ENERGY DOMAIN

DATA SPACES FOR ENERGY, HOME AND MOBILITY

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Abstract

The European Commission has promoted the deployment of the Digitalisation of Energy Action Plan (DoEAP), in order to develop an efficient, competitive market for a digital energy infrastructure and digital energy services that are both cyber-secure and sustainable.
A central aspect of DoEAP is represented by the concept of Energy Data Spaces. Data exchange is crucial for emerging energy data services in the digital energy market and will help suppliers and energy service providers to innovate and cope with an increasing share of renewables in a more decentralised energy system. The data includes metering data, data from consumers such as home appliances, building automation, EV charging stations, or prosumers PV panel & inverters. Its availability and timely sharing and use among the relevant players is key for the energy transition.
This document addresses main issues of data exchange in the three interconnected key sectors: energy, buildings and mobility; the analyses focus on existing concepts of data formats and data standards, reflecting on how to facilitate data sharing across the different sectors based on a common data framework.
The foremost use cases of European projects and initiatives in the specific sector or at cross-sector level are presented, depicting the current state of data exchange deployments and identifying the necessary actions for the upcoming developments.

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Rational for an Energy Data Space

The success in achieving the target of the Green Deal will require harnessing energy from low-carbon sources, massively scale up investment in renewables, to power our homes, businesses, and vehicles. To achieve this, millions of installations — including solar panels, battery storage, heat pumps, boilers and electric vehicles will need to be seamlessly integrated onto current electricity networks.

This move to a more decentralised energy system will create millions of energy data points, needed to manage more complex energy flows, which will rely on the digitalised exchange of data to be managed effectively in, real-time across different domains like mobility, buildings, retail, energy and industry. This digitalised data exchange facilitates an energy system which can accelerate, automate, plan, and anticipate processes far better than at present.

The growth of smart, customer-owned renewable energy sources and electric vehicles, as well as IoT connectivity, cloud computing and app economy, creates an opportunity to shift from a central and distributed control paradigm toward decentralized coordination and control across the traditional boundaries of grid operator (GO), third-party digital service provider (DSP) and end-user, as charge station operator (CSO) or EV driver. Rooftop solar generation, the availability and capacity of energy storage, EV chargers, smart thermostats and other flexible demand response assets are currently operationally invisible to utilities. These devices will gather the consumers' data and use market information about the carbon footprint of a service, availability of power and cost.

The data points like the carbon foot print and fresh water usage while generating and distributing the energy are very critical to collect in real-time to give visibility to consumers. These data points are also needed for calculation of "Carbon Pricing" for example to handle costs of greenhouse gases[1].

Enabling on boarding and real-time information flows can encourage broad market participation by asset owner and system operators and enhance the reliability and resiliency of the power distribution system with an increasing number of renewables, while lowering costs. Data, crucially that of consumers, is key to the digital energy market and will help suppliers to innovate and offer new services. Data exchange is a baseline for being able to control flexible resources to be switched on or powered down according to the availability of renewable resources, local congestion challenges, or system wide disruptions. Developing a data-sharing infrastructure is an imperative for new energy services and flexible integration of appliances.

From an integration perspective, the data and technology components must be standards based, capable to capture the data in real-time, providers of data sovereignty, stakeholder driven, interoperable, easily accessible and open. It requires consistency of data. Systems can interoperate if they share the same semantic definitions of data, for example, if the data model is uniform. The support of data spaces targets to establish standards for a data model, semantics and ontologies. Definitions should be open and have an open source reference implementation. Informed consent and consumer protections are key to engage consumers as an active player in the energy market and leverage private investments. These must be consistent with the current regulatory actions like the GDPR, Data Governance Act and Data Act.

This report is dedicated to reflect on a data-centred, multi-layered challenge of exchanging data based on common information models, data formats and standards.

Digitisation of Energy Action Plan

Access to data and emerging energy data services are crucial to the digital energy market and will help suppliers and energy service providers to innovate and cope with an increasing share of renewables in a more decentralised energy system. To develop a competitive and innovative European market for energy services we need easy and non-discriminatory access to data and interactive data exchange.

The European Commission is preparing an Action Plan on the Digitalisation of Energy (DoEAP), to be published in 2022. Digitalisation is a prerequisite and allows to the efficient and effective operation of the energy system and energy markets.

[1] more information at https://carbonpricingdashboard.worldbank.org/what-carbon-pricing

The goal of the Action Plan is to contribute to the implementation of the Clean Energy Package, as well as Europe's Digital Decade targets. It will provide solutions on how to overcome challenges related to cybersecurity, data access governance, data protection and privacy, and the growing energy consumption of ICT, while putting EU citizens at the centre of the energy system and benefitting the environment. Building a common European energy data space will create a single market for energy data and support the energy transition; it will help connect existing projects, like Open DEI, and benefit from synergies with other data spaces, notably with the mobility data space to support the electrification of transport.

The Commission paid special attention to aligning the Digital and Energy Strategies, while bringing together stakeholders from different domains (electricity grids, charging electric vehicles, energy efficient buildings) and ensures that EU policies create a momentum on the market rather than become a burden and delay the digital transformation of industry.

The concept of Energy Data Spaces will be tackled as a pillar of the DoEAP. A data space will set a technical framework for data exchange and governance to spur innovation in the data economy. These concepts allow orchestration of data access across different market actors like TSOs, DSOs, aggregators and other energy service providers. As a baseline for a data space, the data and technology components must be built on formal or pre-normative standards, stakeholder driven, interoperable and open. Systems can interoperate only if they share the same semantic definitions of data, for example, a common ontology like SAREF. Definitions for semantic annotations, metadata and a data model should be open and harmonised across different system suppliers.

Impact of Re-Power - Ukraine crisis

Sky-rocking energy prices and the implications on EU energy security following Russia's attack on Ukraine require to revisit the targets of the Green and Digital transition. Rising energy prices make investments in renewable energy sources more attractive to consumers and businesses. Due to further stains on the electricity grid, digital solutions for flexibility management are an imperative for an efficient integration of volatile energy sources. Data exchange frameworks between consumer assets, energy producers and energy grids are the baseline for increasing the share of renewable and matching demand and response. At the same time, scarce fuel and gas supply require consumers to implement demand-side flexibility to replace carbon-based energy sources by electricity, which make solar and wind more attractive to secure energy supply. High fuel prices will accelerate the transition towards electrical transport which will give strong impulse on the use of electric vehicles. Their battery capacity could be instrumental for the sustainable, secure and carbon-neutral energy sources for homes and buildings if EV charging capable of smart and bidirectional functionalities, is combined with solar, heat pumps and other home appliances. In conclusion, the crisis will give a positive spin to the green and digital transition.

2. DOEAP – BEST PRACTICES FOR ENERGY DATA SHARING

Source for text: Shaping Europe's digital future, published on 21 February 2022; https://digital-strategy.ec.europa.eu/en/news/digitalisation-energy-best-practices-data-sharing

Aiming to gather support from stakeholders and other Commission services on its work in the energy sector, the Commission set up a workshop on **"Best Practices for Energy Data Sharing"** that took place on 16 February 2022. This was the first of a six-part series of workshops on the digitalisation of the energy system, co-organised by the Directorate-General for Energy (DG ENER) and the Directorate-General for Communications Networks, Content and Technology (DG CNECT), and discussed the potential of energy in the context of the digitisation of our economy and society.

The Commission paid special attention to aligning the Digital and Energy Strategies, while bringing together stakeholders from different domains (electricity grids, charging electric vehicles, energy efficient buildings) and ensures that EU policies create a momentum on the market rather than become a burden and delay the digital transformation of industry.

The digital infrastructure of the energy system is going to be complex. It will need to accommodate numerous devices and appliances from different manufacturers (from electric vehicles and heat pumps to smart meters, as well as other home devices like thermostats or boilers) and integrate the renewable energy sources. All these components need to act in concert with one another to for a balanced grid operation. Moreover, to develop a competitive and innovative European market for energy services the easy and non-discriminatory access to data and interactive data exchange is of outmost importance.

During the workshop **four challenges** have been identified to develop a performant European data-sharing infrastructure, which build on current national and European level initiatives on national and European level and which would trigger private and public investments to support the green and digital transition of the energy system.

Challenge 1: Interoperable building blocks for open, scalable data space

An energy data space cannot be delivered as a single platform or one central data hub; it must be built incrementally, meaning that applications and systems must be capable to interoperating and exchanging data across different data spaces. The following key aspects have been identified to guarantee the synchronous actions of stakeholders:

i. Use cases should drive the design, development, real-time data exchange and implementation of energy data spaces.
ii. Information barriers, diversity of standards and interoperability issues within energy and across sectors (e.g. transport, buildings, industry, etc.) need to be addressed.
iii. Modular reusable building blocks and open standards based interfaces and data models have to be used in accordance with the reference architecture agreed by all the stakeholders.
iv. Should be inclusive to be able to adapt or create connectors to make the existing data (legacy data) compatible with the recommended standards and architectures used.

Actors that are contributing to the creation of modular reusable building blocks and open standards have been identified, corresponding to: International Data Spaces Association (IDSA), Gaia-X, Linux Foundation Energy (particularly for the open source components), the H2020 project I4Trust; standardization committees active in the data exchange area are CEN-CENELEC and JTC1-SC41.

Moreover, this challenge is addressed by several ongoing actions: the Data Management working group of H2020 BRIDGE, the Expert Group 1 (EG1) "Standards for Smart Grids" in the Smart Grids Task Force (SGTF) and the "Harmonised Electricity Role Model" developed by ENTSO-E together with EFET and ebIX.

Challenge 2: An Economic and Legal Framework across different policy streams

A data framework, to be accepted by all players at EU level, should be built around high level use cases that encompasses three interconnected areas: Building, EV charging and Energy.

Digitalisation may relax financial investments in the energy infrastructure (e.g. renewables, grid, new electrical assets, etc.); moreover, the cross-sectoral cooperation regarding data can accelerate these investments and render infrastructure investments more efficient. To this point, market rules should allow new entrants, innovation, data services that are 'Digital-native'. The developments at European level rely on very relevant progress that has been demonstrated by several national initiatives.

The identified key actions, to foster the deployment of an economic and legal framework, are:

i. Focus on use cases of energy (electricity) sector, building sector and E-mobility sector, as well as use cases crossing these sectors, involving a well-balanced ecosystem (e.g. manufacturers, service providers, system operators, research institutions, etc.).
ii. Involve member states in the definition of economic and legal framework and consider actions to scale up national best practice for "European energy market design".
iii. For the market design, the legislation should not act against private/public investments. It is necessary to speed up the full implementation of the Clean Energy Package and the adoption of new market mechanisms, where necessary, allowing new market entrants and competition for services at different hierarchical levels.
iv. Recognise the complexity in combining the national level and European level: energy, mobility and ICT are often dealt with by different Ministries across different policy streams.
v. Provide all needed tools for data providers to have the data sovereignty and a trust framework.

Challenge 3: Establish a Governance System for the Energy Data Space

The challenges for a governance system to drive the digitalisation of energy systems are driven by the fact that more players are entering the energy market as owners (in a sense of holders of data storage) and/or users of relevant energy data and the need for decentralisation of the energy system to cope with the increasing complexity.

Two key elements have been identified as part of a governance scheme:

i. Trust in Decentralised (hierarchical) Systems: to allow exploiting sub-metering data from third parties for grid operations. Different trust options have been presented to access sub-meter data either through a decentralized or centralised governance schemes (e.g. data hub, energy control rooms, a facilitator, aggregators or public-private intermediaries.
ii. Local-for-Local: digitalisation could support local data exchange and decision-making to exchange energy locally, keeping data at the source. In developing such infrastructure, interoperability needs to link the static electricity system with the dynamics and physical behaviours of the field components behind the meter. Solutions could be implemented through an Energy OS, which would allow federated data exchange and mechanisms to zoom-in from central control to decentralised functions.

The Energy data spaces governance could follow the similar model to Eco Platform (Providing EPD - Environment Declaration of Products across EU member states[2]) where the stakeholders from all the EU members states are involved, data is stored in decentralised nodes and standard interfaces and data models are used to provide access to the data. Various data points are provided by the manufacturers regarding the products. Similarly, energy data spaces should have the data provided by the energy providers, energy transporters and consumers in real-time to make it more impactful.

Challenge 4: A Forum for Open Standards, Open data models, open source

The digitalisation of the energy system could be accelerated through shared architecture views, through open interfaces and standards, and through leveraging vibrant developer communities. In general, the energy system is suffering from having well established formal processes for standardization, whereas the adoption of digitalization calls for more agile and accelerated processes. The use of open interfaces, reference architectures, API and open source would avoid vendor lock-in, facilitate cooperation between different communities, and be attractive to new wave of innovators, and new market entrants.

For these reasons, a regular exchange on what exists, what is being developed and how to engage could be fostered through establishing a forum, with the following aims:

i. Stimulate the use of open standards and open source in projects and pilots, e.g. by linking existing repositories. Actors identified as references are: the H2020 project BD4NRG (involving the alignment among IDSA, I4Trust and Gaia-X), the SAREF standardization activities, the SmartDataModels.org initiative, the working group "Regulation" of H2020 BRIDGE and the Common Information Model (CIM) together with its flexibility expansion.

[2] More reference about EPD at https://www.eco-platform.org/home.html

ii. Consider agile processes for the adoption of emerging pre-normative or de-facto market norms and standards, and seek support by the established Standard Development Organisations (SDOs).
iii. Create a forum to link to and exploit the momentum of communities.
iv. Create a reference architecture for digital twin for energy distribution grid and generation.

3. DATA SPACES FOR ENERGY, BUILDING AND MOBILITY

Considering the presented outcomes of DoEAP workshop, in the previous paragraph of this document, the analysis focuses on the harmonization of data exchange among the interconnected, critical sectors: Energy, Mobility and Building.

This section aims at presenting an overview of latest deployments and initiatives in each of these sectors at European level. These references aim to identify the basic building blocks and mechanisms for the creation of suitable data spaces, in order to ease the energy production, distribution and consumption and to properly face the presented challenges.

3.1. Energy sector

The global energy system is experiencing a tremendous and fast revolution: the transition from unidirectional power flow (from generator to consumers) to multidirectional power flows, due to the presence of distributed energy resources and, accordingly, the new prosumers role. For this reason, the efficient integration and management of the tremendous amount of data are of foremost importance.

In the following paragraph, the importance and role of Common Information Model (CIM) in the electrical power systems is depicted. Successively, the document focuses on the solution developed by the H2020 project PLATOON in defining ontologies for the energy sector, in relationship with SmartDataModels and digital twins approaches.

3.1.1 The CIM Power System reference architecture

Source for text: SmartEn Position Paper "Setting a digital strategy for a cost-effective decarbonisation of the energy system" at www.smarten.eu

Moving towards a Power System of Systems

The impact of renewables, distributed energy resources, electricity demand growth due to the increased sector electrification has major implications for future grid capacity and operation. Moving towards further sectorial integration – whether for green hydrogen production, deployment of decarbonized heat networks in cities and heat pumps as well as Vehicle to Grid (V2G) charging infrastructures in residential environments is key to ensure the overall energy system decarbonisation is managed at lowest cost to end users.

Storage is confirmed to form a significant piece of the solution emerging across various sectors of the energy value chain. Furthermore, interconnectivity of systems and smart integration will be key for TSO & DSO Grid Operators in delivering the capacity and flexibility that is needed to reach the next complex miles of the European energy transition while taking advantage of Distributed Energy Resources developed at the lowest grid-edge levels.

Prosumers – whether at residential, community, city, or industrial scales - will end up forming the central focal point of such cross-sectorial integration investigating best financial options to mitigate the impact of the current energy crisis, decarbonize their process and operation and so mitigating their growing exposure to Emission Trading Schemes which progressively get expanded beyond energy intensive sectors. Overall, we should expect all sectors to develop appropriate metrics and KPIs to manage their carbon footprint efficiency expanding the integration of real-time data exchange across sectors federated several layers of data exchange platforms interacting with grid and market operator in their control room environments. The importance to track carbon origins across these different energy value chains will grow, indirectly supporting the development of undisputed carbon measurements across sectors, which will constitute a solid base to trade carbon abatements through Prosumer energy communities.

Such transformation indirectly questions the methods used for infrastructure planning – going towards cross sectorial cost benefit analysis as initiated with Power & Hydrogen – as well as tools used for System operation where Grid flexibilities will have to be searched across sectors hence requiring a proper definition of critical cross sectorial interfaces and interoperability principles.

Without doubts the future energy system will consist in one coordinated system of interconnected systems working seamlessly together. Each sectorial system will have to manage its real-time operation through the boundaries of its own set of operational requirements however establishing new "market coupling interfaces" making use of best available standards. So the digital infrastructure required to support such transformation is evolving from central monolithic vendor protected environments, as historically observed in SCADA control rooms, into new "platform of platforms" architectures. In these solutions data streaming, interoperability and open Application Programmable Interfaces (API) will become most critical components, offering new data interfaces to prosumers and integrating flexibility into the system – directly or through independent aggregator – potentially up to smart disconnection in grid emergency situations.

Expanding data integration boundaries across systems

TSOs have long been recognized as strong experts in balancing supply and demand; however, the current energy transition presents a new complexity that requires integrating new vertical coordinated approaches with DSOs, new independent aggregator as well as potentially any IoT devices located at the edge of their system. It is furthermore practically getting impossible to expand grids to the speed envisaged through the new RePowerEU plan for renewables and building electrification, hence requiring reconsidering grid optimization strategies to incorporate real-time grid capacity calculation and congestion management into energy market operation.

With the recent exponential development of EVs and the further electrification of the heat sector particularly, demand side dynamics is rapidly changing through the accelerated adoption of virtual power plant and independent aggregation of behind the meter IoT resources. This means a lot more resources – a majority of them located at residential level - are becoming available to potentially balance the system and participate into Grid frequency response. These resources are however much more dispersed, hence requiring to develop real-time digital connectivity to the lowest voltage levels of the electrical system taking advantage of new Edge-IoT architectures rapidly deploying through Distributed Energy Resource (DER) assets. Over the coming years it is therefore expected a rapid shift on how energy markets operate: from markets interacting with a limited number of large power plant entities – where manual operator interactions are still possible - into a future with a multiplicity of automated flexibility resources in residential environments, with potentially several flexibility service providers operating them (as suggested by Elia Group in their recent "Customer Centric Market Design" recommendations and recently considered through the draft Framework Guideline established by ACER for the next European flexibility code).

This change indirectly poses new questions on the extent of the role of grid operators into future market facilitation as most of the future flexibility will actually be physically connected to distribution system at Medium and Low voltage levels, then creating new congestion management and requiring innovative voltage control strategies. There is no doubt several of the System Operator functions will in the future evolve into coordinated processes across TSO and DSO, raising new questions in term of control room connectivity and integration strategies as well as interoperability with data exchange platform managing prosumer data.

To avoid the fragmentation of marketplaces and data exchange platforms across Europe and to ensure the best usage of flexibilities available across sectors, the key is to expand interoperability, transparency and a level playing access for all distributed flexibilities across the value chain. The data exchange platforms should also consider the business model of the stake holders involved.

Interoperability must therefore be enforced across Europe while the number of market participant increases:

- **Horizontally between Power exchanges & TSO marketplaces,** as largely initiated through the integration of Pan-European market processes such as Flow Based Market coupling on day ahead and intraday as well as coupling of European balancing platforms. These significant efforts have largely fostered CIM Market extension and associated ontology to harmonize backend TSO exchanges, which needs to be further leveraged to harmonize grid-to-market participant exchanges across Europe.

- **Vertically between TSO and local DSO marketplaces,** to ensure the coordinated operation of flexibility from highest voltages down to residential prosumers on lower voltages. Such coordination should cover all aspects of DER flexibility registration and qualification processes as well as baselining and real-time activations from long term to fast acting flexibilities such as for storage resources located behind the meter. Horizon 2020 projects such as TDX-Assist, CoordiNet, Interrface & OneNet have started to analyse the required CIM Market Model expansion to enable DER participation.

- **Between Grid operators, market participant and stakeholders,** to ensure that DER integration is made with minimal entry costs into the system across Europe while ensuring level playing interactions between wholesale assets and distributed flexibility at grid-edge. Today this mechanism is not in place for a large majority of grid service rules (often due to limitations in grid control room capability in observing and validating the performance of such distributed assets).

Flexibility services are expected to be traded through different marketplaces (day-ahead, intraday, balancing and frequency response markets as well as local flexibility markets) and enable revenue stacking to ensure a proper flexibility remuneration to prosumers. For such marketplaces to scale across Europe and to avoid fragmentation, further efforts should be made by TSOs and DSOs towards market interface interoperability and Control Room integration so that all marketplaces and market participants can access relevant information under consistent real-time data formats (as currently developed through the ENTSO-E transparency platform framework).

In the case of local flexibility markets, it is important for TSO & DSO to work at consolidating local flexibility marketplaces while maturity progresses to increase the size of the market and therefore its liquidity. This needs to be supported by interoperability of the market data and product so progressive integration is smooth and seamless leveraging DER asset data available through new interoperable data exchange platforms.

Exchanging with market stakeholders, future marketplace designs need to consider such interoperability as a base requirement, e.g. by having a published API, and work towards open standards to further promote open competition. Considering the large usage of CIM Market extension (IEC-62325) based APIs across the market platforms recently deployed such as Xbid as well as the new electricity balancing platforms, TSO & DSO should consider a progressive transition of this interface towards harmonized APIs across Europe leveraging CIM IEC-62325 message profiles and associated reference data models and ontologies (as successfully started by ENTSO-E through its transparency platform). This approach will naturally facilitate further vertical connectivity between TSOs and DSOs core operational processes and control room environments. In order to encourage DSOs to adopt the same standards, TSOs should be encouraged to open up CIM standard developments to DSOs taking advantage of first developments done through European projects such as TDX Assist, EU Sysflex, CoordiNet, Interrface and OneNet as well as more generally to broad market participant stakeholder environments as suggested by recent SmartEn European Prosumer associated digital whitepaper.

3.1.2 PLATOON Common Data Models for Energy

Source for text: D2.3 PLATOON Common Data Models for Energy https://platoon-project.eu/

The H2020 project PLATOON addresses the topic of semantic interoperability in implementing the energy services of its pilots, proposing new ontology models for the energy domain. The semantic interoperability is the ability of different agents, services, and applications to communicate data, information, and knowledge in a coherent purpose. On the other hand, Semantic Data Models (SDM), more known as ontologies, are recognized as the corner stone element, relying on ontology to describe domains in unambiguous manner and allowing experts to reach a consensus in a specific domain.

Starting from several works in state-of-the-art of ontology design domain, the PLATOON methodology to design the semantic data model is applied to reach the requirements of each Low-Level Use Case (LLUC) defined in the project pilots. The main steps of this methodology, after examining the existing semantic data models (ontologies) of the energy sector, are:

1. *Ontology Requirement Specification*

This action consists of the analysis and definition of requirements and specifications from the ontology or semantic data model. It corresponds to:

- **Use-case analysing**: according to high level description and IEC-62559 standard.
- **Ontology scope delimitation:** considering the application domain, the scope is defined to facilitate its definition and sharing.
- **Competency question definition:** the proposed questions must be answered by the ontology in its field implementation.
- **Term elicitation:** identifying and extracting all terms or notions that are relevant for a particular domain, according to IEC-62559.

2. *Ontology Analysis*

Following the principle of ontology domain, the ontology reusing is recommended before starting any new designing. The specific tasks to be carried out are:

- **Identification of concepts and relationships:** each term or key notion is associated to a concept or relation name to be used in semantic data model.

- **Reusing ontology:** the possible existence of each identified concept in the previous task is checked in the existing ontology.
- **Extending ontology:** in case the ontological module exists in the domain, but the concept is not covered, the existing ontology is extended.
- **Ontology construction:** in case the existing ontology does not cover the use case domain, a new ontological module is created.

3. Overview of ontological modules

This step aims at integrating all modules together into a harmonized semantic data model and producing an example for each pilot. The inputs are: (i) a list of identified ontological modules, (ii) a list of concepts and relations coming from the list of ontological modules, and (iii) a new designed ontological module. The tasks are:

- **Diagrams integration:** different modules are merged together in schema diagrams in order to check all classes and properties, identifying the semantical relationships.
- **Ontology evaluation:** the goal is to evaluate the ontological modules to ensure that its definitions correctly implement the use case requirements and competency questions: (i) competency of the ontology and (ii) quality requirements.
- **Use Case instantiation with an illustrative example:** using diagrams to define the scenarios of use cases.

4. Interaction with stakeholders and ontology formalization

The goal of this step is to interact with stakeholders and to code all ontology modules by using an ontology editor and a standard language and integrate all modules into an ontology system. The two steps are:

- **Discussion with stakeholders:** to validate the proposed outcomes.
- **Ontology formalization process:** provide an owl file for each new ontological model and an RDF file for each use case.

3.1.3 Connection to SmartDataModels and Digital Twin concept

SmartDataModels is a collaborative initiative impulse by FIWARE Foundation, TMForum, IUDX and OASC as well as many other organizations contributing to the data models. The data models are open-licensed allowing free use, free modification, and free sharing of modifications. So data models can be customised and evolved as per the needs of use cases. Data models have been harmonized to enable data portability for different applications including, Smart Cities, Smart Agrifood, Smart Environment, Smart Sensoring, Smart Energy, Smart Water, Smart Mobility, Smart House, Smart Robots and Smart Manufacturing[3]. They are intended to be used FIWARE NGSI version 2 and ETSI NGSI-LD. There are many similarities between PLATOON common data models and SmartDataModels. The Data models evolved in the process of creating Data Spaces should be contributed to the SmartDataModels and vice versa. The option of customising and evolving the existing data models from the Energy[4] and Mobility[5] domain from Smart Data Models initiatives should also be explored.

3.1.4 Energy Data Space architecture with Digital Twin concept

To deploy energy data spaces that rely on digital twin concept, the reference architecture should take various factors into consideration, about different data inputs, data access and sharing methodologies. Entities reported in Fig. 1 represent, as example, the various entities that constitute an Energy Data Space.

[3] Available at https://github.com/smart-data-models

[4] The existing energy data models are at https://github.com/smart-data-models/SmartEnergy

[5] Mobility data models are at https://github.com/smart-data-models/dataModel.UrbanMobility

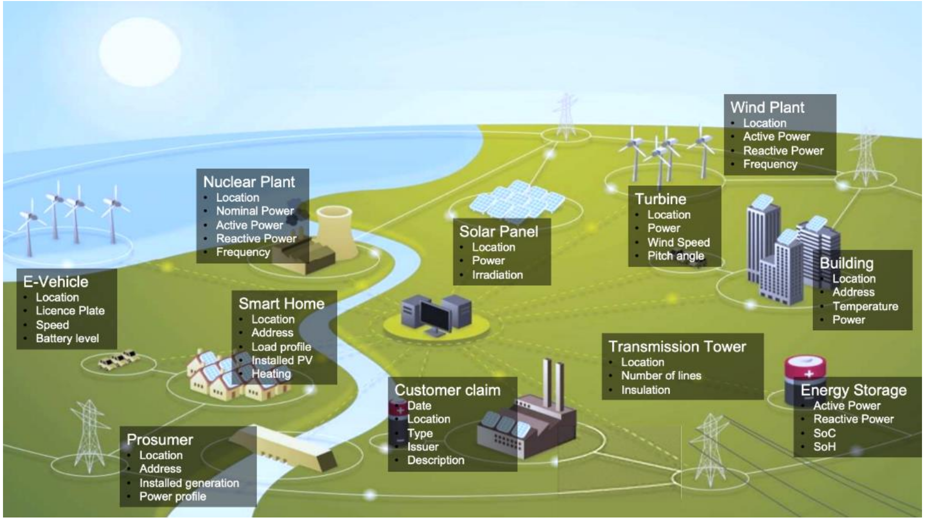

FIGURE 1 - DIGITAL TWIN ENTITIES FOR ENERGY DATA SPACES

Moreover, in the following Fig. 2 the reference architecture for Digital Twin based Data Space is represented.

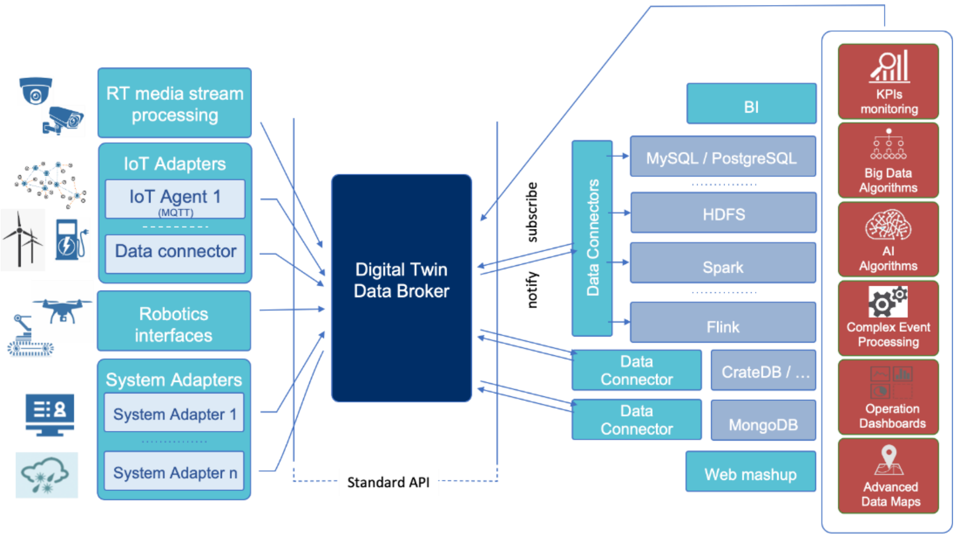

FIGURE 2 - REFERENCE ARCHITECTURE FOR DIGITAL TWIN BASED DATA SPACE

3.2. The Interoperability of Smart Grids and Smart Buildings

The successful energy transition cannot be implemented without improving the efficiency for buildings and home facilities, which constitute a considerable role in the overall energy consumption. Considering that more and more home devices rely on electricity (for heating, cooking, etc.), the automation of these devices is necessary to coordinate the operation of electrical distribution system and optimize the energy management. In doing so the smart building devices must achieve a systematic interconnection with the smart grids, by means of efficient data exchange solution.

3.2.1 Harmonisations between EEBUS and OpenADR

Source for text: "Whitepaper - OpenADR and EEBUS for Energy Control" at https://www.eebus.org/media-downloads/

Buildings have a high flexibility regarding energy needs through their electrical assets. Therefore, cross-domain networking of energy-relevant devices is essential, which is ensured by EEBUS' device level use cases. Supplemented by OpenADR's grid level use cases the grid and end-customer domains can be seamlessly connected to realise full end-to-end communication.

Secure capacity and tariff management provided by OpenADR and EEBUS will create a solution which significantly mitigates or even solves the upcoming grid issues due to the transition in energy supply, mobility, and heating. By combining the established standards OpenADR and EEBUS there is a solution available today to handle the rapidly growing power demands while increasing the share of renewable energy sources without major expenditures for grid expansion. Short-term grid capacity expansions to secure the energy supply are largely unnecessary and grid capacity expansions may be planned more mid- or long-term according to needs.

OpenADR represents a framework for the underlying communication protocols needed to automate load response and has contributed to the development standard demand response signals, basing the integration of smart grid implementation on the Common Information Model (CIM). Key roles of OpenADR are the communication technology for Demand Response and Distributed Energy Resource management, while EEBUS provides the standard for networking energy relevant devices on the building level and offers a standard based interface at the grid connection.

The cooperation is deployed to integrate the Distribution System Operator (DSO) and device level communication into one system, to realize fully secured end-to-end communication. The main objective is the management of over or underload scenarios, which require seamless bidirectional communication from grid to device level to enable local power monitoring and control.

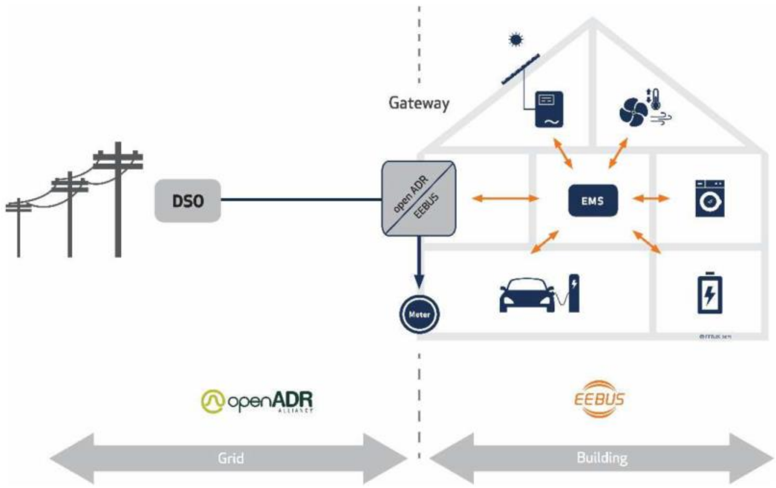

FIGURE 3 - SCHEME OF OPENADR AND EEBUS SOLUTION

Data point mapping of OpenADR and EEBUS can be made e.g., in the grid gateway, which is in charge of the DSO. An energy management system (EMS) with controllable devices or a controllable device is directly connected to the grid connection box to interpret the received commands and to act accordingly.

The following use cases can be then applied:

- **Energy security:** energy supply systems have high security requirements to make sure there will be no external intervention. Thus, the secure communication from the grid to the device level is one of the key elements that the integration of OpenADR and EEBUS technology provide, including consistent TLS based security starting from OpenADR's VTN server on the grid side through the building's control box at the grid connection point, to the EMS or devices at the end-customer side. If the communication behind the grid connection fails, the heartbeat mechanism of the EEBUS ensures that the devices operate in a fail-safe mode and return to a normal operation as soon as the communication is re-established.
- **Capacity management:** the DSO will be able to significantly reduce over and underload scenarios in the low voltage grid without static power limitations on end-user devices. Both the EV and HVAC system do have high flexibility in their energy behavior which makes them ideal as flexible loads for grid support: in times where energy is short, flexible loads can be operated with reduced power and in times of over production they will take as much energy as possible. By measuring the power consumption, the DSO may identify hotspots and take in-time corrective action by limiting power consumption via setpoints. In addition to controlling the power demand, the feed-in power of a PV system may also be controlled according to the needs of the grid.
- **Tariff management:** energy service providers (ESP) will be enabled to manage high or low energy amounts through influencing the local power consumption or production by incentives. The ESP will submit

the price of energy to an EMS or the device directly which will interpret the tariff information and optimize the consumption plan to lower the costs of energy.

OpenADR commands are exchanged between a Virtual Top Node (VTN) and a Virtual End Node (VEN). EEBUS the commands are exchanged between a client, that reads or changes data, and a server, that is the owner of the data that is read or changed by the client. A bridging device that maps OpenADR and EEBUS messages must be capable of receiving OpenADR commands and map them to EEBUS commands that are sent to the corresponding EEBUS receiver and vice versa.

Above solutions were successfully presented jointly by OpenADR and EEBUS as a showcase at DistribuTECH 2022 (the leading event for transmission and distribution systems and technologies in the US), for which the cross-domain networking up to the EV was of particular interest. Future topics such as bidirectional EV charging in connection with self-consumption or grid support were also discussed with interested parties.

3.2.2 SAREF for InterConnect project

Source for text: D2.3 InterConnect Interoperable and secure standards and ontologies (to appear) https://interconnectproject.eu/

The main challenge in the Internet of Things (IoT) landscape is the fragmentation of existing platforms, protocols and standards[6]. In this fragmented landscape, cross-platform interoperability among various platforms from different vendors is essential to avoid vendor lock-in, while preserving essential values in Europe, such as openness and level playing field. Furthermore, in our interconnected world it is crucial to share data and become interoperable within a certain vertical domain (e.g., energy, mobility, buildings, smart home) and especially across different domains. That is where the full potential of combining data still needs to be unlocked. By using ontologies as common vocabularies to share and reason about data[7], it is possible to address both the cross-platform and cross-domain interoperability challenges at the semantic (information) level, rather than at the technical communication level, as it used to be in the past. The IoT industry started to understand the impact that ontologies can have to enable the missing interoperability, also as a result of significant standardization efforts such as SAREF[8]. However, most industrial practitioners are not familiar with this technology and do not have an incentive to adopt it, as they believe the learning curve is too steep. Information on ontologies appears to them abstract and scattered over the Internet, thus, not easily applicable. Concrete guidelines and successful stories of semantically interoperable large-scale implementations, which are at the same time easy to be adopted, are still missing. In this context, promotion, experimentation and roll-out of interoperability innovation based on standardised ontologies is of paramount concern. SAREF and its extensions for Energy, Building and City are a solid example of mature, standardised and sustainable ontologies that can be used as basis to configure Data Spaces for energy, home and mobility. They provide the technological basis to enable distributed knowledge federation on top of which data spaces can be established with data sovereignty and governance.

By using the SAREF suite of ontologies as the main pillar, the H2020 InterConnect project has brought semantic interoperability to the next level, deploying large scale solutions in operational environments for connecting smart homes, buildings and grids with active involvement of industry. The core of the InterConnect innovation lies in a Semantic Interoperability Framework (SIF) that establishes, in practical terms, an open-source toolset to allow companies the ability to offer new services while focusing on integrating interoperable service features in a cross-domain ecosystem (data space). A number of new ontologies have been developed as part of the InterConnect SIF that extend SAREF in order to cope with the variety of use cases and services implemented by the seven InterConnect large scale pilots (i.e., 112 Use Cases and 66 Services from 21 InterConnect partners, based on 166 APIs, for a total of 864 parameters to be "SAREFized"). These use cases and services include, among others, smart

[6] AIOTI report on IoT standards landscape (2019) https://aioti.eu/wp-content/uploads/2019/10/AIOTI-WG3-SDOs-Alliance-Landscape-IoT-LSP-standrad-framework-R2.9-Published.pdf

[7] A catalogue of the main IoT ontologies structured by their domain of interest and classified regarding sustainability (who is maintaining it?) and technology readiness level (how mature is it?) can be found in the AIOTI Ontology Landscape Release 1.0 (2021) at https://aioti.eu/aioti-ontology-landscape-report/

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

appliances monitoring and control, energy flexibility, consumption/production forecasting and EV charging in residential and commercial buildings. The methodology adopted by ETSI for the development of the SAREF ontologies[9] was reused also for the InterConnect ontologies development. Main activities of this methodology are the ontology requirements specification, implementation and maintenance. A series of four workshops with the InterConnect partners was organized in one year to collect their input, validate the intermediate results produced by the ontology development team and iteratively collect new requirements to improve and complete the ontologies. The process resulted in the ontologies documented at the InterConnect Wiki and ontology repository[10] that are, like all SAREF ontologies, continuously in evolution with the feedback of their users.

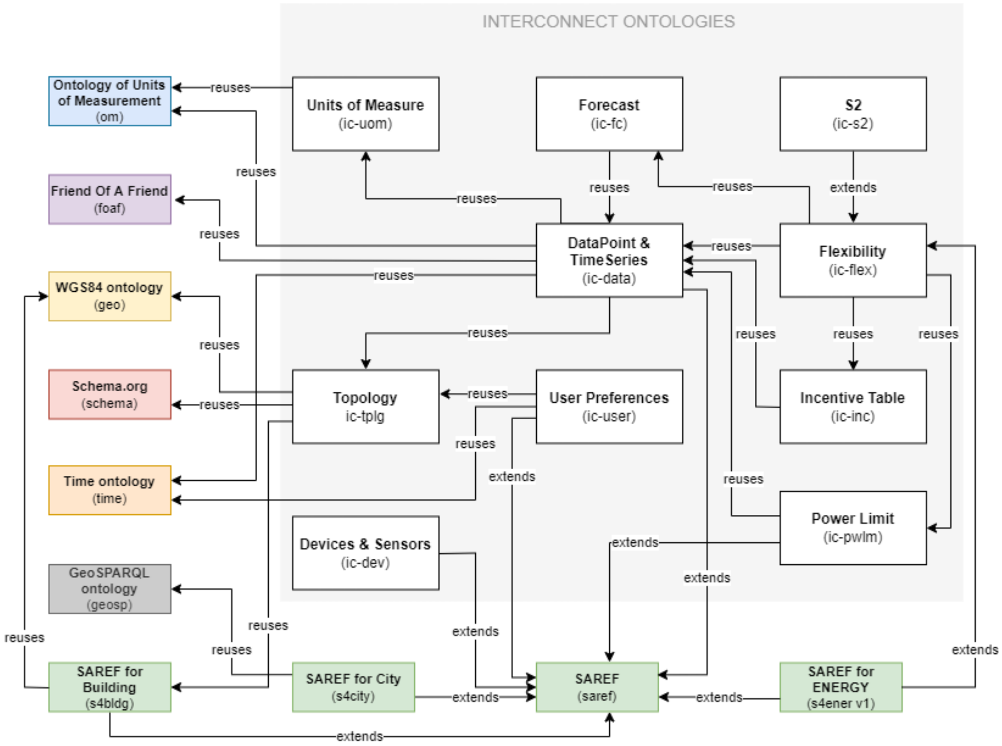

FIGURE 4 - THE INTERCONNECT ONTOLOGIES

A key result reached with the InterConnect work is the creation of four new ontology modules fully dedicated to energy flexibility, namely the flexibility (ic-flex), S2 (ic-s2), incentive table (ic-inc) and power limit (ic-pwlm) ontologies depicted in Fig. 4. The ic-s2 module is based on the recently published EN50491-12-2 standard specified by CLC TC 205 WG18 and complements the already existing ETSI SAREF4ENER v1 specification, which was originally based on EEBUS SPINE. The process of standardizing in ETSI the newly developed ontologies by InterConnect in order to officially extend the current SAREF suite of ontologies has been initiated in March 2022 and is currently ongoing. The combination of ic-S2, ic-flex, ic-inc and ic-pwlm will be used to create the next SAREF4ENER release (v2). Other ontology modules, like ic-data for datapoints and time series, are domain agnostic and will be therefore incorporated into the SAREF core ontology.

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[9] Methodology based on https://lot.linkeddata.es and documented in ETSI TR 103 411: SmartM2M Smart Appliances SAREF extension investigation, Technical Report (2017)

[10] https://gitlab.inesctec.pt/groups/interconnect-public/-/wikis/home#interconnect-ontology and https://gitlab.inesctec.pt/interconnect-public/ontology

3.2.3 Ontology design of building use case with PLATOON methodology

Source for text: D2.3 PLATOON Common Data Models for Energy https://platoon-project.eu/

The goal of the use case is to optimize the control of the HVAC in a building, regarding the occupancy property. It aims to providing a demand response service through HVAC control. To reach this purpose, two mains' elements are in this semantic data model: Building and HVAC.

Figure 5 represents an extract of Building, its occupancy and comfort properties. The building concept is represented by *`s4bldg:Building`* from SAREF for building ontology which is equivalent to the concept *`seas:Building`* from seas ontology. The building can be subdivided in different zones (*`bot:Zone`*) and is linked to these zones with the (*`bot:containsZone`*) relationship. Each zone (*`bot:Zone`*) has an occupancy property (*`saref:Occupancy`*). The zone and its occupancy property can be related with three types of occupancy relationships: the first one *`plt:hasOccupancy`* which is a generic property of occupancy that can be specialized on two sub properties *`plt:hasClientsOccupancy`* to indicate that the zone is occupied by customers and *`plt:hasEmployeesOccupancy`* to indicate that the zone is occupied by employees. The occupancy can be assessed either by some statistical algorithm or detected by occupancy sensor (*`dogOnto:OccuapncySensor`*) which observes the occupancy property (*`seas:ObservesProperty`*).

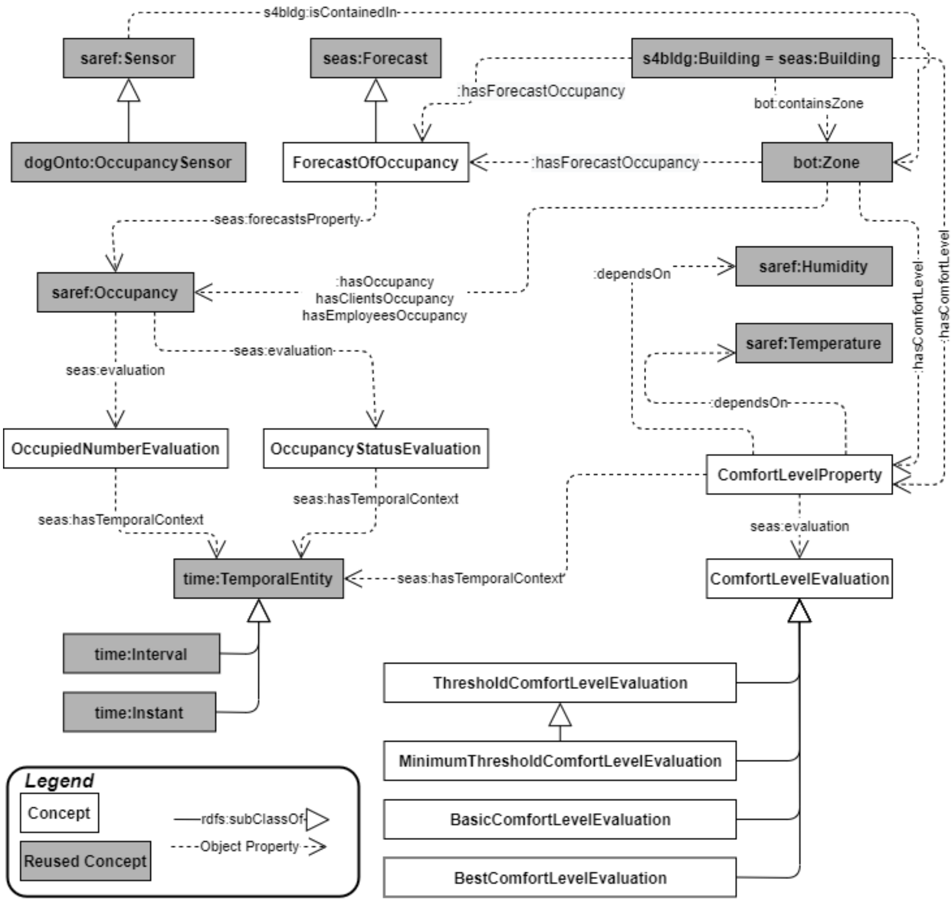

FIGURE 5 - SEMANTIC DATA MODEL OF BUILDING PROPERTIES

We can associate two types of evaluation to the occupancy. The first is the occupancy status (*`plt:OccupancyStatusEvaluation`*) to know if the zone is occupied or unoccupied. The second is the number of persons that occupy the zone (*`plt:OccupiedNumber-Evaluation`*). As each Evaluation, these two evaluations have a temporal context of validity. For optimization of HVAC control, forecasting of the occupancy is important to schedule the cooling and the heating of the zones. This forecast is represented by *`plt:ForecastOfOccupancy`* concept that forecasts (*`seas:forecastsProperty`*) the *`saref:Occupancy`*

Property. The optimization should respect for each `bot:Zone` the comfort level (`plt:ComfortLevelProperty`) which depends on (`plt:dependsOn`) `saref:Temperature` and `saref:Humidity`. This comfort level has four levels of evaluation (`seas:evaluation`). We can distinguish between four levels of comfort: `plt:ThresholdComfortLevelEvaluation`, `plt:MinimumThreshold ComfortLevelEvaluation`, `plt:BasicComfortLevelEvaluation` and `plt:BestComfortLevelEvaluation`.

3.3. Mobility sector

Source for text: https://transport.ec.europa.eu/

Today, transport still relies on oil for 94% of its energy needs. Research and technological development have led to successful demonstrations of alternative fuel solutions for all transport modes. Market take-up, however, requires additional policy action: the Clean Power for Transport package aims to facilitate the development of a single market for alternative fuels for transport in Europe.

The Sustainable Transport Forum (STF) was set up to assist implementation of the European Union's activities and programmes aimed at fostering the deployment of alternative fuels infrastructure to contribute to the European Union energy and climate goals.

The subgroup for "Common data approach for electromobility and other alternative fuels" has identified two main activities to be deployed in 2022, particularly related to the challenges presented in the "DoEAP - Best practice for energy data sharing" section:

1. **Characterisation of the different data dimensions required to enable the future creation of digital services in the alternative fuels market**
   The objective of this activity is to define the main building blocks to create and put in place an open data ecosystem for electro-mobility and other alternative fuels (H2, CNG, LNG, highly blended biofuels). Particularly, the deployed work will reflect the impact of both technical and governance issues. Moreover, the sub-group shall consider other upcoming policy initiatives, such as in the direction of "Mobility Data Space".
   The sub-group will analyse the different data dimensions (e.g., aggregation, quality, format, sharing, reusability, etc.) required to enable the creation of digital services in the alternative fuels market. Additionally, the sub-group will define the future needs concerning static and dynamic data types for the different fuels and vehicle types (e.g., LDVs vs. HDVs) and related needs and concepts for the localization, booking, payment and billing process of recharging/refuelling alternatively fuelled-vehicles. Finally, the sub-group will identify the relationship between key technical and governance aspects in order to create an open data ecosystem.
2. **Mapping of the roles and responsibilities of the different types of market actors within the alternative fuels ecosystem**
   For this activity, the goal is to review and map the roles and responsibilities of the different types of market actors as part of the future alternative fuels data ecosystem (including e-roaming platforms, data brokers, DSOs, TSOs, charging aggregators and traditional fuel suppliers). In addition to publicly accessible infrastructure, the influence of recharging points at private dwellings and business buildings is addressed as a unique ecosystem, reflecting the challenges and aspects reported in the building sector paragraph of this document.
   The following aspects will be analysed:
   - Role and responsibilities of every type of market player, considering B2G, B2C and B2B interactions.
   - Architectures (i.e., database, data warehouse, data market place, data register), identifying the advantages and disadvantages of each format.
   - Assess the incentives of every type of market actor for the creation of an open and competitive data ecosystem.
   - Technical specifications that may be required for the transmission and reception of data in real-time among the different market players.
   - Different regulatory requirements associated with each member state.

3.3.1 E-Mobility use cases of EEBUS

Source for text: https://www.eebus.org/release-eebus-use-case-specification-e-mobility/

As EVs consume significant amounts of power, it is important to integrate them into an energy management system to coordinate the charging process with other consumers, such as heat pump, and producers, such as photovoltaic system (PV). This will help optimize cost and sustainability.

The increased power demand of EVs will be challenging for the power grid. As the number of EVs is continuously and rapidly increasing, it is important to balance consumption and production by energy management systems. This will ensure the EV can be charged by a stable grid condition within the limits set by the owner. Furthermore, the batteries of EVs can, in the future, also be used to stabilize the grid.

EEBUS proposes the SPINE toolbox, with corresponding data models and functionalities, to address the following use cases:

- **Coordinated EV Charging.** Relying on the energy broker, the consumption of an EV is guided through incentives. Additionally, the energy guard avoid overload situations during charging. The EV will inform the energy guard and broker about its actual energy demand. This information enables the energy guard and energy broker to provide the maximum power limitation, and to tailor its incentives to the energy demand of the EV.
- **Overload Protection by EV Charging Current Curtailment.** To avoid an overload situation, the energy guard continuously monitors the power consumption through the according measurement points. It will immediately initiate curtailing of the charging power of the EV if a potential overload at the corresponding circuit breaker is detected.
- **Optimization of Self-Consumption during EV Charging.** This use case aims to optimize consumption of self-produced energy (e.g. PV energy), via the Customer Energy Manager (CEM), during the EV charging process.
- **EV Charging Electricity Measurement.** This use case aims to continuously monitor the power consumed by the EV charging process to enable the CEM to evaluate the charging power and react accordingly.
- **EV Charging Summary.** The energy broker continuously monitors the percentage value of the used energy source, as well as the energy costs of the current charging session. During, or at the end of the charging process, the EVSE can request a charging summary.
- **EV Commissioning and Configuration.** This process is needed as basis for the deployment of further use cases in the EV charging process.
- **EVSE Commissioning and Configuration.** The EVSE usually serves as gateway that transmits the necessary information between the CEM and the EV.

4. USE CASES AND STANDARDS

A use case is a specification of a set of actions performed by a system, which yields an observable result. Each use case identifies the participating actors that play a role within it, together with the associated scenarios and the information to be exchanged to realize them. In particular, the IEC 62559 series of standards defines a methodology and a template to harmonize the use-case description.

In the Smart Grid and Smart Building/Home domains, several initiatives have contributed to identifying and characterizing the main relevant use-cases:

Initiative	Description & references of interest	Link
BRIDGE bridge	EC initiative gathering **90+ H2020 projects on smart grids**, with a total funding ≈ €1bn. One WG focusing on Data Management WG. A **use-case repository** has been developed.	Link
InterConnect interconnect	Major H2020 project focusing on **interoperability for Smart Home, Building and Grid** (2019-2023, €30m funding) D1.3 defines the **112 high-level use-cases** (HLUC) of the project. D2.3 defines the InterConnect ontology based on the 66 services and 166 APIs developed in the project.	Link
SmartBuilt4EU Smart Built4EU The European Smart Buildings Community	**Community on Smart Building innovation** (H2020 CSA). "TF2 Topic A" white paper is on building interoperability "TF3 Topic A" white paper is on the provision of power flexibility by building to the grid	Link
IEC SyC Smart Energy IEC International Electrotechnical Commission	IEC System Committee focusing on the **system definition of the Smart Energy** domain. Relevant series: IEC 62559, IEC 63200, IEC 62913, … In particular IEC 62913-2 series describes the smart grid requirements for the Grid, Market, DER and E-Mobility domains	Link

The analysis of the use-cases from these initiatives leads to the following three main categories of use-cases, also depicting cross-sector synergies:

- Energy sector: Flexibility products for the energy markets
  - It includes flexibility for the grid operators (grid support), flexibility for the BRPs (portfolio optimisation), but also flexibility for the local communities (e.g. collective self-consumption) or for its own interests (individual self-consumption).
- Energy sector × Home & building sector: Smart buildings & smart appliances
  - It includes comfort, energy efficiency, self-consumption at home/building level, minimization of the energy bill, maximization of renewable energy sources, increase of the consumer involvement, ...
- Energy sector × Mobility & transports sector: Smart charging & V2G
  - It includes optimization of energy cost, reduction of connection impact, optimization of the contractual power, valorisation of the storage capacity, …

These use-case require the exchange of the following types of data:

Sector	Data	Relevant standards and data models (not exhaustive)
Energy	Grid & topology Energy & power Flexibility function Metering & tariff	IEC CIM (incl. CIM-Market), FlexOffer, IEC 61850, USEF, OpenADR, DLMS/COSEM, SAREF4ENER

Home & building	Building Flexibility function	IFC, SAREF4BLDG
Mobility & transport	Mobility / transport Charging contract	OCPI, OCPP, IEC 63110, IEC 63119, IEC 63382
Domain agnostic	Device (sensors, actuators, …) Measures Commands Time series Geospatial Time Time series (*) Forecast (*) User preferences (*)	SAREF and (*) InterConnect ontology extension, Smart-Energy OS

While sector-specific standards or open specifications (e.g. data models) largely exist to cover these needs, one of the main challenges is to "connect" these sector-specific models to enable cross-sector data exchange and interoperability. This is where ontologies can help, in particular we can mention the following initiatives:

- SAREF ontology (and its extension: InterConnect ontology), see above §3.2.2
- IEC TS 63417 "Guide and plan to develop a unified IEC Smart energy Ontology" (work in progress)

5. DATA SPACES FOR EFFECTIVE AND TRUSTED DATA SHARING - I4TRUST BUILDING BLOCKS

Source for text and figures: "i4Trust Building Blocks" at https://i4trust.github.io/building-blocks/docs/i4Trust-BuildingBlocks_202109.pdf

The H2020 project i4Trust integrates standard-based building blocks from the FIWARE and iSHARE frameworks. Together with common data models, the FIWARE Context Broker building block supports effective data exchange among parties by using the standard NGSI-LD API. Additionally, FIWARE Data Marketplace components, based on relevant global industrial recommendations and data catalogue (DCAT) standards, bring support to data publication and trading, including the monetization of data. On the other hand, the iSHARE scheme brings the foundation for trustworthy exchange among parties based on well-established security standards and robust legal frameworks. Hence i4Trust provides the foundation for the core functionalities in every Data Space, namely data interoperability, data sovereignty and trust and data value creation.

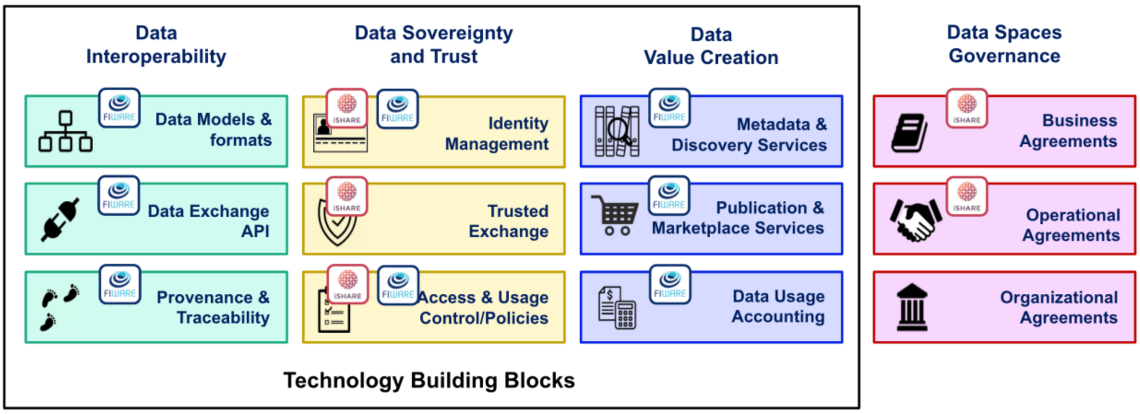

FIGURE 6 - COMBINATION OF FIWARE AND ISHARE BUILDING BLOCKS TO MATERIALIZE DATA SPACES

5.1. Data Interoperability

Data providers joining data spaces must be able to publish data resources at well defined endpoints knowing that data consumers, unknown by them a priori, will know how to retrieve and consume data through those endpoints. Data consumers, on the other hand, must know how data available through endpoints they discover can be consumed.

Participants in i4Trust data spaces will essentially exchange digital twin data using the domain-agnostic NGSI-LD API. Context Broker servers are the endpoints through which systems connected to the data space publish digital twin data, very much like web servers publish html content on the world wide web. Those systems can in turn connect to Context Broker servers in order to obtain information they need. Note that i4Trust data spaces enable near real-time exchange of digital twin data, which is fundamental in the design of innovative value chains demanding a very dynamic exchange of data among participants.

Being domain-agnostic, NGSI-LD API is designed to work for any type (class) of digital twin. Consequently, achieving full interoperability also requires the adoption of common data models to be represented in formats compatible with the API. The Smart Data Models initiative (https://smartdatamodels.org/) suits perfectly well. It brings a powerful resource for developers who can rely on the way data model specifications are mapped into concrete JSON and JSON-LD structures under the initiative, the latter being compatible with NGSI-LD.

Completing the picture of building blocks for Data Interoperability, i4Trust is planning to incorporate components which provide the means for tracing and tracking in the process of data provision and data consumption/use. They will provide the basis for a number of important functions, from identification of the provenance of data to audit-proof logging of NGSI-LD transactions, very relevant for data spaces with strong requirements on transparency and certification.

5.2. Data Sovereignty and Trust

Data spaces must provide means for guaranteeing organizations joining data spaces that they can trust the other participants and that they will be able to exercise sovereignty on their data. A first fundamental building block to support within data spaces has to do with **Identity Management** (IM). This building block is implemented in i4Trust through multiple distributed Identity Providers (IdP) allowing identification and authentication of organizations, individuals, machines and other actors participating in a data space. For human identities the specifications are based on the OpenID Connect standard, which has been adapted in the iSHARE specification to overcome limitations in business and legal contexts and to improve interoperability. For organizational identities iSHARE relies on Public Key Infrastructure (PKI) and OAuth2.0 standards, which have been adapted as well to overcome their limitations. Currently, for EU wide acceptability, iSHARE uses eIDAS based digital certificates for digitally signing data and assertions.

A second fundamental building block will be the facilitating **trusted data exchange** among participants, providing certainty that participants involved in the data exchange are who they claim to be, and that they comply with defined rules/agreements. Trust refers to the fact that data providers and data consumers can rely on the identity of the members of the data ecosystem and beyond that, between different security domains.

The third building block of this category facilitates **authorisations at data attribute level** and further complements it with usage rights. This building block is key to data sovereignty and enables data sovereign data spaces. The iSHARE standard specifies the role of an Authorisation Registry that enables organizations to specify access rights on specific data points to other organizations and users. Additionally, it allows attaching the data license to the authorisation so that consumers know what their usage rights are on the data.

5.3. Data Value Creation

Data spaces becomes essential to incorporate building blocks enabling the management of data resources as true assets with a business value. Assets which can be published, discovered and, eventually, traded. This way boosting the creation of multi-side markets where innovative services can be created.

FIWARE Business Application Ecosystem (BAE) components enable creation of Marketplace services which participants in data spaces can rely on for publishing their offerings around data assets they own. Different types of data assets can be defined via plugins that can be installed in the BAE, taking care of data validation, provider permissions and service activation. Nevertheless, three kinds of standard data asset types are supported by default, namely static data files, right-time data resources provided via NGSI-LD at well defined endpoints, and data processing services, which typically have associated well defined endpoints for providing input data and publish results, both in right-time, using NGSI-LD.

5.4. Data Spaces Governance

Participants as well as potential participants of the data space need certainty not only on the above mentioned technical building blocks but also on non-technical aspects of data space like Operational, Legal and Business aspects. Data spaces should provide for data sovereignty to its participants. This can be achieved by using the right technical solution with a legal framework like the one provided by iSHARE. Apart from that the participants need to agree on other business aspects like the costing model, purpose and usage of data based on its criticality and liabilities. Such agreements are part of the **Business Agreements building block**. Additionally, the data space participants also need to identify and decide which data exchange standards they would like to use to interoperate with each other. Equally important is for them to decide the data vocabularies so that all participants can interpret the data correctly.

Another fundamental building block is about the **Operational Reliability** within the data space. Service providers such as identity providers, authorisation registry providers, marketplaces, etc. should be reliable so that parties can trust them and conduct business with confidence when using their services. Service providers are needed to be legally obliged to maintain uptime and availability of the services as it is critical for participants' businesses. Such arrangements can be made via Service Level agreements.

For effective governance a right governing body is required to be set up by the data space participants with consensus. This is a key agreement in the organisational agreements building block. Ideally, for open data spaces a neutral and unbiased body suits better so as to create a level playing field for participants and service providers.

6. THE SMART-ENERGY OPERATING-SYSTEM AND THE MIMS

Source for text and figures: "The Smart-Energy Operating-System and the MIMs"; Henrik Madsen, Martin Brynskov, Razgar Ebrahimy; Technical University of Denmark; July 2022

The Smart Energy Operating System (Smart Energy OS) concept is designed as hierarchy system for data handling and information exchange frameworks, ensuring a unique coherence across all relevant spatial and temporal aggregation scales, and with a focus on multi-objective criteria like energy efficiency and flexibility. Conceptually, the Smart Energy OS relies on the Minimal Interoperability Mechanisms (MIMs) roadmap, which aims at providing building blocks for an efficient digitalization of the society in general, and in providing functionality across different but related domains like energy, transportation and water. The intention is not to replace existing market mechanisms, where end-users bid into appropriate markets, but to accomplish this with a MIMs-compliant framework for an efficient scale-up of local flexibility concepts (e.g. for large-scale integration of wind and solar energy) while supporting local initiatives like district heating, local flexibility markets, and local energy communities.

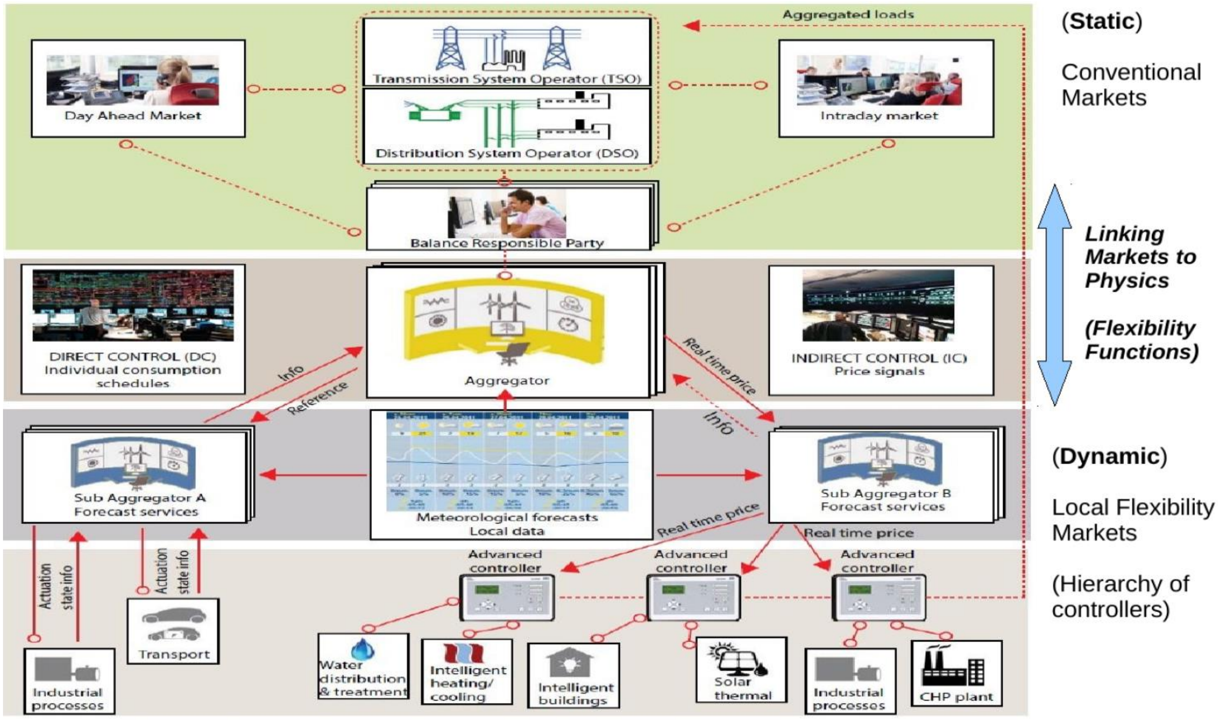

FIGURE 7 - THE SMART ENERGY OS FOR POWER SYSTEMS

Data for energy systems forecasting and services is an important example being built upon the Smart Energy OS concepts. Here unique frameworks and data spaces for exchange of information between all relevant aggregation levels have been established. More specifically, the Smart Energy OS concept contains a framework of spatial and temporal hierarchies for ensuring that forecasts of, for instance, the wind power generation are coherent across all relevant aggregation levels.

To apply this concept, a new framework has to be implemented to ensure coherent data exchange covering data on all aggregation levels from the transformers/substations to the relevant distribution network grids (DSOs) and up to the transmission systems net operated by the TSO. This hierarchy of aggregation of data and operations ensures that grid-related actions and services provided by various stakeholders with different subsystems are consistent.

Integrity – including privacy (GDPR), transparency, security and reliability – has foremost importance in the Smart Energy OS, and in all essential cases such issues are dealt with by design in a consistent and verifiable way. Energy efficiency and flexibility of residential buildings are important examples where design-specific data exchange metrics have been adopted.

A key element of the data exchange framework between, e.g., residential homes and grid operators is the Flexibility Function[11]. The Flexibility Function is one of the fundamental MIMs-related features within the Smart Energy OS setup, and it represents a condensed data exchange framework which is used, for instance, to create a coherent link between the low-level physics (e.g. thermal inertia) of the building and high-level electricity markets. The Flexibility Functions are used also for sector coupling and for hybrid energy systems; an example being buildings with both district heating and heat pumps. Finally, the Flexibility Function can be used at all aggregation levels, e.g. for the appliance, the house, the district, the city to larger regions.

Another key element of the Smart Energy OS is the grey-box modelling concept (also called data-driven Digital Twins), which offers real-time data from sensors and measurements to improve the forecast and control performance. Moreover, the Smart Energy OS manages to keep privacy-related information at the edge. This is possible due to the fact that the Flexibility Function contains all relevant information for instance for the balance responsible parties as well as for the distribution net operator.

The Smart Energy OS concepts, and in particular the integrated standard Flexibility Function for activating flexibility at all levels and across all relevant energy vectors, imply that flexibility and interoperability can be obtained everywhere using low cost technology. The simplicity of broadcasting price signals for activating demand-response implies that basically all appliances can contribute to unlocking the needed flexibility at the relevant spatial and temporal coordinates. At the same time the end-user can easily set up local preferences in a weighted combination of a focus on costs, emission and energy efficiency. The overall simplicity of the concepts ensures fast adaptation and stimulates an effective scale up the use of flexibility and demand response technologies in the market.

In this framework, the computations are done at many levels of the system hierarchy (Figure 7). The Smart Energy OS for Power Systems, Home Energy Management Systems (HEMS) and Home Management Information Systems (HMIS) can be used to provide information about the aggregated flexibility which can be offered from a particular building, and for energy communities similar aggregation principles apply.

The concept has been demonstrated in the ebalance-plus project (H2020), to provide flexibility using a hierarchy of controllers at multiple levels. In this case, the data is fetched from various end user's edge devices and sensors, which is then locally computed and optimised by reacting to price/CO_2 signals broadcasted by the flexibility function. Interoperability is ensured at multiple levels by having a common middleware platform developed in the ebalance-plus project to bridge between different systems layers described in Figure 7.**Fehler! Verweisquelle konnte nicht gefunden werden.** The SE-OS concept can also enhance the functionalities of the current market setups in the future local and decentralized flexibility markets, which will be the source of high intensive real-time edge data.

In conclusion, the Smart Energy OS principle ensures minimal but sufficient interoperability on all relevant levels. Data is kept, and computations carried out, in a coherent hierarchy consisting of edge, fog and cloud levels with privacy, transparency and fairness in mind. By taking advantage of the European MIMs Plus initiative the Smart Energy OS represents an example of a low-cost framework for achieving minimal but sufficient interoperability with appliances, while enabling possibilities for human-in-the-loop technologies and edge computing.

[11] IEA EBC - Annex 82 - Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems; https://annex82.iea-ebc.org/

7. STANDARDISATION: INTERNET OF THINGS AND DIGITAL TWIN

Source for text and figures: "BUSINESS PLAN FOR JTC 1/SC 41 Internet of Things and Digital Twin" at https://www.iso.org/committee/6483279.html

The technical committee ISO/IEC JTC1 about Information Technology and, in particular, the SC 41 on "Internet of things and digital twin" are addressing the standardisation challenge for the data exchange at different levels and domains. Smart energy is a relevant topic for SC41, which has formed a joint working group with the IEC Systems Committee for Smart Energy and one with IEC TC 57, which standardizes power system management systems.

A digital twin is a digital representation of a real-world entity or system. It is an evolving digital profile of the historical and current behaviour of a physical object or process. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person or other abstraction. Digital Twins (DTw) are also an enabler Smart Everything, being based on measurements that creates an evolving profile of the entity or system in the digital world, it provides important insights on system performance, leading to actions in the real world such as a change in system and process design, or optimizing business performance.

The IoT brings value as part of a system or a system of systems. IoT systems have the following main characteristics: network centric, distributed (Machine to Machine (M2) driven, with various distributed computing architectures) and data intensive. IoT is a horizontal technology whose system requires heterogeneity. Moreover, IoT systems incorporate other "smart ICT" such as Big Data and Analytics including learning systems and other artificial intelligence (AI) technologies.

Hence, the standardization actions of JTC1 / SC 41 involve:

- A strong need for horizontal and flexible foundational standards (Reference Architecture, Vocabulary)
- Challenges to get a consensus on some technical topics given the continuing evolution of the technology and the market.
- Horizontality challenged from both a technical (overlap with topics like cloud computing, security...) and application domain standpoint.
- An emphasis of 'not reinventing the wheel' given the high level of activity in SDOs and consortia.

The new activities of JTC1 / SC 41 will be deployed according to the following working groups:

- "WG3 - IoT Foundational Standards" considering standardization in the area of IoT vocabulary, architecture, and frameworks.
- "WG4 - IoT Interoperability" that involves aspects related to semantic and syntactic interoperability.
- "WG5 – IoT Applications" focusing on the standardization activities for IoT uses cases, IoT platforms, middleware, tools and implementation guidance promoting interrelationships among various application domains.
- "WG6 – Digital Twin"
- "JWG17 – System interface between industrial facilities and the smart grid" focusing on the industrial facilities, and the industrial automation systems, to communicate with the smart grid for the purpose of planning, negotiating, and managing the flow of electrical power. This activity is a collaboration with with IEC /TC 65 Industrial-process measurement, control and automation.
- "JWG3 – IEC Smart Energy Roadmap", mapping the main Use Cases over the relevant systems architectures within the Smart Energy; this work is a collaboration with the IEC System Committee on Smart Energy domain.
- "JWG24 – IIoT applications in power systems management", focusing on architecture and functional requirements, in collaboration with JWG24 – IIoT applications in power systems management.

8. CONCLUSION

The Data Act makes provisions for better access to data collected or produced by connected IoT devices including energy assets in order to provide new opportunities for data services relying on access to this data.

Data models are elementary baseline for B2B data exchange, since the infrastructure of a digital energy system will be built on numerous devices from appliances to electric vehicles, heating systems and heat pump to solar panels from various stakeholders; all these components have to act in concert with another, requiring a common language for data exchange. To facilitate exchange of data across different manufacturers and between different systems a common understanding of data is needed. Particularly, to seize the full potential of data across different stakeholders with a vertical value chain and across horizontal domains, open specification and standards for a data model or data format are indispensable. Ontologies like SAREF greatly help to understand the context across strategic sectors like mobility, energy, buildings; moreover, smart data models are an enabler to accelerate the integration of applications like energy management across the above sectors and provide an easy translation from one domain to another. Several standardisation working groups have recognised the importance of the subject and the risk that actions are dispersed or fragmented; for this reason, particular effort in aligning the different sectors has to be implemented.

The paper gives a snapshot on data models which are considered an essential building block for a comprehensive energy data space, as a strategic dimension of the Digitalisation of Energy Action Plan (DoEAP) whose next steps are foreseen in the following months.