		
Interface		G3		
Systems involved		IoTP1	EMG	CEM
UC trigger		Manual Request in IoTP1 User Interface		
UC steps				
Step	Sender	Receiver	Data Element(s)	
1	IoTP1	EMG	SAConsumRequest.1	
2	EMG	CEM	SAConsumRequest.2	
3	CEM	EMG	SAConsumData.2	
4	EMG	IoTP1	SAConsumData.1	

Cluster 3: Controlling Smart Meter and Appliance(s)

UC name		Controlling Smart Meter		
Interfaces		G1		
Systems involved		IoTP2	HES	SM
UC trigger		Manual Request in IoTP2 User Interface		
UC steps				
Step	Sender	Receiver	Data Element(s)	
1	IoTP2	HES	MeterCmdRequest.1	

2	HES	SM	MeterCmdRequest.2	
3	SM	HES	MeterCmdReply.2	
4	HES	IoTTP2	MeterCmdReply.1	

UC name	Increasing / Decreasing EEBUS Appliances Consumption			
Interfaces	G3			
Systems involved	IoTTP1	EMG	CEM	
UC trigger	Manual Request in IoTTP1 User Interface			
UC steps				
Step	Sender	Receiver	Data Element(s)	
1	IoTTP1	EMG	SAControlRequest.1a/b	
2	EMG	CEM	SAControlRequest.2a/b	
3	CEM	SA		
4	SA	CEM		
5	CEM	EMG	SAControlResponse.2	
6	EMG	M2M	SAControlResponse.1	

SAControlRequest.2a Request (HTTP):

The parts in red are susceptible to depend on the intent/situation

```
POST / HTTP/1.1
Host: 192.168.1.78
Content-Type: text/xml
```

```
<datagram>
  <header>
    Specificationversion
    AddressSource
      Device
      Entity
      Feature
    Destination
      Device
      Entity
      Feature
    MsgCounter
    CmdClassifier
  </header>
```

```

<payload>
  <cmd>
    <Function>
  </cmd>
</payload>
</datagram>

```

UC name	Inform CEM about tariff			
Interfaces	G3			
Systems involved	M2M platform	EMG	CEM	
UC trigger	Manual request on M2M platform			
UC steps				
Sender	Receiver	Data Element(s)		
M2M	EMG			
EMG	CEM			
CEM	EMG			
EMG	M2M			

Example of SAREF instantiation in the demo

```

# baseURI: http://www.esmig.eu/resources/saref/examples/euw17demo
# imports: https://w3id.org/saref4ener
@prefix euw2017-demo: <http:// www.esmig.eu/resources/saref/examples/euw17demo#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix saref: <https://w3id.org/saref#> .
@prefix time: <http://www.w3.org/2006/time#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix euw17demo: <http://www.esmig.eu/resources/saref/examples/euw17demo#> .

<http://www.esmig.eu/resources/saref/examples/euw17demo>
  rdf:type owl:Ontology ;
  owl:imports <https://w3id.org/saref4ener> ;
.

euw17demo:SmartMeter
  rdf:type s4ener:Device ;
  rdfs:label "Smart Meeter"^^xsd:string ;
  saref:hasDescription "Kamstrup Smart Power Meter"^^xsd:string ;
.

euw17demo:Energy_1
  rdf:type s4ener:Energy ;
  rdfs:label "Energy 1"^^xsd:string ;

```

```
saref:relatesToMeasurement s4ener:Measurement_1 ;  
saref:isMeasuredByDevice s4ener:SmartMeter;
```

.

```
euwl7demo:Power_1  
rdf:type s4ener:Power ;  
rdfs:label "Power 1"^^xsd:string ;  
saref:isMeasuredByDevice s4ener: SmartMeter;  
saref:relatesToMeasurement s4ener:Measurement_2 ;
```

.

```
euwl7demo:Measurement_1  
rdf:type saref:Measurement ;  
rdfs:label "Measurement 1"^^xsd:string ;  
saref:hasValue "0.2"^^xsd:string ;  
saref:isMeasuredIn <http://www.wurvoc.org/vocabularies/om-1.8/kilowatt_hour> ;  
saref:relatesToProperty s4ener:Energy_1 ;
```

.

```
euwl7demo:Measurement_2  
rdf:type saref:Measurement ;  
rdfs:label "Measurement 2"^^xsd:string ;  
saref:hasValue "0.2"^^xsd:string ;  
saref:isMeasuredIn <http://www.wurvoc.org/vocabularies/om-1.8/kilowatt> ;  
saref:relatesToProperty s4ener:Power_1 ;
```

.

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