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European (energy) data exchange reference architecture 2.0

Data Management Working Group

June - 2022

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List of Acronyms and Abbreviations

AC	Alternating Current
ACS	Access Control Server
ADMS	Advanced Distribution Management Systems
AI	Artificial Intelligence
AIM	Agricultural Information Model
AIOTI	Alliance for Internet of Things Innovation
AIS	Agricultural Interoperability Space
AMQP	Advance Message Queuing Protocol
API	Application Programming Interface
ASP	Authentication Service Provider
BDVA	Big Data Value Association
BFM	Building Flexibility Manager
BIM	Building Information Modelling
BRP	Balancing Responsible Party
BSE	Brokerage Service Environment
BUC	Business Use Case
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CGMES	Common Grid Model Exchange Specification
CIM	Common Information Model
CKAN	Comprehensive Knowledge Archive Network
COSEM	Companion Specification for Energy Metering
COSMAG	Comprehensive Architecture for Smart Grid
CSA	Coordinated Security Analysis
CSV	Comma-Separated Values file
DC	Direct Current
DEP	Data Exchange Platform
DEPO	Data Exchange Platform Operator
DER	Distributed Energy Resources
DERA	Data Exchange Reference Architecture
DERMS	Distributed Energy Resources Management System
DHO	Data Hub Operator
DLMS	Device Language Message Specification
DoEAP	Digitalisation of Energy Action Plan
DR	Demand Response
DSO	Distribution System Operator
DSS	Decision Support System
DT	Digital Transformation
E.DSO	European Distribution System Operators
ebIX®	European forum for energy business Information Exchange
EC	European Commission
ECCo SP	ENTSO-E Communication & Connectivity Service Platform
EDI	Electronic Data Interchange
EFET	European Federation of Energy Traders
EFI	Energy Flexibility Interface
eIDAS	EU regulation on electronic IDentification, Authentication and trust Services
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ESMP	European Style Market Profile
ETL	Extract, Transform, Load
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
EVFM	EV Flexibility Manager

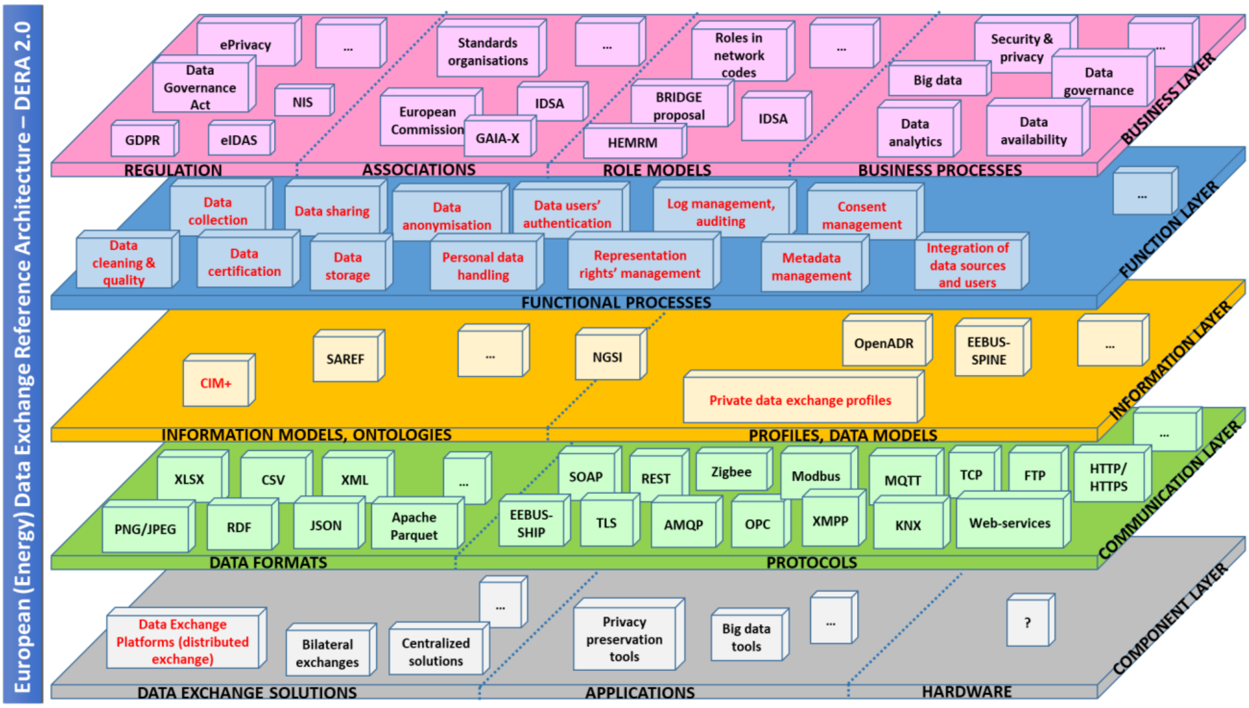
FP	Framework Programme
FR	Flexibility Register
FSP	Flexibility Service Provider
FTP	File Transfer Protocol
GDPR	General Data Protection Regulation
GFM	Global Flexibility Manager
GoO	Guarantees of Origin
HDFS	Hadoop Distributed File System
HEMRM	Harmonised Electricity Market Role Model
HERM	Harmonised Energy Role Model
HPC	High Performance Computing
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICCP	Inter Control Center Protocol
ICT	Information and Communications Technology
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IEGSA	Interoperable pan-European Grid Services Architecture
ILES	Integrated Local Energy System
ILESEM	Integrated Local Energy System and Energy Market
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organisation for Standardisation
JPEG	Joint Photographic Experts Group
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LES	Local Energy System
LF	Linux Foundation
LFM	Local Flexibility Manager
MDA	Metered Data Administrator
MDO	Metered Data Operator
MDR	Metered Data Responsible
ML	Machine Learning
MO	Market Operator
MQTT	Message Queuing Telemetry Transport
MU	Management Unit
MVP	Minimum Viable Product
NEMO	Nominated Electricity Market Operator
NGSI-LD	Context Information Management API (see [ETSI, 2020]
NIS	EU directive on security of Network and Information Systems
OAuth	Open Authorisation
OCPP	Open Charge Point Protocol
OPC	Open Platform Communications
OSCP	Open Smart Charging Protocol
OWL	Web Ontology Language
P2P	Peer to Peer
PDF	Portable Document Format
PNG	Portable Graphics Format
PV	Photovoltaics
R&D	Research & Development
RA	Reference Architecture
RAF	Reference Architecture Framework
RAM	Reference Architecture Model
RAMI	Reference Architecture Model Industrie
RDF	Resource Description Framework
RDFS	Resource Description Framework Schema

RES	Renewable Energy Sources
REST	REpresentational State Transfer
RSC	Regional Security Coordinator
SAREF	Smarty Appliances REFerence ontology
SCADA	Supervisory Control and Data Acquisition
SEE	South-Eastern Europe
SGAM	Smart Grid Architecture Model
SGTF	European Smart Grids Task Force
SHIP	Smart Home IP
SME	Small and Medium-sized Enterprise
SO	System Operator
SOAP	Simple Object Access Protocol
SPINE	Specification Smart Premises Interoperable Neutral Message Exchange
SQL	Structured Query Language
SRD	System Reference Document
SUC	System Use Case
TCP	Transmission Control Protocol
TLS	Transport Layer Security
TSO	Transmission System Operator
UC	Use Case
UCTE	Union for the Coordination of the Transmission of Electricity
UFTP	USEF Flex Trading Protocol
UML	Unified Modelling Language
URN	Uniform Resource Name
USEF	Universal Smart Energy Framework
UUID	Universally Unique IDentifier
WEFE	Water, Energy, Food and Ecosystems
WG	Working Group
XACML	eXtensible Access Control Markup Language
XLSX	Microsoft Excel Open XML Spreadsheet
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol
XSD	XML Schema Definition
ZDM	Zero Defect Manufacturing

Executive Summary

BRIDGE report on energy data exchange reference architecture aims at contributing to the discussion and practical steps towards truly interoperable and business process agnostic data exchange arrangements on European scale both inside energy domain and across different domains.

This is the second version of **D**ata **E**xchange **R**eference **A**rchitecture – DERA 2.0, as improved according to further input from several projects and external parties based on a dedicated survey. This includes updating the reference architecture, reviewing the recommendations associated to it as well as preparatory steps for cross-project data exchange implementation. The figure below depicts high-level SGAM (Smart Grid Architecture Model) based reference architecture for European energy data exchange as proposed in this report.



The improvement of reference architecture was largely based on the results from the survey, answered by several projects and initiatives, summarised in the graphics below.

Recommendations related to the implementation of DERA 2.0:

A. Leverage Smart Grid Architecture Model (SGAM) usage and study its extension to other sectors (similar to the RAMI4.0 for industry – Reference Architecture Model Industrie 4.0; and CREATE-IoT 3D RAM for health – Reference Architecture Model of CREATE-IoT project), incl. for basic interoperability vocabulary with non-energy sectors.

B. Facilitate European strategy, regulation and practical tools for cross-sector exchange of any type of both private data and public data, e.g. through the means of minimum set of requirements for data spaces and data governance, and data interoperability implementing acts.

C. Ensure cooperation between appropriate associations, countries and sector representatives to work on cross-sector and cross-border data management by establishing European data cooperation agency.

D. Harmonise the development, content and accessibility of data exchange business use cases for cross-sector domain through BRIDGE use case repository.

E. Use BRIDGE use case repository for aligning the role selection. Harmonise data roles across electricity and other energy domains by developing HERM – Harmonised Energy Role Model and ensure access to model files. Look for consistency with other domains outside energy based on this HERM – cross-sectoral roles.

F. Define and harmonise functional data processes for cross-sector domain, using common vocabulary, template and repository for respective use cases' descriptions.

G. Define, maintain and ensure access to model files of a generic canonical data model facilitating cross-sector data exchange, e.g. by extending Common Information Model (CIM) and/or integrating other sectors' canonical data models with CIM.

H. Develop cross-sector data models and profiles, with specific focus on private data exchange. Enable access to model files.

I. Ensure protocol agnostic approach to cross-sector data exchange.

J. Ensure data format agnostic approach to cross-sector data exchange.

K. Promote business process agnostic DEPs (Data Exchange Platforms) and make these interoperable by developing APIs (Application Programming Interfaces) which enable for data providers and data users easy connection to any European DEP but also create the possibility whereby connecting to one DEP ensures data exchange with any other stakeholder in Europe.

L. Develop universal data applications which can serve any domain.

Possible next steps for 2022/2023:

- Continue pilot implementation of the reference architecture.
- For improved visualisation model the reference architecture, e.g. by applying Unified Modelling Language (UML).
- Follow the implementation of individual recommendations related to reference architecture as presented in chapter 2.3.
- Add data governance layer to the reference architecture.
- Engage closely new projects funded through Horizon Europe call on Energy Data Spaces.
- Contribute to Digitalisation of Energy Action Plan (DoEAP).

The European Commission is currently defining an Action Plan related to the digitalisation of the energy sector[1]. It will be presented in autumn 2022 to "*help to develop a competitive market for digital energy services and digital*

[1] See EC dedicated webpage: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13141-Digitalising-the-energy-sector-EU-action-plan_en

energy infrastructure that are cyber-secure, efficient and sustainable". It is articulated around five working areas, provisionally identified as:

- Developing a European data exchange framework
- Benefits for consumers: literacy, skills, digital tools to empower citizens
- Mobilising investments
- Enhancing Cybersecurity
- Climate neutrality of the ICT

Among several initiatives, BRIDGE is expected to contribute to the DoEAP. Therefore, the table below maps the generalised findings & recommendations of this report to the five working areas, replying to the following question: "how each 'finding & recommendation' contributes to the five DoEAP areas?"

<table>
<tr><th></th><th>Developing a European data exchange framework</th><th>Benefits for consumers</th><th>Mobilising investments</th><th>Enhancing Cybersecurity</th><th>Climate neutrality of the ICT</th></tr>
<tr><td>EU level orchestration</td><td colspan="2">European data cooperation agency or similar can facilitate European strategy, regulation and practical tools, as well as to ensure cooperation between associations, countries and sector representatives.</td><td></td><td></td><td></td></tr>
<tr><td>Data exchange harmonisation</td><td colspan="4">Harmonisation to the extent possible and justified entails mutual understanding about the content of data exchange related business processes, functionalities, role definitions and information semantics, but also the practical standards and models for universal vocabularies, descriptions and visual representations.</td><td></td></tr>
<tr><td>Data Exchange Platforms</td><td colspan="4">Data Exchange Platforms as physical part of 'data-sharing infrastructure' are increasingly relevant for easy and privacy-respecting access to and sharing of data.</td><td></td></tr>
</table>

1. Introduction

The Data Management Working Group (WG) aims to cover a wide range of aspects ranging from the technical means for exchanging and processing data between interested stakeholders to the definition of rules for exchange, including security issues and responsibility distribution in data handling. Accordingly, the WG has identified 3 areas of collaboration around which mutual exchange of views and discussions have been set:

- **Communication Infrastructure**, embracing the technical and non-technical aspects of the communication infrastructure needed to exchange data and the related requirements;
- **Cybersecurity and Data Privacy**, entailing data integrity, customer privacy and protection;
- **Data Handling**, including the framework for data exchange and related roles and responsibilities, together with the technical issues supporting the exchange of data in a secure and interoperable manner, and the data analytics techniques for data processing.

The objective of this report is to continue working on issues related to organising energy data exchanges on European level. The first version of EU data exchange reference architecture was defined in BRIDGE Data Management WG report in 2021 (Figure 1)[2].

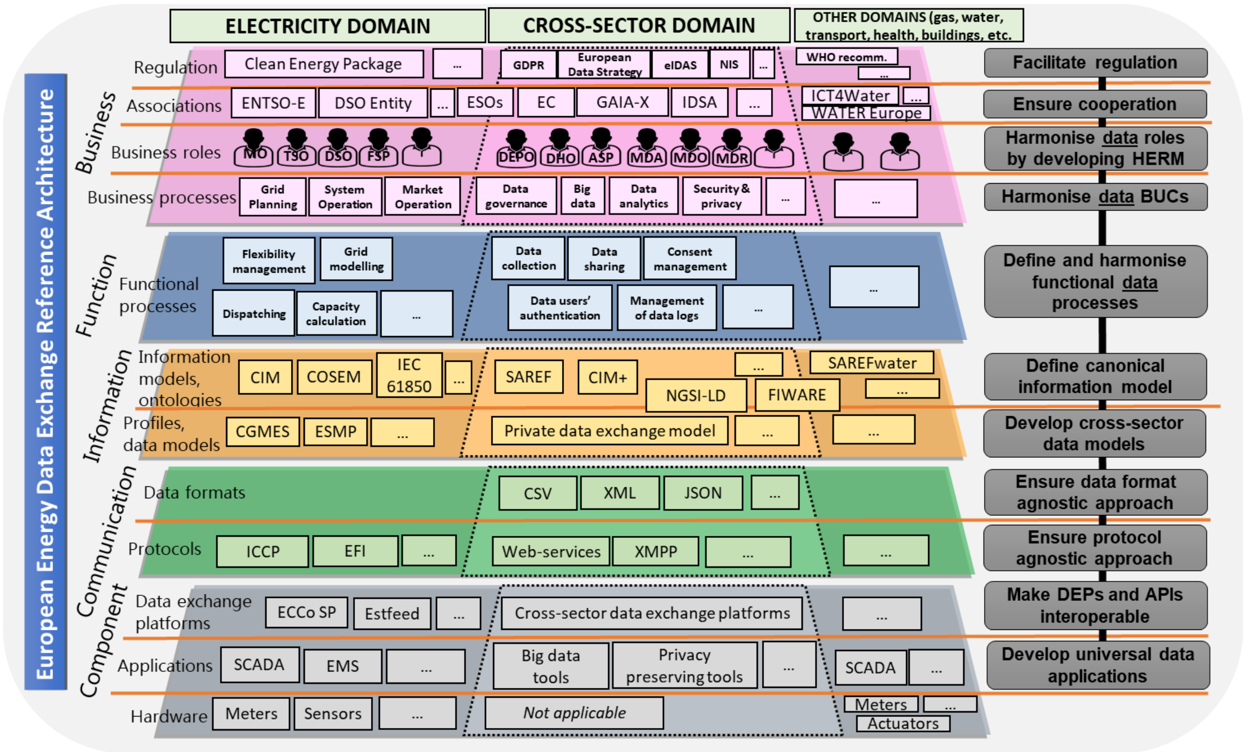


Figure 1: First version of European energy data exchange reference architecture [BRIDGE Data Management WG, 2021]

At BRIDGE 2021 General Assembly some possible improvements were identified:

- Understand in more detail what is sector-specific vs. cross-sector;
- Understand and describe the correspondence between SGAM and other reference architectures (like IoT RA);
- Make sure that besides platform-based approach other communication options and open standards are addressed.
- Intensify communication with other data initiatives, i.e. GAIA-X, IDSA, etc.

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[2] In this architecture 'EFI' was referred to as a protocol. The new name of EFI is S2 (EN50491-12-2) interface, which is an 'information model'. The EN50491-12-1 is an official standard which describes the architecture of the S2.

- Connect to the data strategy and the data space concept (focusing on the projects that will design the energy data space and interact to fine-tune the pan-EU reference architecture for data exchange

Therefore, to achieve cross-sector interoperability, the focus should be put on:

- Identify the common building blocks that we can promote to standardisation – starting with vocabulary;
- Near-real-time and beyond the 'main meter' data availability (like data from EV charging point, also EVs themselves ...);
- Data ownership and data access;
- Cross-sector communication standards and APIs (e.g., TSO/DSO2EV vs EV2Customer).

Links should be set with other BRIDGE activities and external parties:

- Identify how to reach out to gas, heating, cooling research groups and launch the work. A common role model has been mentioned but could also concern definition of common data business processes, common data exchange functionalities, common canonical information model, common data semantics/profiles;
- Similar should concern non-energy sectors – buildings, health, transport;
- Identify the needs of islands' projects.

BRIDGE Data Management WG recognises and is willing to contribute to the ongoing activity of European Commission (EC) to deliver 'data interoperability implementing acts' as mandated in articles 23 and 24 of electricity market directive [2019/944]. The cornerstone of these acts would be 'Reference Model' allowing national specificities which evolves over the time and to be elaborated at the European level. Reference Model consists of information model, role model and process model. While EC's initial focus is on meter data to be complemented later by further data flows from some specific business processes (billing, demand response), the focus of BRIDGE is on business process agnostic data framework.

The European electricity sector is undergoing a radical transformation that emerged, initially, by the growth of distributed generation, renewables and storage. This renders operation of power networks more complex to handle and obviously to optimise. Digitalisation has been already regarded as the main pillar for allowing active system management in the electricity grid, enabling system operators (i.e., both Transmission System Operators (TSOs) and Distribution System Operators (DSOs)) to manage the use of distributed resources towards a cost-effective and secure supply of electricity for all market participants including the customers. The evolving digitalisation enables end-users to actively participate in marketplaces taking advantage of their demand flexibility. This will inevitably create innovative new services, technical solutions, products and marketplaces. The electricity grid, along with an interoperable data exchange infrastructure, may be major factor underlying European energy transition and the European economy [ENTSO-E, THEMA, 2017].

The continuous increase in distributed renewable generation and in storage energy systems, along with the expected rise of active customers engaged in demand response and electric mobility, poses several challenges in the current planning and operational practices of the system operators. A key question to be addressed on the way towards the energy transition is the following: how to embody the demand side flexibility services derived from such new assets and actors into energy market, utilising them for operational and ancillary services capable to tackle any technical issues ensuring resilience, efficiency and reliability for the modern power networks. The latter evolution, is foreseen to bring flexibility products – even from residential consumers – in the foreground of system operation enabling a market uptake for them.

Both traditional retail processes and emerging flexibility services require data and information to be accessed by relevant eligible parties and exchanged among a multitude of actors, networks, systems, devices, applications and components. Legacy and newly developed systems need to cooperate and exchange data and information to enable existing, emerging and future energy services. The definition of a common European Reference Architecture may serve as key driver towards the essential engagement of demand side flexibility, enabling utilities' coordination beyond national borders and reduce market entry barriers.

The introduction of an integrated European electricity market, information exchange and data management are becoming more connected. Increased information access and exchange not only leads to essential benefits in grid operation and planning, but also lowers market access barriers, ensures transparency among market parties and creates new market opportunities (e.g. energy services companies) [CEDEC, E.DSO, ENTSO-E, Eurelectric, GEODE, 2019]. Free flow of data and data exchange is generally necessary for achieving a seamless integration between wholesale and retail markets.

A fundamental element towards the definition of a reference architecture is the proper designation of interoperable data exchange solutions. Several papers [E.DSO, 2020; GEODE, 2020; Elering, Pöyry, 2019] have described the benefits of different data exchange models (decentralised, centralised, hybrid, distributed). Bilateral point-to-point solutions between single actors (decentralised approach), data hubs/warehouses (centralised approach) and data exchange platforms (distributed approach) coexist. All these solutions need to become interoperable with each other through comparability, appropriate standardisation and governance. Beside decentralised solutions platform-type solutions (hubs, DEPs) have emerged recently across Europe to ensure efficient processes and improved data quality and volume with minimal delay, initially in retail markets. Lately, the endeavour has been directed by the Clean Energy Package and other initiatives concerning the active incorporation of end-users in both the retail and wholesale energy markets, increasing the requirement for data exchange between all stakeholders. Integrated data exchange architecture will play a vital role in the overall power system and point towards an integrated wholesale-retail market.

In EU-wide scale, use case based approach to business and functional processes, Common Information Model (CIM) for standardised data exchange (semantics and syntactics) and Harmonised Electricity Market Role Model (HEMRM) clearly defining roles and responsibilities are building blocks for the definition of a common European reference architecture, the principle also addressed by SGTF (Smart Grid Task Force). Hence, those are set in place in several H2020 projects, involved also in BRIDGE.

There is need at least for a platform/framework/architecture that enables different applications and (energy) roles and actors, able to be modular enough to serve multiple objectives and possibly capable to be used in cross-sectoral applications. It should be, also, able to use existing data models, and map these to a higher level of abstraction and (semantic) interoperability. Data models and architecture should be open source. Using standards is preferred. Security and privacy is important, but still difficult to embed from the start in the architecture.

Sorting those factors from the most important to the less important on the establishment of a common European reference architecture, it is in the following order [BRIDGE Data Management WG, 2021]:

1. the unwillingness among players to exchange private data and models due to privacy issues,
2. the limited standards and generally the need for updates,
3. the vulnerability to cyber-attacks, and
4. the competition among vendors/tech procurers.

The current energy sector comprises, mainly, of electrical, natural gas and district heating utilities. Traditionally, these utilities of such networks targeted to design and operate their networks in an optimal way to ensure an efficient and reliable energy supply from systems to the end-user towards the distribution network. More recently, environmental concerns have led to an increased integration of renewable energy resources in these networks. The increased interconnection of renewable energy can be challenging for each of these systems individually due to their inherent seasonality and variability. One solution would be to rely on other energy sectors for energy production and usage. This approach requires holistic analysis of these systems to assess their interdependencies and facilitate energy interactions. The fusion of sensory devices along with advanced ICT (information and communication technology) by the utilities (e.g., electricity, gas, heating, water) raises the concern whether interdependencies among different sectors could be addressed via the definition of interoperable data exchange platforms and common technical architectures.

Shaping a common European reference architecture needs to explore the aforementioned points on cross-sector practices. Electricity comprises one of the main vectors of the energy sector. Thus, there are also clear dependencies with other sectors such as the transportation, buildings and the water sector. From data exchange perspective one can go even beyond that as, for example, issues related to private data (e.g. consent management) need to be addressed quite similarly in energy, health, education, etc.

Structure of the report:

- Chapter 2 includes the presentation of reference architecture, description of SGAM interoperability layers and additional sub-layers proposed, as well as findings and recommendations based on BRIDGE 2020 and 2021 surveys.
- Chapter 3 includes the overview of 20 projects answering the 2021 survey following the structure of reference architecture.
- Chapter 4 includes the summary of planned cross-project pilot implementation of reference architecture.

2. DERA 2.0

2.1 Description of reference architecture

This report and the reference architecture to be proposed are not about data exchanges between system operators (TSOs, DSOs) only but are here to address any data exchange involving any stakeholder (e.g. consumer, market operator, energy service provider, energy supplier, flexibility provider).

Figure 2 depicts a high-level SGAM based reference architecture for data exchange. 'European' refers to the cross-border data exchange capability. The focus of this report and reference architecture is on sector agnostic data management – cross-sector domain. 'Cross-border' and 'cross-sector' require biggest efforts in terms of interoperability.

It is the data exchange that can facilitate cross-sector interoperability. Data aspect is quite natural in information and communication layers. But it also can be and should be so in business, function and component layers. Thus, the joint and well-coordinated actions should be dedicated to the elements in cross-sector domain.

The figure concentrates on the elements which have been mentioned by BRIDGE projects or otherwise were retrieved as relevant for cross-sector domain. Obviously, the list of elements mentioned is not comprehensive.

All the elements are presented based on SGAM layers which are further split into sub-layers according to what is relevant to data exchange. The elements with red text require relatively more urgent attention for cross-sector data exchange according to the experts in BRIDGE working group.

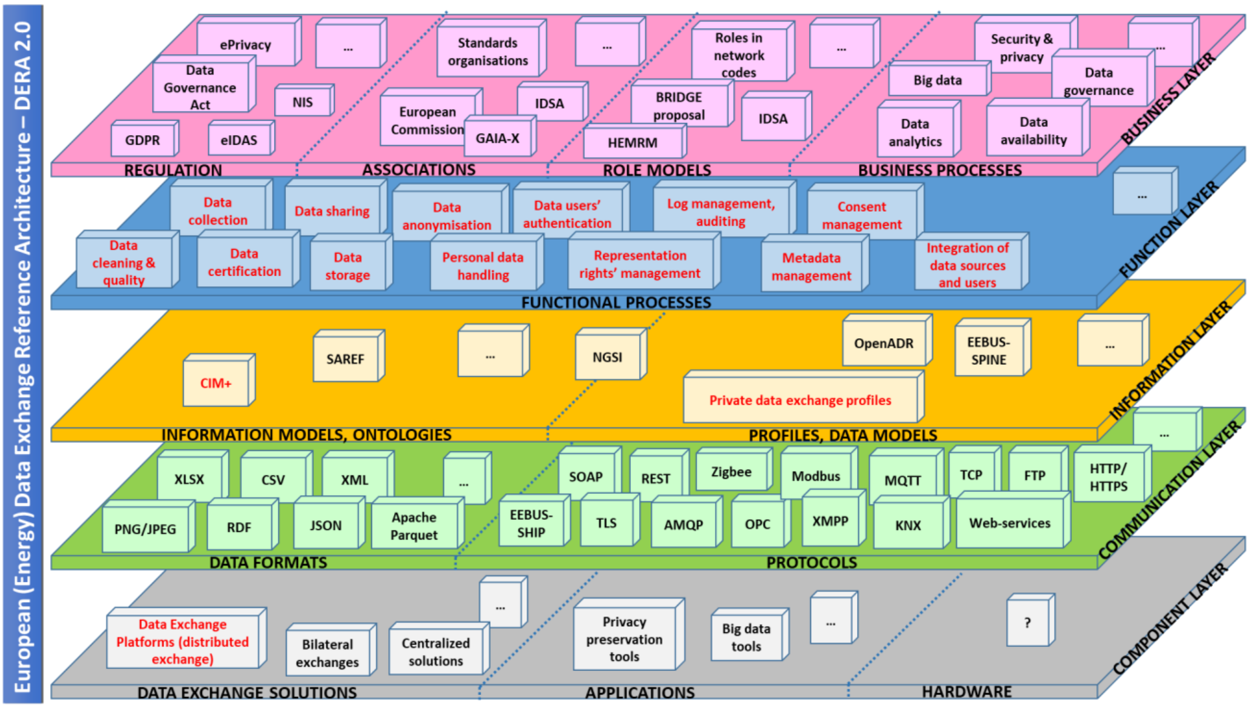


Figure 2: European (energy) data exchange reference architecture 2.0

2.2 Interoperability layers of reference architecture

In 2011 European Commission had issued a mandate to CEN, CENELEC and ETSI to develop an interoperable framework for standardisation in the field of Smart Grids – Mandate M/490 [EC, 2011]. A reference architecture was requested to address smart metering, grid operation, grid automation, distributed energy resources management, industry automation, building and home automation and other domains. As the response, CEN, CENELEC and ETSI Smart Grid Coordination Group has proposed the Smart Grid Architecture Model [2012].

Figure 3 depicts the dimensions of SGAM framework. It is a three dimensional model that is merging the dimension of five interoperability layers (Business, Function, Information, Communication and Component) with the zones dimension (Process, Field, Station, Operation, Enterprise and Market) and domains dimension (Bulk Generation, Transmission, Distribution, DER and Customers Premises). The SGAM Framework can be used for designing and assessing smart grid use cases and link these to standards (incl. identifying missing standards) – in order to support interoperability on all layers of SGAM.

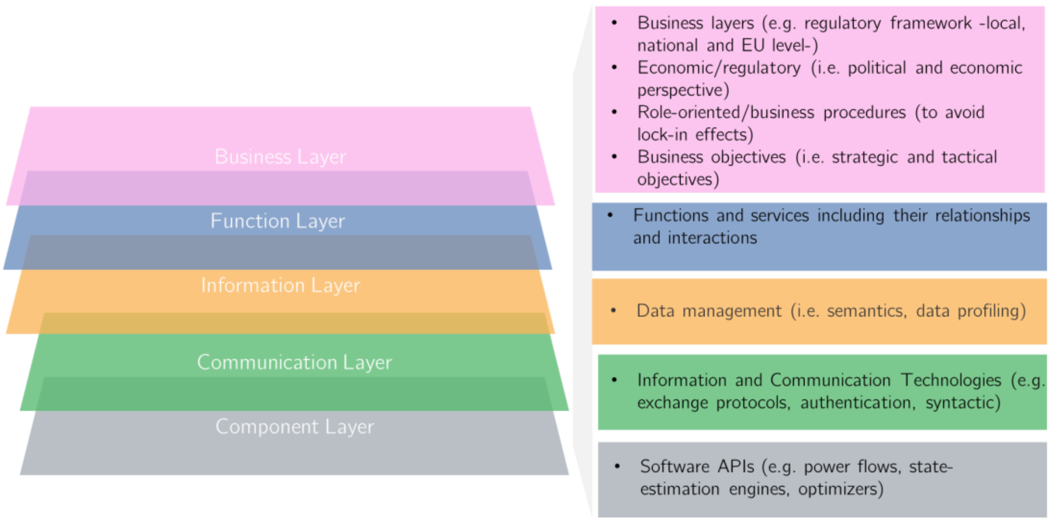


Figure 3: SGAM interoperability layers and implications to the properties of data exchange platforms

IEC has started to further formalise SGAM in order to provide official definition of SGAM and expand it to heat and gas systems by issuing system reference document (SRD) IEC SRD 63200: Definition of extended SGAM smart energy grid reference architecture model [2021]. This SRD defines the framework elements, associated ontology, and modelling methodology for designing the Smart Energy Grid Reference Architecture using the SGAM.

The SGAM framework [CEN-CENELEC-ETSI, 2012] provides a three-dimensional (interoperability layers' dimension, domains' dimension, zones' dimension) representation that is established by merging the concept of the interoperability layers with the Smart Grid Plane. Nonetheless, considering that explored data exchange platforms constitute a key integral component in the sense of bundling zones as well as coordinating domains, separate zones and domains are not addressed.

As the figure shows, the SGAM consists of five interoperability layers representing business objectives and processes, functions, information exchange and models, communication protocols, and components. Note that in addition to the relations between objects on the same layer (e.g. physical connection of components on the component layer), there exist interrelations between objects on different layers. Business processes, as objects of the business layer, are realised by functions (objects of the function layer), which are in turn executed by components (objects of the component layer). The execution of the functions requires the components to support data models – objects of the information layer, and communication protocols - objects of the communication layer.

Therefore, the projects aim to capture interoperability features within all interoperability layers of SGAM (i.e. from the component to the business layer). As depicted in Figure 3, in the component layer there are APIs accommodated at the data exchange platforms level, which may deploy for instance steady state analysis for the power system, weather forecasts, flexibility baseline calculations *etc.*, in a way to allow the coordination of multiple systems and platforms. In the communication layer, exchange protocols as well as authentication or authorisation standards are used. The information layer is of significant importance since the data modelling appears to be the integral part of data exchange platform, fact which was clearly captured in the trend of standardised processes.

2.2.1 Business Layer

The business layer represents, in principal, the business viewpoint on the information exchange. This layer essentially maps regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved, as well as business capabilities and business processes [CEN-CENELEC-ETSI, 2012]. Therefore, this layer essentially explores business executives in decision making related to novel business models which are usually designated through the definition of business use cases and the regulatory authorities in defining new market models.

2.2.1.1 Regulation sub-layer

While Clean Energy Package (e.g. electricity market directive) is quite specific to electricity domain, then for cross-sector interoperability GDPR, European Data Strategy (incl. Data Governance Act), regulation on electronic identification, authentication and trust services (eIDAS), directive on security of network and information systems (NIS) and others need to be properly implemented, avoiding silo applications.

2.2.1.2 Associations sub-layer

ENTSO-E and EU DSO Entity are for electricity. Cross-sector approach can be facilitated by European Commission but also by several initiatives (GAIA-X) and associations (IDSA). ESOs (European Standardisation Organisations) are in-between as some of them are more focused on electricity (CENELEC) and others are more generic (CEN, ETSI).

2.2.1.3 Role models sub-layer

Some usual business roles in electricity are TSO, DSO, MO (Market Operator), FSP (Flexibility Service Provider). But many data related roles can be highlighted which are relevant for several sectors: Data Exchange Platform Operator (DEPO), Data Hub Operator (DHO), Authentication Service Provider (ASP), Metered Data Administrator (MDA), Metered Data Operator (MDO), Metered Data Responsible (MDR).

Actors involved in any process form a necessary part of an architecture describing the process. Since it is about reference architecture here the focus should not be on specific actors but rather on roles, especially business roles, which would enable unified understanding of the parties involved in a process. Roles can be easily translated into specific actors of specific processes all over Europe (because it is about European reference architecture). Moreover, the focus here is on data exchange architecture. This means that such an architecture should be agnostic to business processes – therefore also role model wise the interest is not in all business roles but only in 'data business roles'.

The Harmonised Electricity Market Role Model (HEMRM) was created and is being constantly developed in order to facilitate information exchange "between the market participants from different countries through the designation of a common name for each role and related object that are prevalent within the European electricity market information exchange" [ebIX®, EFET, ENTSO-E, 2020]. 'Data roles' in HEMRM include Consent Administrator, Data Provider, Market Information Aggregator, Meter Administrator, Meter Operator, Metered Data Aggregator, Metered Data Collector, Metered Data Responsible, Metering Point Administrator, Metered Data Administrator. HEMRM is well recognised by European Commission and seems to be the most widely used role model, incl. by Horizon2020 projects [BRIDGE Regulation WG, 2021].

Figure 4 depicts data exchange related roles, classes and relationships as they are in latest version of HEMRM but adding roles, classes and relationships proposed as new in this report.

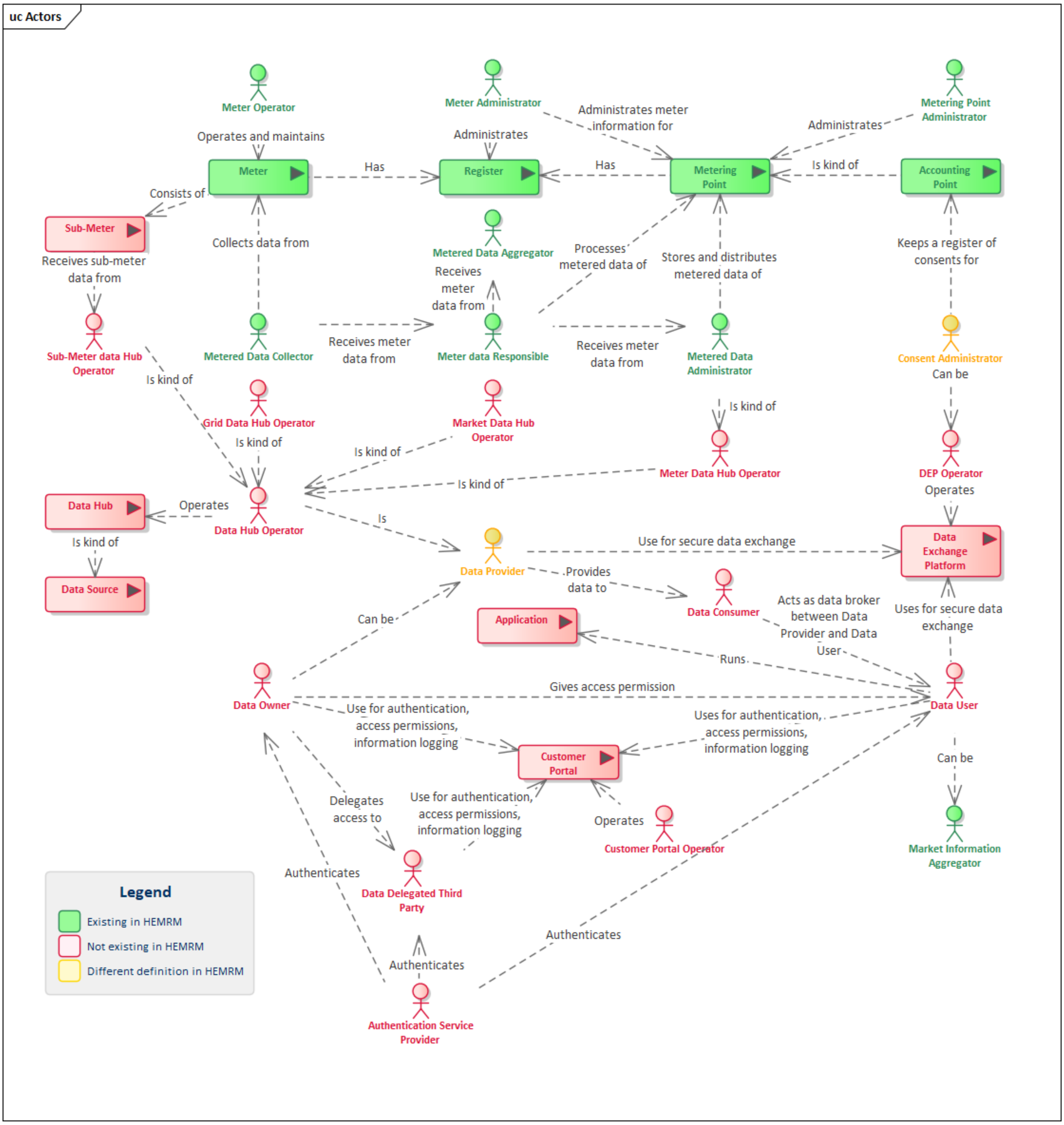


Figure 4: Data exchange role model [BRIDGE Data Management WG, 2021]

2.2.1.4 Business processes sub-layer

Commonly mentioned generic processes in electricity are grid planning, system operation and market operation. For cross-sector domain data management related processes should have the priority, e.g. processes related to data governance, big data, data analytics, security & privacy.

2.2.2 Function Layer

The function layer aims to describe functions and services including their relationships and interactions from a conceptual and architectural point of view. The existing or proposed functions are deduced by determining the use cases' functionalities and physical implementations in applications, systems and components. In this layer, it is observed based on the analysis of the results that the majority of proposed data exchange platforms mainly act as a common framework or middleware for applications sharing the access to the relevant parties, regardless of the underlying data models and structures; hence, this proposition allows data management efforts and responsibilities without their direct involvement.

Examples of electricity sector functions include flexibility management, grid modelling, dispatching, capacity allocation, grid monitoring & operation, aggregation, grid maintenance, network planning, fraud detection, smart houses/buildings/industries energy management.

For cross-sector interoperability data related functions should be addressed: data collection, data sharing, consent management, data users' authentication, management of data logs, data analysis, integrating data sources and data users with data platforms, data visualisation.

2.2.3 Information Layer

The information layer provides a descriptive analysis of the information that is being used and exchanged between functions, services and components. This contains informational objects and data models. Information objects and canonical data models need to represent the common semantics for functions in order to allow an interoperable information exchange. The designation of a well-defined semantic repository (e.g. semantic vocabulary and ontologies) is of vital importance.

2.2.3.1 Information models and ontologies sub-layer

Most common information models in electricity are CIM, COSEM and IEC 61850. For sector agnostic approach SAREF and NGSI-LD could be applied. CIM+ is proposed to label the future enhancement of current CIM in order to support modelling of data management related process both inside and beyond electricity and which are not covered yet.

According to SGTF EG1 [2019] recommendation #2: "To facilitate interoperability adopt and use a common information model for semantics, for example consider building on the available IEC CIM model." CIM is supporting extensively European regulation. IEC CIM is one of the three core information models identified by IEC Smart Grid Standardisation Roadmap [IEC 63097, 2017] as illustrated in Figure 5. The other two, which are complementary to IEC CIM are IEC 61850, and COSEM which were also recommended as the result of EC Mandate M/441 for Smart Metering [EC, 2009].

The Common Information Model (CIM) is widely accepted for interoperability and integration in modern power systems, allowing to support object-oriented programming concepts and represent power system components, towards addressing infrastructure, management and operation issues. CIM is used for network modelling (61970 series), but also supports market-related use cases (62325 series) and utility integration related use cases (61968 series). CIM supports several IEC network codes and guidelines. In general, CIM profiles strengthen the coordination between different TSOs, but it will be more and more used between TSOs, DSOs and other market participants.

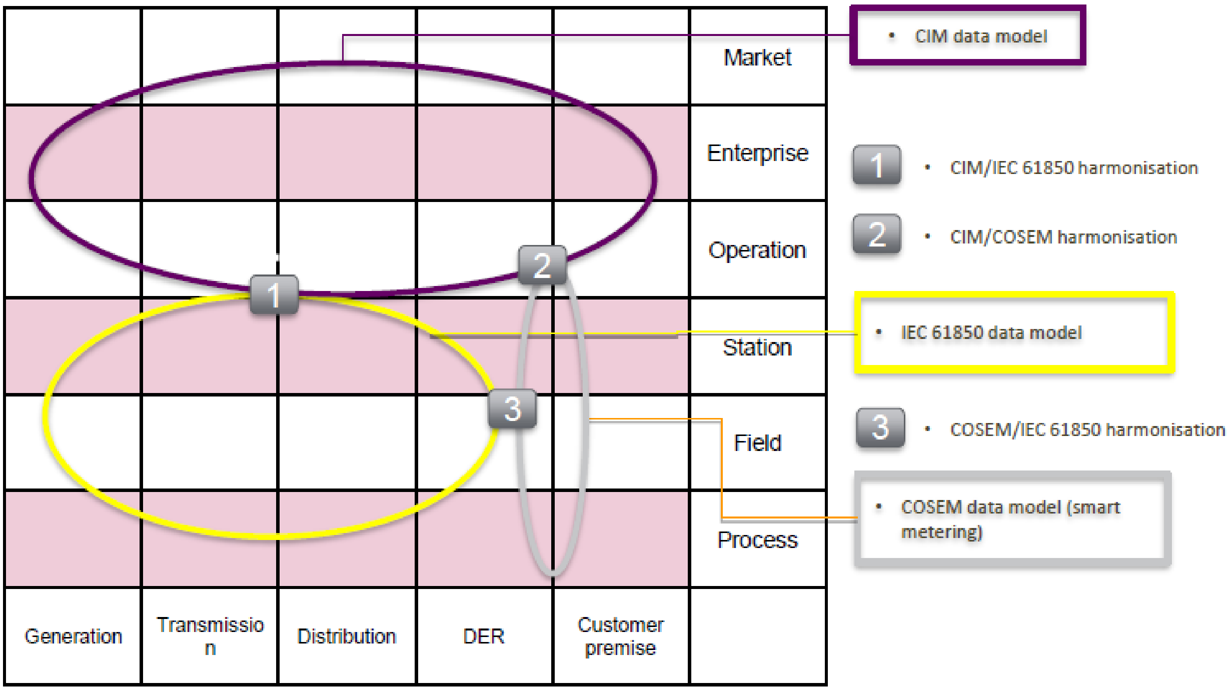


Figure 5: IEC core information models: CIM, IEC 61850, COSEM [IEC 62357-1, 2016]

SAREF open standard and its multiple extensions are also widely used and supported in the data platforms in order to transfer messages from smart building and devices. The local data model representation within the data platform in some cases is designated by tailored solutions; nonetheless, more advanced solutions propose data model following NGSI-LD to ensure compatibility with different platforms and legacy systems. Data APIs and adapters are widely set in place in data platforms as the interface between built-in applications and software with external resources; thus, allowing the reuse of services by multiple vendors due to the middleware interpretation.

2.2.3.2 Profiles and data models sub-layer

The CIM model is being incorporated in many smart grid projects. In most cases, existing profiles are being used, while some projects also aim at complementing the CIM libraries with new profiles covering the communication between new roles and systems. Commonly used groups of electricity sector profiles are CGMES (Common Grid Model Exchange Specification) and ESMP (European Style Market Profile), which are based on CIM canonical model. An example of cross-sector data model/profile could be private data exchange profiles, which still need to be elaborated. Private data management, e.g. consent management process or rectification of data in data hubs, is a challenge for many sectors. Of course, there are also many public/open data where commonly defined profiles would facilitate cross-sector data exchange.

2.2.4 Communication Layer

The target of the communication layer is to describe data formats, protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models. Only by adopting standardised solutions, it will be possible to achieve communication between versatile systems. Standardised solutions for establishing communication channels, such as ENTSO-E's ECCo SP platform, has been frequently mentioned by smart grid projects. The IoT (Internet of Things) and device level interoperability is addressed by SAREF in many projects, ensuring the standardised matching of appliances in the smart grid domain. Similarly, FIWARE plays an integral part in many projects in this same field. The complexity of integrating with countless existing and emerging devices, systems, data hubs and platforms is placing scalability and replicability in the spotlight. Therefore, the adoption of common communication standards is highlighted as crucial for the development of data platforms.

2.2.4.1 Data formats sub-layer

Data formats should generally not be sector-specific. Commonly used formats like CSV (Comma-Separated Values file), XML (Extensible Markup Language) and JSON (JavaScript Object Notation) can be used in any sector. CIM information model uses UML (Unified Modelling Language) syntax. From UML, profiles can be defined. But CIM could be exported in other syntaxes like OWL (Web Ontology Language), from which profiles would also be generated. Profiles are a restriction of the Information Model. These profiles are using a syntax: XSD (XML Schema Definition), RDFS (Resource Description Framework Schema), etc. The choice of the syntax is closely related to the communication protocol, and implementation considerations. A profile can be derived in different syntax. The syntax is different but the semantic remains the same.

In smart grid projects the main information model syntax clearly appears to be CIM XML format in its different versions according to the application. European Style Market Profile (ESMP) associated to IEC 62325-45x series uses CIM XML format, is widely used for the data exchange for market processes. Data exchange of network models follows the CIM-CGMES standards (IEC 61970-600 series), and is using a CIM RDF syntax. This format is used between TSO and DSO for the long-term joint planning or for coordinated operational purposes.

2.2.4.2 Protocols sub-layer

Protocols like ICCP, Energy Flexibility Interface (EFI) are for electricity sector only. Protocols like web-services and XMPP (Extensible Messaging and Presence Protocol) are of general nature. Smart grid projects have reported several communication protocols, e.g. HDFS (Hadoop Distributed File System) layered on top of the TCP (Transmission Control Protocol) / IP (Internet Protocol). As a general observation in communication protocols, internal data processes (e.g. data request and ingestion) among services are mostly following REST web services over secure HTTP connections. CIM XML files can be exchanged through AMQP interface of ECCo SP. Machine readable format of data and AMQP interface are used to enable automatic information exchange between applications without human intervention.

2.2.5 Component Layer

The component layer refers to the physical distribution of all participating components in the data exchange platforms and other solutions. This includes system actors, devices and applications. It is vital for data platforms, according to the objectives that are set in place, to embody all the necessary modules for their effective operation. Along with data platforms, there are software systems and tools like Advanced Distribution Management Systems (ADMS), capable to interpret meter and sub-metered data or historical data into useful information regarding the operational state of the power system; thus, providing critical information to the system operation regarding its operational needs. Such applications described by the participants are: 24-hour demand/generation forecasting, predictive optimisation algorithms, congestion management and peak shaving, price analysis strategies, dispatching module, operation in islanding mode.

2.2.5.1 Data exchange solutions sub-layer

Different data exchange arrangements exist – centralised, distributed, bilateral, hybrid. However, the focus in this report is on data exchange platform, mostly associated with distributed data exchange. A multitude of data platforms has been developed during the last years and is constantly being developed. This, in turn, highlights the need for these data platforms to be able to interact with each other. Interoperability is the new challenge and many EU funded R&D projects are now focusing their activities on this critical issue.

Examples of DEPs which are focussed on electricity sector today are message-based communication solutions like ECCo SP and Estfeed, but also others reported by the projects. For cross-sector interoperability these and other DEPs should be open to exchange data of any sector. Furthermore, these platforms need to be able to communicate with each other.

Data exchange platforms act as the middleware in the electricity sector for several actors to provide coordinated and transparent grid operation and planning allowing the participation of end-users. Cross-border interactions for the provision of multiple ancillary services is seen as an important element of pan-European market in a common European reference architecture for the electricity sector. The increasing harmonisation of standards across Europe is certainly a significant step to allow system operators and market players to provide services beyond the borders, yet it is not necessarily the focal point towards data exchange platforms definition [CEDEC, E.DSO, ENTSO-E, Eurelectric, GEODE, 2019].

Data exchange platforms may be perceived as a middleware framework that bundle versatile processes, information exchanges and data management and integration for a more consumer-centric power system. Attention to attributes of data such as volume, type and source of data stored and exchanged will become increasingly important while setting up an appropriate data infrastructure. Relevant data types range beyond meter data to embody market data, such as weather forecasts or spot prices, grid congestions, unavailability of assets or possibly even grid planning data, especially where this is relevant for other stakeholders besides system operators [ENTSO-E, THEMA, 2017]. Data exchange platforms may evolve from simply being focused on a list of standardised processes related to the retail market, advancing to a modular architecture capable to incorporate new third parties to provide services and functionalities amongst them and the system operators. It is necessary to ensure that interoperable data exchange platforms provide the following functionalities related to information and data exchange handling and management:

- Privacy and data security: any data and meta-data must be treated per the relevant data privacy regulations.
- Neutrality, non-discrimination and transparency of data exchange: data exchange and free flow of data has currently indispensable and increasing value to market players and stakeholders. Therefore, the assurance for neutral and non-discriminatory data access is of significant importance. It is related particularly to standards that permit any stakeholder to access data in a non-discriminatory manner. Non-discrimination also concerns the access by third parties to data and corresponding privacy as stated earlier. The common point of all explored data platforms is to act as the interface of data and services between applications and data sources, avoiding lock-in effects between different vendors and platforms.

2.2.5.2 Applications sub-layer

SCADA and EMS are examples from electricity sector. Data management related systems like big data tools or privacy preserving tools should be addressed in cross-sector domain.

2.3 Findings and recommendations

Topic	All SGAM layers
Findings	Smart Grid Architecture Model originated from European M/490 smart grid mandate. It was then used at IEC level and a document was published in 2021 (IEC 63200) explaining SGAM and the usage of domains, zones and the five interoperability layers. It explains how SGAM can be used and more importantly how architecture is defined with focus on Function Layer described through the System Actors. It has been extended to Gas and Heat. SGAM has also been used to document Power System Management Reference Architecture (IEC 62357-1). It's worthwhile to investigate adding additional or alternative components to SGAM satisfying the features of other sectors.

Recommendation	Leverage Smart Grid Architecture Model (SGAM) usage and study its extension to other sectors (similar to the RAMI4.0 for industry – Reference Architecture Model Industrie 4.0; and CREATE-IoT 3D RAM for health – Reference Architecture Model of CREATE-IoT project), incl. for basic interoperability vocabulary with non-energy sectors.

Topic	**Business layer – regulation**
Findings	Electricity market directive is highly relevant in the context of meter data access and GDPR for personal data handling. Both indicate the increasing importance of private data to achieve interoperability inside electricity domain as well across sectors. Projects highlight the need to ensure data owners' control over their data. Many other emerging legislative acts are setting the scene for data management. In addition, CIM is promoted through electricity network codes and guidelines.
Recommendation	Facilitate European strategy, regulation and practical tools for cross-sector exchange of any type of both private data and public data, e.g. through the means of minimum set of requirements for data spaces and data governance, and data interoperability implementing acts.

Topic	**Business layer – cooperation**
Findings	Inside the electricity sector the importance of TSO-DSO cooperation is deepening, it also has entered the area of data management. European institutions like EC and standardisation organisations (CEN, CENELEC, ETSI) promote cross-sector coordination and this is being taken on board by many BRIDGE projects. Several bottom-up initiatives are emerging to support cross-sector (and cross-border) data exchange – GAIA-X, FIWARE, IDSA, OPEN DEI, BDVA, AIOTI. Also the associations from different sectors (e.g. ICT4Water) could learn from each other and cooperate for further synergies, incl. in further defining of data exchange reference architecture. All this could be facilitated by some orchestration on European level.
Recommendation	Ensure cooperation between appropriate associations, countries and sector representatives to work on cross-sector and cross-border data management by establishing European data cooperation agency.

Topic	**Business layer – processes**
Findings	There are obvious dependencies of the electricity with other vectors of energy sector (e.g. gas, combined heat and power). Concurrently, the water sector presents interdependencies with electricity due the fact that water usage and delivery follows seasonal and weather changes. Projects from health, manufacturing and agri-food sectors confirm the feasibility and need for cross-sector business synergies. Data management business processes like data security & privacy, data analytics, etc. are similar to all energy vectors, also to water, but in many aspects also to any other sector (e.g. health, transportation).

Recommendation	Harmonise the development, content and accessibility of data exchange business use cases for cross-sector domain through BRIDGE use case repository.

Topic	**Business layer – data roles**
Findings	Considering the universal nature of the data exchange roles HEMRM could be renamed to Harmonised Energy Role Model in order to facilitate interoperability at least among energy sectors (electricity, gas, heating & cooling). Harmonising the electricity roles and gas roles is already ongoing.
Recommendation	Use BRIDGE use case repository for aligning the role selection. Harmonise data roles across electricity and other energy domains by developing HERM – Harmonised Energy Role Model and ensure access to model files. Look for consistency with other domains outside energy based on this HERM – cross-sectoral roles.

Topic	**Function layer**
Findings	The key transformation of both electricity domain and the cross-sector domain is the data exchange and management. It is essential to identify a set of comprehensive functional data processes that will allow the data sharing, data governance etc. towards the exploitation of cross-sector exchanges to achieve certain business processes. Consequently, and in line with European Interoperability Framework [EC, 23.03.2017] in a common reference architecture common functional block can be defined for standardised data governance such as data source integration, data handling, consent management, etc.
Recommendation	Define and harmonise functional data processes for cross-sector domain, using common vocabulary, template and repository for respective use cases' descriptions.

Topic	**Information layer – canonical data model**
Findings	The development of use cases according to IEC 62913-1 (Generic smart grid requirements) allows to define Business Objects which have to be exchanged between Applications, Systems, Functions providing interfaces. Business Objects define the semantics that has to be exchanged. The Canonical Data Model is used to define the Business Objects (information exchange requirement). It is equally important to develop mechanisms for life-cycle management of the canonical data model (facilitating enrichment with new concepts, extension to further domains, relations' management, etc.).
Recommendation	Define, maintain and ensure access to model files of a generic canonical data model facilitating cross-sector data exchange, e.g. by extending Common Information Model (CIM) and/or integrating other sectors' canonical data models with CIM.

Topic	**Information layer – data models and profiles**

Findings	European electricity sector has put in place a robust methodology based on system approach, which promotes interoperability by using standards (Use Case definition, Role Model, Canonical Data Model like CIM, Smart Grid Architecture Model). It would be valuable to extend this approach to other energy vectors and to cross-sector domain. In order to facilitate data exchange between sectors, it would make sense to develop cross-sector data models. Profiles define how the semantics of an interface relate to the Canonical Data Model. Profiling methodology is defined in IEC 62361-103.
Recommendation	Develop cross-sector data models and profiles, with specific focus on private data exchange. Enable access to model files.

Topic	**Communication layer – protocols**
Findings	Some communication protocols reported by the projects involve: HDFS (Hadoop Distributed File System) layered on top of the TCP (Transmission Control Protocol) / IP (Internet Protocol); internal data processes (e.g. data request and ingestion) among services are mostly following REST web services over secure HTTP connections; CIM XML files can be exchanged through AMQP interface of ECCo SP.
Recommendation	Ensure protocol agnostic approach to cross-sector data exchange.

Topic	**Communication layer – data formats**
Findings	Data profiles use data format, i.e. syntax: XSD, RDFS, etc. The choice of the syntax is closely related to the communication protocol, and implementation considerations. A profile can be derived in different syntax. In particular, the main information model syntax clearly appears to be CIM XML format in its different versions according to the application.
Recommendation	Ensure data format agnostic approach to cross-sector data exchange.

Topic	**Component layer – data exchange platforms**
Findings	BRIDGE projects are increasingly using business process agnostic data platforms, e.g. ECCo SP, Estfeed, IEGSA, Atos FUSE, Enterprise Service Bus, Cloudera, etc. The platforms should be made available to other R&I projects. Interoperable data exchange platforms embody functionalities across all the interoperability layers as defined in the SGAM framework. The interconnection of such multiple data exchange platforms would release data-driven services among the different stakeholders.
Recommendation	Promote business process agnostic DEPs (Data Exchange Platforms) and make these interoperable by developing APIs (Application Programming Interfaces) which

	enable for data providers and data users easy connection to any European DEP but also create the possibility whereby connecting to one DEP ensures data exchange with any other stakeholder in Europe.

Topic	**Component layer – data applications**
Findings	Projects use wide range of existing and newly developed applications for data management. For example, there are many applications in the area of Advanced Distribution Management Systems (ADMS), capable to interpret meter and sub-meter near-real-time data or historical data into useful information regarding the operational state of the power system.
Recommendation	Develop universal data applications which can serve any domain.

3. Mapping of individual projects and initiatives to reference architecture

3.1 Overview of architectures

3.1.1 BD4NRG *(ENERGY)*

The BD4NRG Reference Architecture (Figure 6) aims to specify the building blocks and main elements that need to be considered by smart and decentralised data-driven energy ecosystems to create value out of Big Data by exploiting AI technologies. Through a concise and detailed RA, BD4NRG foresees to overcome barriers hampering the exploitation potential of energy Big Data, offering a standardised way of managing, sharing and using data and related AI services.

The architecture considers four main layers of the data value chain and a vertical pillar focusing on data space enablers that allow decentralised energy ecosystems to make their data available, in a trusted and sovereignty-preserving manner, to analytics services providers so that value can be generated.

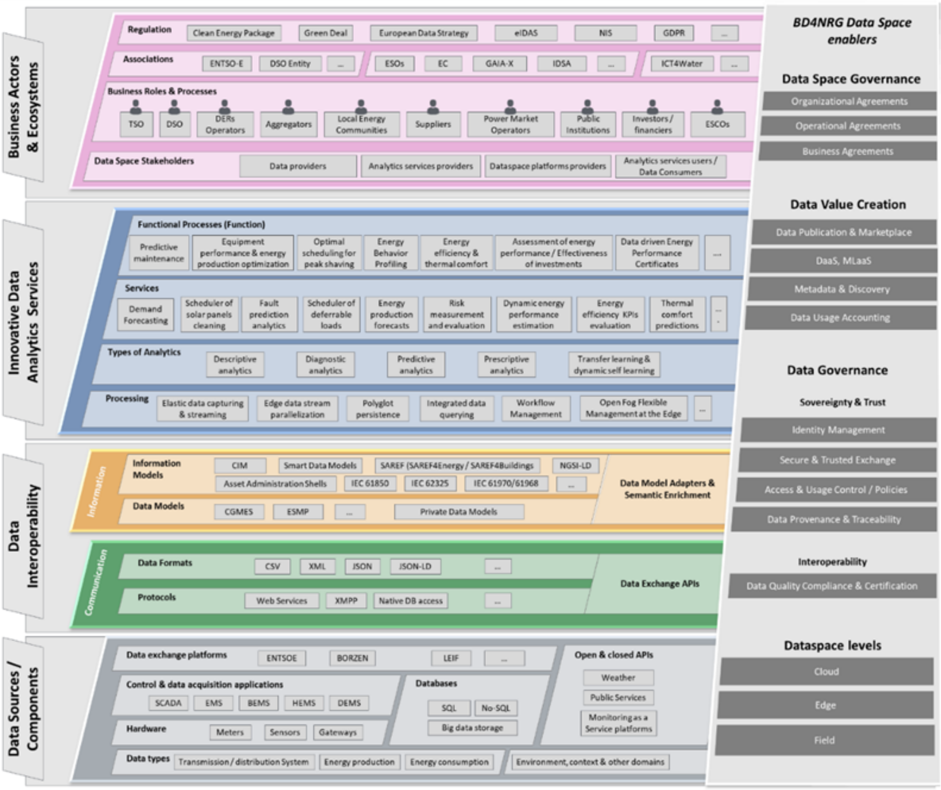


Figure 6: BD4NRG Reference Architecture [BD4NRG, 2020]

The **Data Sources Layer** focuses on identifying and understanding the Big Data provided by numerous sources, including energy sensors and meters, data monitoring and acquisition platforms such as SCADA systems or Building Energy Management systems, databases with historical or real time data, smart grid data exchange platforms and cross-domain information such as environmental information and data coming from public administration services (e.g., related to energy performance contracts). Essentially, this layer includes all the data generating hardware, applications and platforms as described in the Component Layer of the BRIDGE architecture.

The **Data Interoperability** Layer focuses on identifying the communication interfaces with the data sources and corresponding data formats, as well as on providing a set of data and information models which could be followed or used for data transformation, aiming to ensure interoperable data exchange and use. This layer integrates the Communication and Information layers of the BRIDGE architecture.

The **Data Analytics Services** Layer comprises four sublayers and specifies:

- the processing infrastructure required for Big Data processing;
- different types of analytics that are employed depending on user requirements and data analytics use cases;
- the analytics services that take as input the energy and cross-sector Big Data;
- the functional process which are supported by the analytics services and receive the value extracted from Big Data. This layer represents the Function layer of the BRIDGE architecture by consolidating aspects related to data analytics and correspondingly supported functions.

The **Business Actors and Ecosystems** Layer identifies stakeholders who participate in the data analytics ecosystem and corresponding energy data spaces and maps to a **Data/Service Marketplace Layer.** They include data providers and analytics services users / data consumers, analytics applications providers and providers of data space enablers and related platforms. Note that an organisation or business role in the energy ecosystem can have one or more roles in data space, for example a TSO can be a data provider and a consumer of analytics services at the same time.

The vertical pillar of **BD4NRG Data Space Enablers** identifies the components and functions required to realise the distributed BD4NRG data space and is aligned with the design principles specified by OPEN DEI.

Main business processes enabled by the BD4NRG RA are:

- Grid Operation
- Predictive Asset Maintenance / Management
- Flexibility Assets Forecasting
- Predictive Analytics for performance & comfort
- Demand and Generation Forecasting

Main data management functionalities:

- Data Collection
- Data Space Governance
- Data Usage Accounting
- Secure & Trusted Exchange
- Data Provenance & Traceability
- Access & Usage Control

Existing relevant standardised approaches for the concept:

- Information models – CIM, IEC 61850, IEC 62325
- Data Formats – CSV, XML, JSON, JSON-LD
- Protocols – HTTP/S, MQTT/S, XMPP

BD4NRG encompasses 12 Large Scale Pilots located in nine countries. Pilots are separated in three groups based on their goals:

- "BD-4-NET": Increasing the Efficiency and Reliability of the Electricity Network
- "BD-4-DER": Optimising the Management of Assets (DER - Distributed Energy Resources) Connected to the Grid
- "BD-4-ENEF" Large Scale Pilots: De-Risking Investments in Energy Efficiency and Increasing the Efficiency and Comfort of Buildings

Cross-sector dimension is present in BD4NRG "by-design" and is validated along all the 12 Large Scale Pilots, including interaction among:

- electricity and other energy carriers, such as district heating/buildings;
- electricity versus non-energy sectors, such as transport/e-mobility, water and financial sectors (through ESCOs).

3.1.2 BD4OPEM *(ENERGY)*

BD4OPEM develops a Data Exchange and Analytics Services Platform (Figure 7): **Service Marketplace** offers energy services enabled via data exchanges as well as via analytics infrastructure as a service, offered through the platform; **Data Marketplace** offer seamless data exchange as an individual offering of the platform.

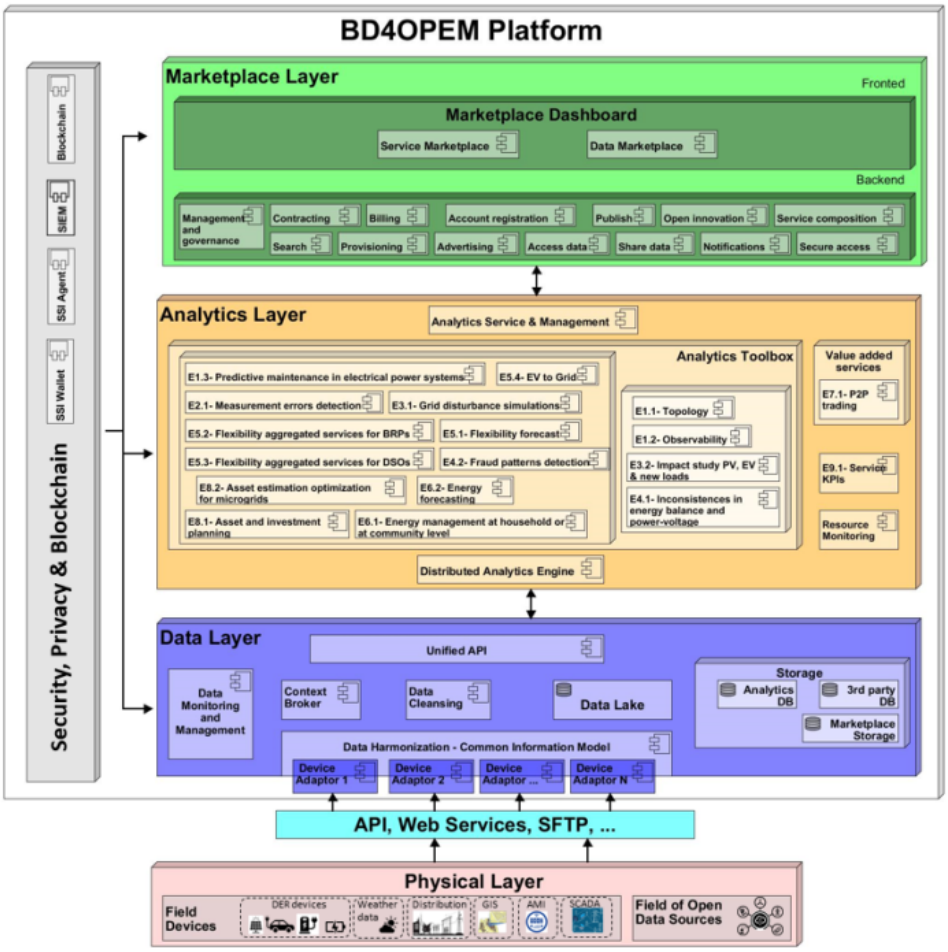


Figure 7: BD4OPEM platform architecture [BD4OPEM, 2020]

Marketplace Layer enables matchmaking of buyers and sellers of data and/or services, contracting, request for new services (open innovation, service composition) and billing (among other).

Analytics Layer enables the hosting of applications that enable services offered through the Marketplace Layer. However, its main offering is the Distributed Analytics Engine, a scalable infrastructure for execution of analytics processes on top of big data, accessible through the data layer (see below).

Data Layer offers the integration of the various data sources with the BD4OPEM platform and access to the service providers (and in general data users), either as real-time data flows (through the Context Broker) or via storage and access (via the Data Lake).

Security, Privacy and Blockchain Layer offers mechanisms for secure access and authorisation of all users and external system communicating with the BD4OPEM platform. It incorporates a Blockchain solution to support the Smart Contract based value added services and Self Sovereign Identity for Secure access for all stakeholders in the ecosystem.

Main business processes enabled by the platform:

- Operation and maintenance (grid topology identification, grid observability, predictive maintenance, impact study of PV, EV and new loads, etc.)
- Fraud detection (inconsistencies in energy balance and power-voltage)
- Flexibility and demand response

- Smart houses, buildings and industry
- Trading
- Grid planning
- Processes related to data exchange – Data Harmonisation, (Distributed) Storage, Data Mediation/Access, Data Governance, Quality Management (cleansing, monitoring)
- Processes related to analytics and the marketplace layer

Main data management functionalities:

- Contracting (and authorised access)
- Harmonisation
- Cleansing
- Storage
- “Health” monitoring

Existing relevant standardised approaches for the concept:

- Role Model – IDSA (adapted)
- Information Model – IEC CIM, SAREF4ENER, FIWARE/NGSI-LD
- Data Formatting – JSON, Apache Parquet
- Communication Protocols – HTTP, FTP, Apache Kafka protocol

There are five different pilots in the project, in different locations: Spain, Slovenia, Turkey, Denmark and Belgium. Different energy services enabled by the platform will be tested in these locations. With regards to cross-sector activities **EV** chargers will be utilised in the Danish pilot, for distribution grid services.

3.1.3 DEMETER (*AGRI-FOOD*)

The DEMETER Reference Architecture (Figure 8) integrates heterogeneous technologies, platforms and systems, while supporting smooth data exchange across the entire chain agri-food industry, addressing the scalability and governance of data ownership by fostering interoperability by adopting a common data model, such as the Agricultural Information Model (AIM). The main goal is to promote interoperability between the ICT platforms, semantic models and existing applications capable of supporting scalable data management. In this way, it offers a way for the integration of platforms and intelligent agriculture already implemented, which could employ different technologies communication, data collection and processing. The approach used to design and then implement the DEMETER Reference Architecture (RA) allows existing agricultural knowledge information systems to continue to function, but also allows such systems to make available and consume data from other cooperating systems.

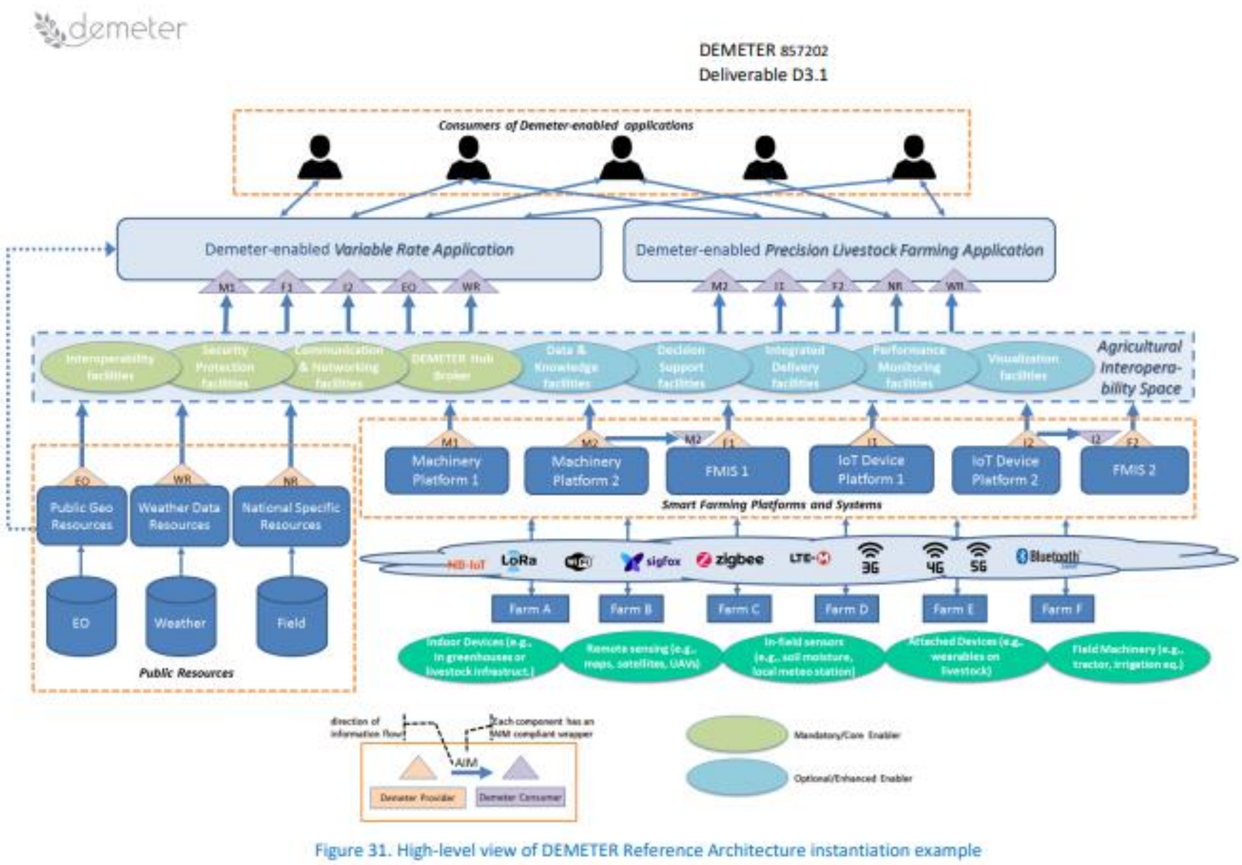


Figure 8: DEMETER Reference Architecture (release 1) [DEMETER, 2020]https://h2020-demeter.eu/wp-content/uploads/2020/10/D3.1-DEMETER-reference-architecture_v1.0.pdf

DEMETER-enhanced Resources (platform, thing, service) register their capabilities to the DEMETER Enabler Hub which makes them available to interested parties. DEMETER-enabled Resource can make use of other Enablers registered in the DEMETER Enabler Hub to enhance its features. DEMETER-enabled Service is a third party service that is provided by a stakeholder external to the DEMETER project, which is integrated to the DEMETER ecosystem. It can both register its Service Logic to the DEMETER Enabler Hub, thus making it discoverable by interested parties, as well as discover other DEMETER Enablers via the DEMETER Enabler Hub and directly consume their exposed interfaces without any interoperability implications.

DEMETER-enabled Application: The “Application Logic and User Interfaces” are DEMETER agnostic and are provided by an application provider external to DEMETER. The DEMETER-enabled application can communicate with the DEMETER eco-system and browse its Enabler Hub to discover available resources that are compatible with and registered in DEMETER. End-users directly access the user interfaces provided by these applications. Furthermore, users can consume functionalities exposed by the DEMETER enabled Resources (or resources in general, including data) only through these applications.

The DEMETER Agricultural Interoperability Space (AIS) focuses on delivering a full set of interoperability mechanisms to actually develop, validate and then deploy the solution. DEMETER does not define completely new interoperability mechanisms but instead uses (and extends) a wide range of pre-existing mechanisms at sensor, data and service levels.

The data management module block module consists of three main software sub-modules: ACS – Access Control Server, DEH – DEMETER Enabler HUB, BSE – Brokerage Service Environment. Each of these modules exposes standard APIs that depending on the case, perform specific tasks in the data management process. As can be seen from the figure, the databases in which data are saved are: DEMETER User Registry (where the user entities are stored), DEMETER Resource Registry (where DEMETER DEEs are stored), DEMETER BSE Registry (where the non-static DEMETER services are enabled which can be invoked at runtime and assembled together to other services to build business scenarios within the Pilots).

Main business processes enabled by the platform:

- Communication & Networking
- Security & Governance
- Run-time Deployment & Orchestration
- Discovery, Provisioning & Resource Management
- Service/Application life-cycle Management
- Performance Monitoring
- User Interaction & Data Visualisation.

Main data management functionalities:

- Data storage in specific databases.
- The information or entities made available to business processes via APIs at the higher level of the architecture or at the presentation layer.
- Information security management.

As data interoperability is of critical importance, the DEMETER proposed solution provides the necessary data translation mechanisms combining the use of a semantic data model (the DEMETER AIM) along with the respective data translation/management/inference mechanisms adopting widespread standardised solutions. The DEMETER AIM (DEMETER information model) is a data model and ontology that describes all data needed by DEMETER applications and the usage of which ensures semantic interoperability between data and various components.

DEMETER RA will be demonstrated in 20 Pilots that map the whole of European countries each of which implements a specific heterogeneity from the technological and infrastructural point of view. The main DEMETER modules have already been integrated into many DEMETER pilots and are currently being tested. The functional and technical tests will follow up on the final result which will demonstrate the effectiveness of the implementation of the architecture in different contexts and use cases. DEMETER RA focuses on the agri-food sector but could be contextualised to the different sectors.

3.1.4 Ebalance-plus *(CROSS-SECTOR)*

The ebalance-plus project applies and extends the data exchange platform developed in the FP7 project e-balance. It is was initially focused on energy applications, but was further extended to support other areas. The data exchange platform is distributed over many computational units called management units (MUs). Figure 9 shows an example architecture of a management unit. The units are interconnected and create a hierarchical structure, as shown in Figure 10.

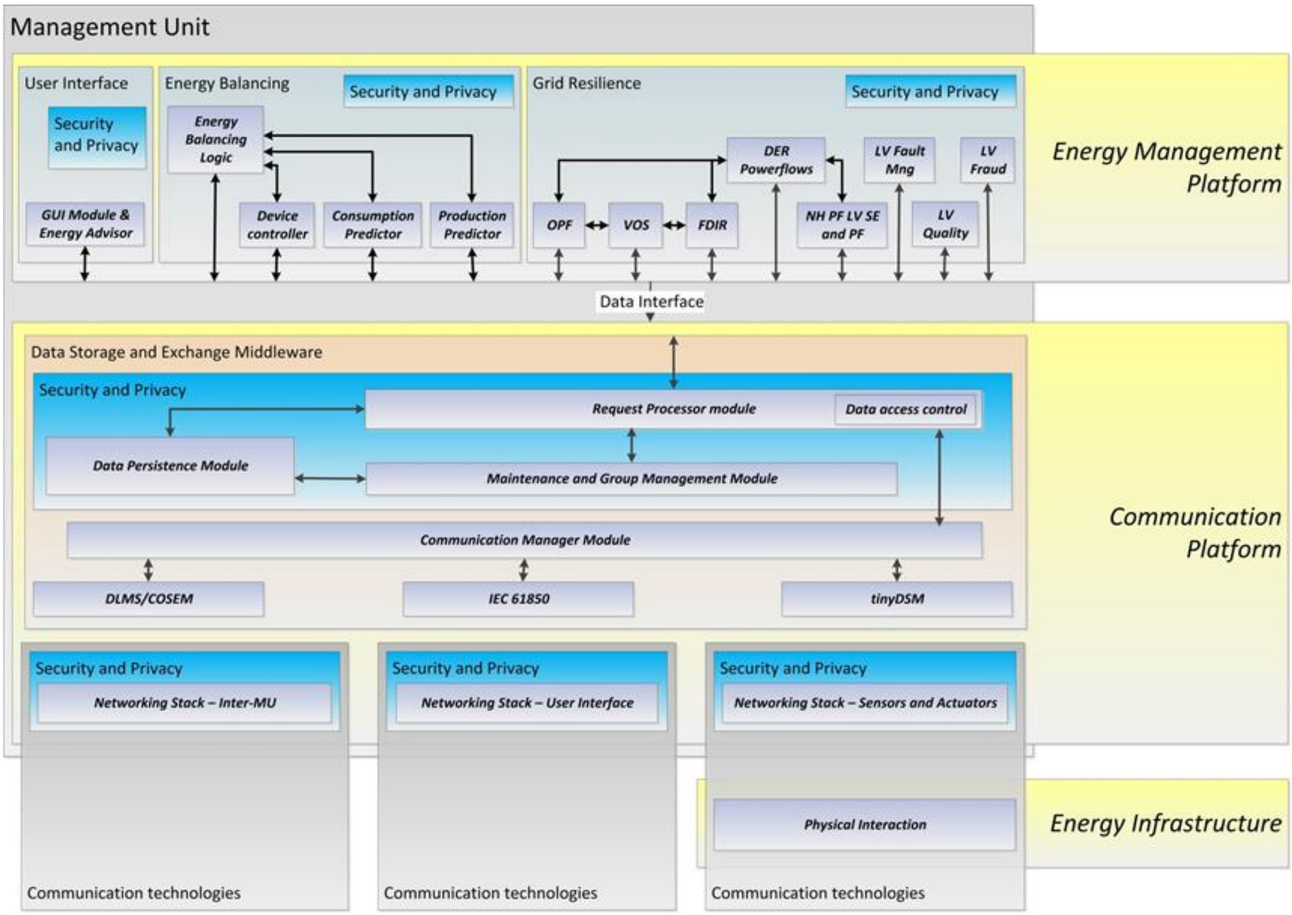


Figure 9: The architecture of the ebalance-plus platform management unit [ebalance-plus, 2015]

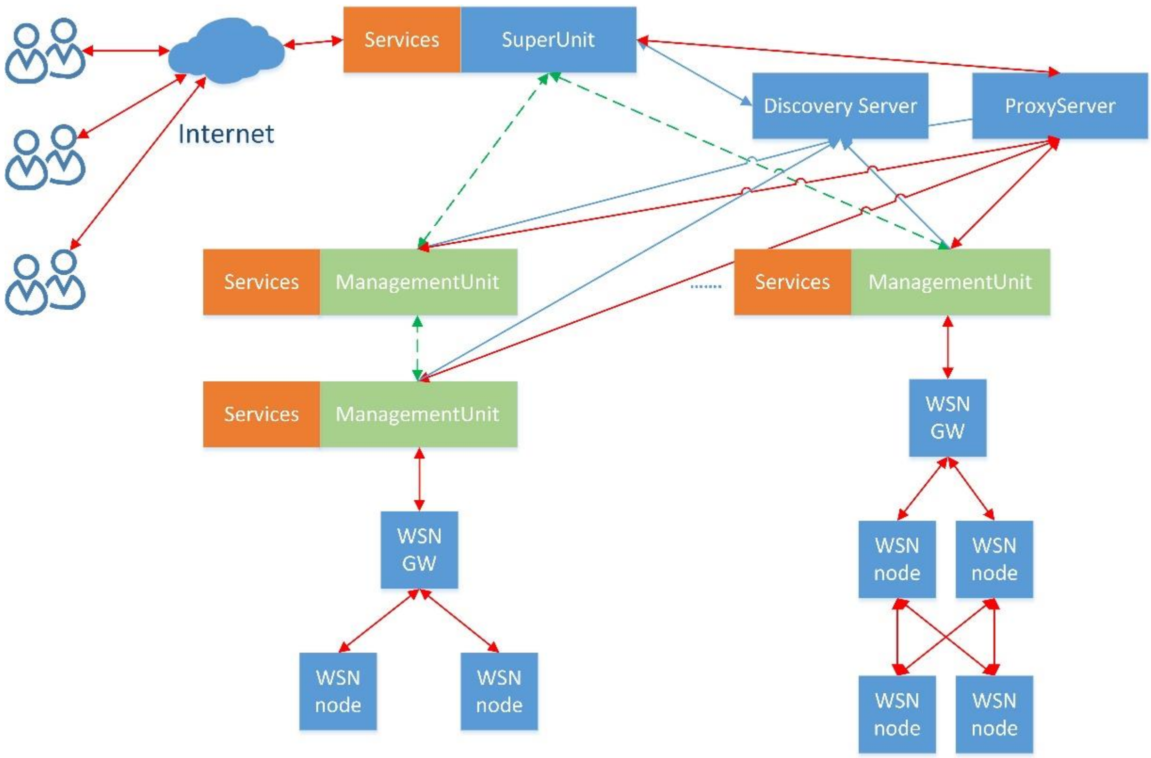


Figure 10: The hierarchical architecture of the ebalance-plus platform (to be published)

The data exchange platform is composed of middleware instances distributed on remote, but connected machines, we called the management units. The middleware defines a distributed data storage, where the data is represented by variables (each with defined type and/or structure). These variables store values that are shared between the instances of the middleware. On top of the middleware layer there are services that access the data in the middleware using the Data Interface. As the services run on behalf of different users (stakeholders) the middleware and the Data Interface allow controlling who accesses the data and the user that created the specific data (the data owner) defines who else can access the data and how. By that we have the division between the data storage and sharing (the data exchange platform) and the data processing (the services).

Main business processes enabled by the platform:

- The pure data exchange platform enables the business process “data sharing”. It might be possible to buy and sell data.
- In the energy management related application we are going to implement in the ebalance-plus project there will be several energy related business processes, like flexibility enabling and energy resilience related ones.
- We are also using the data exchange platform for environmental monitoring in other projects. In that case we store the sensor data in the middleware and use the platform to distribute the data processing and presentation to the users. This application will also support multi-owner data for environment monitoring and analysis.

Main data management functionalities:

- Data ownership and access control (for security and privacy)
- Data discovery
- Multi-party data sharing

The ebalance-plus uses internally proprietary protocols (based on HTTPS) to exchange data between the middleware instances, but for the outside world many adapters will be developed. Adapters are services that connect to the middleware, but on the other end talk a different protocol and follow the required security and other requirements. Examples here are Amazon cloud, SOAP, Modbus, and others. This allows the platform to talk to existing, standardised solutions.

The platform will be demonstrated in the ebalance-plus project demonstrators, but also in the SmartRiver project (INTERREG V A BB-PL, #85029892) for environmental monitoring. The platform can easily be applied for other energy sectors (**gas**, **heating**), also **water**. Such coexistence in a house could be used to create multi-aspect algorithms to optimise the overall energy consumption taking into account the cross sector dependencies. The platform is also applied for **environmental monitoring** applications. Indeed, weather data can be used also to optimise energy usage. Similar as it can be used in **agriculture** to dose fertiliser or water. In current environmental monitoring scenario the platform is used to implement a system to manage water (rain, ground water, river) and related infrastructure (embankments, water storage to buffer water) to observe and protect citizens from too much and too less water (drought). It should be further extended by other **smart city** scenarios (air quality).

3.1.5 EEBUS (*ENERGY*)

The primary objective of EEBUS is to define a universal, machine-readable and interoperable standard. For this reason, EEBUS technology is designed to harmonise with various protocols and transmission channels. Only through this consistent approach can different technologies merge to form a customer solution. In order to guarantee maximum flexibility, the EEBUS architecture is based on the SGAM architecture model (Figure 11).

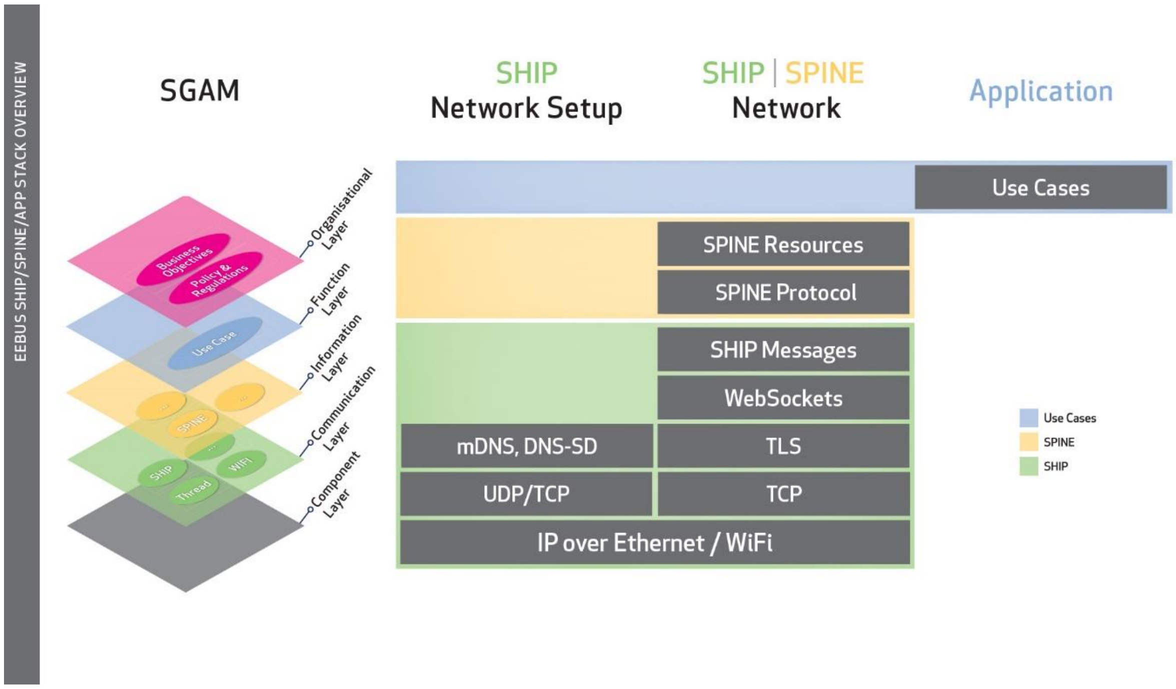


Figure 11: EEBUS architecture [EEBUS webpage]

SHIP describes the standardised transport of data over IP (Internet Protocol); includes device discovery and security mechanisms. SPINE comprises of an application protocol and a set of data models (which can be reused in use cases). Use Case (UC) specifications: each UC defines a functionality and responsibilities between actors; then, it is defined how this is achieved using SHIP/SPINE.

Main business processes enabled by the platform:

- Energy cost reduction
- Support of grid stability

Main data management functionalities:

- Resource-based approach, comparable to REST (an appliance provides its data/resources; access via read-reply, write, notify, call)
- Subscriptions and bindings on data
- Discovery of data and supported use cases

Existing relevant standardised approaches for the concept:

- Data models, formats: XSD, XML, JSON
- Communication protocols: TCP/IP, DNS-SD/mDNS, WebSockets, TLS

There are already devices in the market with SHIP/SPINE implementation. Theoretically, it could be applied in other sectors. With very little extensions it could be applied for energy management of other energy forms than electricity.

3.1.6 EU-SysFlex (*CROSS-SECTOR*)

EU-SysFlex concept is called 'Recommended data exchange conceptual model for Europe' (Figure 12). It is based on SGAM for general architecture, CIM for data modelling, HEMRM for role modelling, Estfeed platform for data exchange concept.

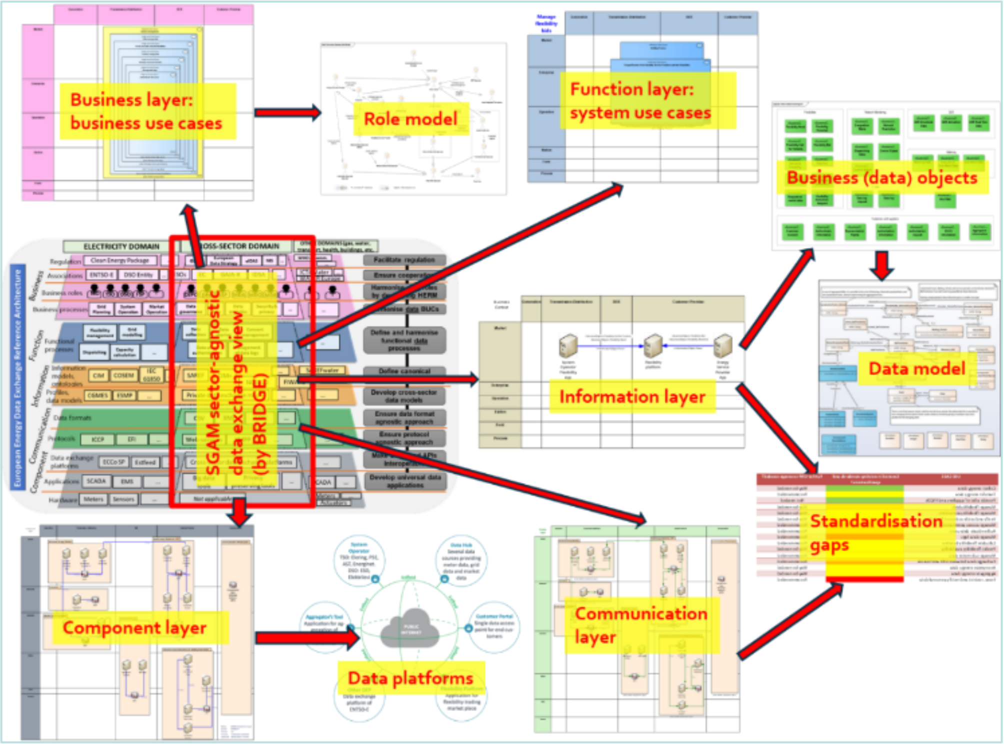


Figure 12: EU-SysFlex 'Recommended data exchange conceptual model for Europe' [EU-SysFlex, 2021]

The focus is on cross-sector and cross-border data exchange, agnostic to specific business/market processes. Therefore, there is direct link with 'Cross-sector domain' of BRIDGE reference architecture. Several data exchange SUCs were identified and described using IEC 62550-2 approach and BUCs were established for several data exchange demonstrators. Most of the SUCs were implemented in these demonstrators. Many information could be retrieved from SUCs in order to map to five SGAM interoperability layers. One major missing subject not recorded in SUCs was the references to standards.

However, standardisation gaps were identified in a different deliverable. The focus was on data exchange standards relevant for Information and Communication Layers. A model for roles was developed based on information from SUCs, again focussing on data exchange roles. The compliance with HEMRM was assessed and the updates of HEMRM have been proposed. Also business objects were identified in SUCs. These were used for data modelling. Initially project-specific models were developed. Afterwards couple of business objects were mapped to CIM as preferred canonical model – this was called 'CIMification' process.

Main tool for data exchange is the concept of Data Exchange Platform (DEP). All SUCs and demonstrators were built around the DEP – any data exchange could benefit from using such approach. However, it is acknowledged that other types of data exchange can and must exist, but still the interoperability between all these approaches needs to be ensured.

Main business processes enabled by the platform:

- Secure and privacy respecting data exchange, including cross-border and cross sector
- Flexibility market functioning
- Data governance
- Big data solutions

Main data management functionalities:

- Data collection
- Data sharing
- Consent management
- Erasure and rectification of private data
- Data user's authentication

- Representation rights' management
- Management of data logs
- Sub-meter data management
- Data anonymisation
- Data aggregation

Existing relevant standardised approaches for the concept:

- HEMRM for role model
- CIM for information/data model
- XML for data format, but DEP based approach should enable any format
- REST, SOAP for communication protocol, but others also possible
- eIDAS compliant approach for data users' authentication

Many of the aspects have been demonstrated. Business/market process agnostic use cases could be applied or at least mapped to the needs of **any other sector**. This concerns any layer of SGAM.

3.1.7 HYPERRIDE *(ENERGY)*

HYPERRIDE ICT platform is a combination of existing solutions (e.g. FIWARE, REASENS and H2020 SUCCESS project) and new software components (Figure 13).

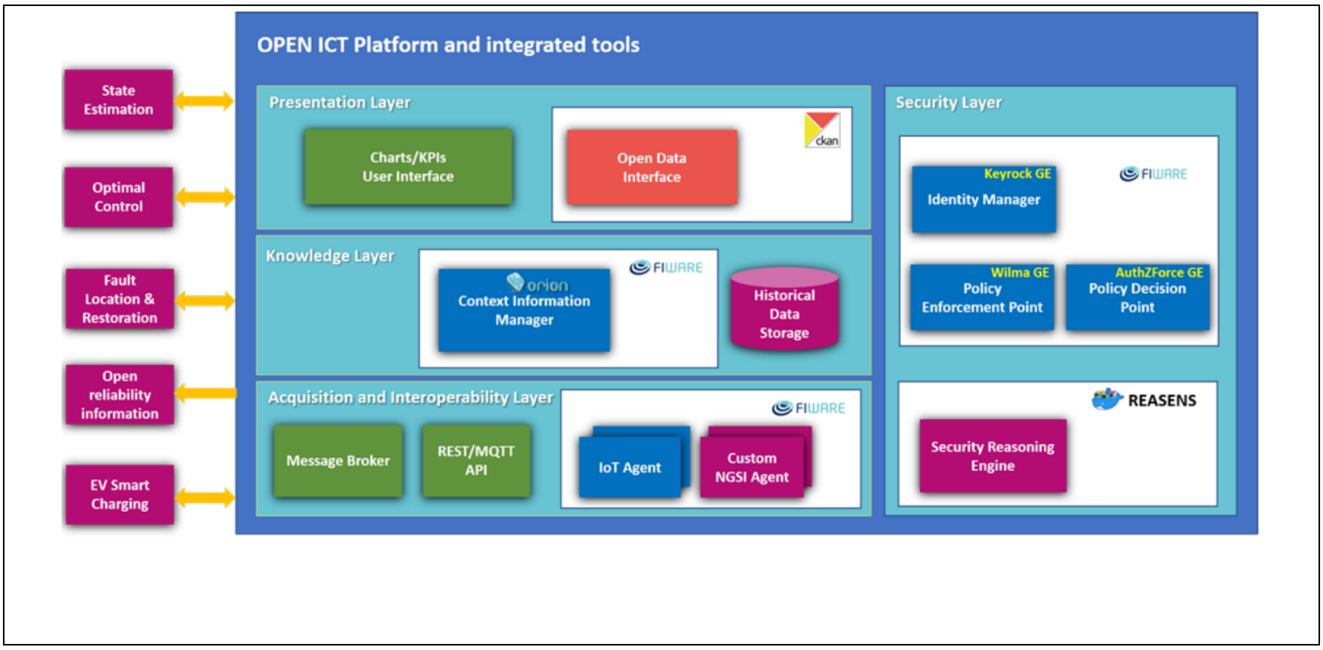


Figure 13: Preliminary overview of the HYPERRIDE architecture components [M. Mammina, A. Rossi, 2021]

The HYPERRIDE architecture aims at performing the efficient monitoring and operation of hybrid AC/DC distribution grids. The architecture is divided into five parts (layers).

Acquisition/Interoperability Layer: for the communication interface with the IoT field devices to exchange data (collect measurements, statuses and provide setpoints and commands), specifically adapted to the novel DC grid and underlying devices; this is carried out, for example, via the FIWARE IoT Agents software component.

Knowledge Layer: as an open reliability information database, to provide a common platform for storing and sharing component reliability Information. For this scope, Orion Context Broker and FIWARE database components are implemented.

Presentation Layer: as API to access and manage the platform and its data, for user interface

Security Layer: the cybersecurity aspects of the platform are addressed via: (i) Generic Enablers from the FIWARE catalogue (Keyrock, Wilma and AuthZForce), (ii) the security monitoring framework developed in H2020 SUCCESS project and (iii) the REASENS proprietary solution for root cause analysis. REASENS is a distributed framework for root cause analysis that uses Evidential Networks to reason about the causes of events that are generated by distributed sensors; two approaches to deployment: using MQTT and the ElasticStack.

Moreover, several Energy Services are interconnected with the platform. They correspond to the specific middleware software components developed as on-demand services for the operation and management of the AC/DC electrical grids. These services consist of: the State Estimation to monitor the network, the Optimal Control to enhance the energy management of the facilities, the Fault Location and Restoration to deploy the protective measures, the Open Reliability Information to guarantee system security and the EV Smart Charging Solution.

The HYPERRIDE ICT platform aims to be open, interoperable and able to support scalable data-collection and management; this is performed in order to deploy near real-time observability and to optimise the operation of modular and resilient hybrid AC/DC distribution grids.

Main data management functionalities:

- Scalable and interoperable integration of DC field devices, in order to exchange data and perform efficiently the grid management operations.
- Due to the particularity of the grid application (hybrid AC/DC distribution grids), the acquisition layer must be compliant with the DC communication standards and DC operational requirements.
- The analysis of the grid data allows the deployment of cybersecurity solutions, to promptly detect intrusions or cyberattacks.

Work on “Identification, definition and adoption of data model for interoperability” has started. Its activities include the selection and review of the relevant standards, architectures and ontologies, the identification of scope and boundary for the data models, the development of selection criteria for adoption and the development of the new models, and/or extension of existing ones. Starting point will be the analysis of IEC 61850 data models and IEC 61968 for our specific implementations.

HYPERRIDE project includes three pilot tests that involve different AC/DC and DC electrical components and several operation strategies. The HYPERRIDE ICT platform will be integrated in the control systems to ease and improve the grid reliability and efficiency. The implementations of the HYPERRIDE project will uniquely involve the electricity sector.

3.1.8 ICT4WATER: FIWARE (*CROSS-SECTOR*)

ICT4Water cluster has promoted since 3-4 years ago the adoption of FIWARE as a reference architecture (Figure 14). Under this vision, the adoption of FIWARE has been monitored for water-energy-materials symbiosis (ULTIMATE, AQUASPICE, B-WATER-SMART projects), water quality and security (PATHOCERT, AQUA3S), water distribution and management (FIWARE4WATER, NAIADES), WEFE (Water, Energy, Food and Ecosystems) policy-making (SIM4NEXUS) and waste-water management and social engagement (SCOREWATER) to mention a few. Figure 15 depicts the example from FIWARE4WATER project about the adaptation of the FIWARE architecture. ICT4WATER cluster is on the transition to promote Water Data Spaces through the use of a compatible architecture with IDSA and FIWARE to enable cross-domain interrelation of the information and data exchange.

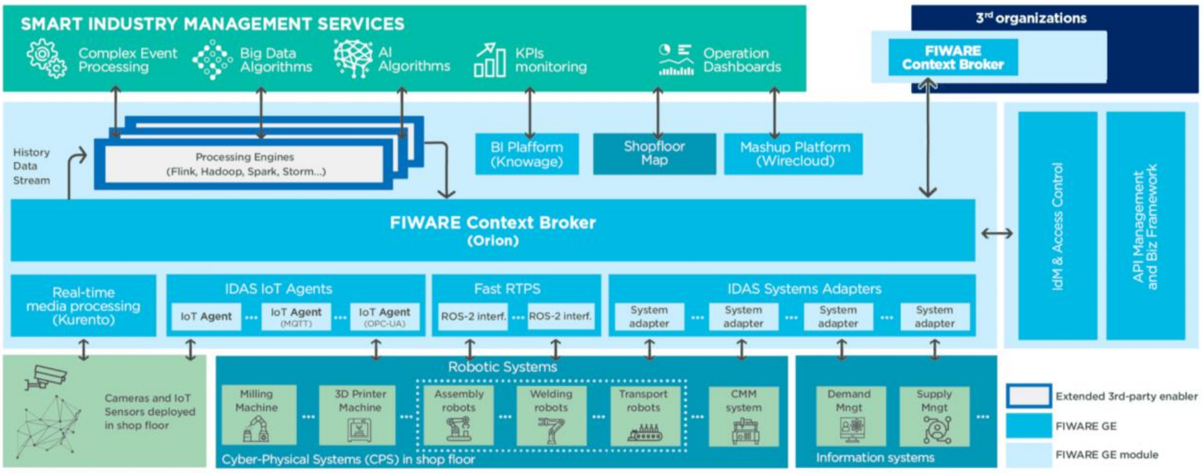


Figure 14: FIWARE architecture [FIWARE webpage]

Main FIWARE components are described in https://www.fiware.org/developers/catalogue/. As a summary, the main components are:

Core-Context-Management. A Context Broker component is the core and mandatory component of any "Powered by FIWARE" platform or solution. It enables to manage context information in a highly decentralised and large-scale manner.

Interfaces to capture information. Generic Enablers (called Agents) focused on gathering valuable context information or trigger actuations in response to context updates (e.g. capture information from water systems, energy systems, etc.). Currently, FIWARE contains IoT agents for making it easier to interface with devices using the most widely used IoT protocols (LWM2M over CoaP, JSON or UltraLight over HTTP/MQTT, OPC-UA, Sigfox or LoRaWAN). Other interfaces are available for video cameras (Kurento), OneM2M (OpenMTC) and robotics (FastDDS).

Context Processing, analysis and visualisation. Generic Enablers to process, analyse or visualise context information for the purpose of implementing the "smart behaviour" expected in any application. In this regards, FIWARE provides an enable for developing dashboards (WireCloud), generate dynamic processing flows (FogFlow) and complex-event-processing (Perseo).

Context Data/API management, publication and monetisation. Transversal enables for ensuring data security (OAuth – Open Authorisation, XACML – eXtensible Access Control Markup Language) and data publication and sharing (compatibility with Open Data Management Systems like CKAN – Comprehensive Knowledge Archive Network).

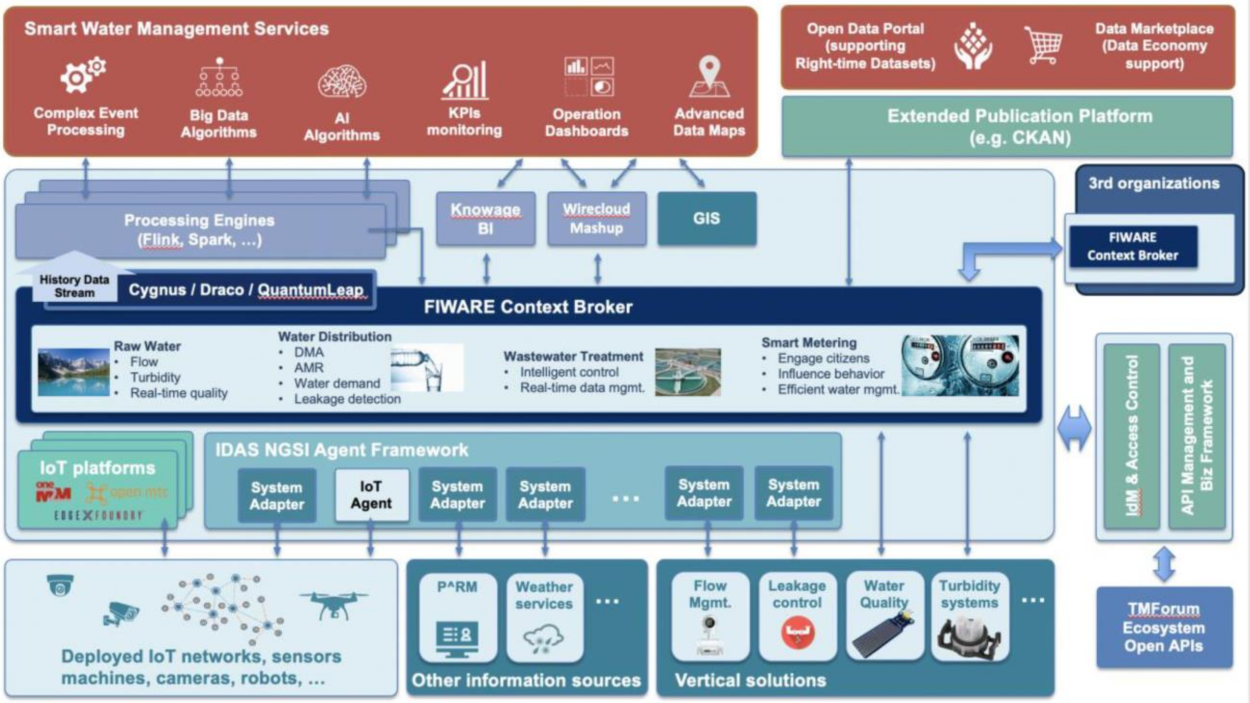


Figure 15: FIWARE4WATER reference architecture [FIWARE4WATER, 2020]

Main business processes enabled by the platform:

- Water-energy-materials symbiosis
- Water quality and security
- Water distribution and management
- WEFE policy-making
- Waste-water management and social engagement

Main data management functionalities:

- Interfacing with IoT and remote water systems and tools (including legacy systems)
- Context Data/API management, publication and monetisation of the information that enables common data sharing mechanism to consume the information from other platforms
- Common data catalogues of the information (called Smart Data Models) that permit to interlink the information across different domains
- Short-term and long term data storing and management to enabling real-time access to the information but also, historic data management (including time series) for enabling further data analytics
- Security and data accessibility to ensure data privacy and enabling a secure-based data sharing

From FIWARE architecture, interesting models are the Smart Data Models (catalogue of information context by domain) and also the Context-Broker.

FIWARE architecture is being demonstrated for the water domain successfully for the projects of FIWARE4WATER, SCOREWATER, AQUA3S and NAIADES. Moreover, it is being expanded for the demonstration under ULTIMATE, PATHOCERT, AQUASPICE, B-WATER-SMART and NEXOGENESIS.

FIWARE architecture is being demonstrated for manufacturing, water, agriculture, environment and aeronautics (see successful stories: https://www.fiware.org/community/impact_stories/#explore-stories). ICT4WATER cluster is analysing the impact of the correlation of water-energy and materials information to optimise industrial symbiosis in different regions. This will serve to assess the potential to interrelate cross-domain information.

Considering this architecture, the interrelation with BRIDGE are in the Components/Communication Layers (IoT Agents), Information Layer (context management), Function Layer (data analytics) and Business Layer (ICT4WATER, IDSA).

In relation to BRIDGE recommendations, it could be interesting to reinforce synergies with the water sector due to water and energy infrastructures similarities. Indeed, establishing common data exchange frameworks between both domains could serve to demonstrate the potentiality for cross domain data sharing and also decision-making procedures (operational or political).

3.1.9 InterConnect (*CROSS-SECTOR*)

InterConnect concept is called Semantic Interoperability Layer (Figure 16). This is a new concept, covering both Smart Home/Building and Smart Energy requirements.

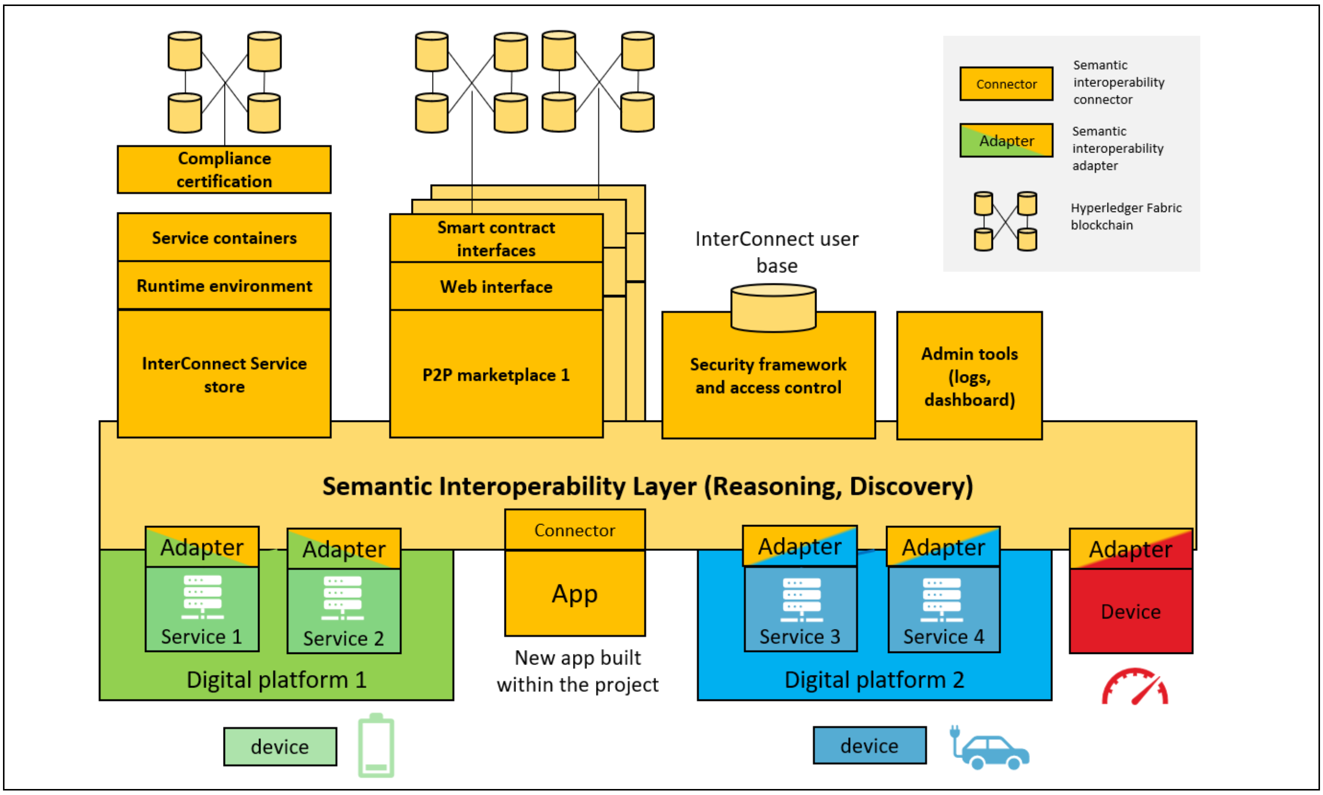


Figure 16: InterConnect Semantic Interoperability Layer [InterConnect, 2020]

Each pilot of the project comprises a set of digital platforms, services, applications, devices and other resources provided by participating partners. The InterConnect Interoperability Framework enables semantic interoperability of all participating digital platforms, providing energy and non-energy services (control, comfort and convenience) and devices, thus ensuring proper instantiation of the SHBIRA (see below) across pilots infrastructures.

The central component of the InterConnect Interoperability Framework is the semantic interoperability layer which interconnects existing digital platforms, and services they offer, among themselves and with the interoperability framework services (service store, P2P marketplaces, compliance certification, data protection and access control and supporting services for production level operation). The semantic interoperability layer comprises configured instances of interoperability adapters and connectors hosted on digital platforms (provided by project partners) and supporting services introduced by the interoperability framework. Therefore, the semantic interoperability layer is completely distributed onto existing endpoints, which eliminates the need for centralised platform facilitating interoperability interface. The semantic reasoning and orchestration processes are also provided by this interoperability layer while the interoperable services are adapted to take full advantage of these semantic web mechanisms.

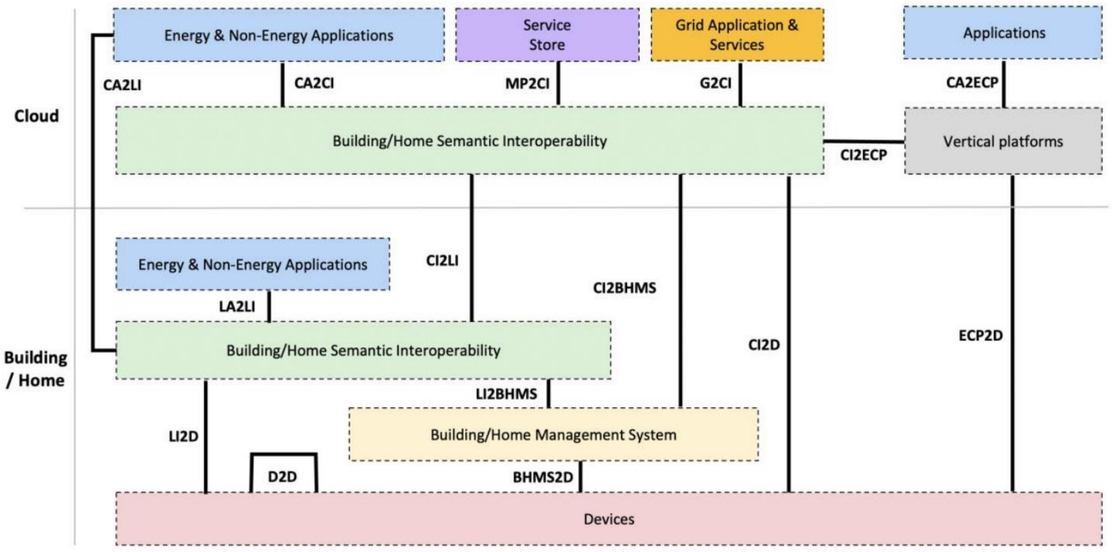


FIGURE 23 – IC'S SMART HOME AND BUILDING IOT REFERENCE ARCHITECTURE (SHBIRA)

Figure 17: InterConnect's smart home and building IOT reference architecture [InterConnect, 2020]

Main business processes enabled by the platform:

- Flexibility collections
- DSO interaction on needs for flexibility (Flexibility request)
- Flexibility activations
- Flexibility prediction
- Etc.

Main data management functionalities:

- Data collection & governance
- Data transfer/sharing
- Authentication of data users
- Consent management
- Personal data handling
- Data logs
- Service provider integration
- Data source integration

Existing relevant standardised approaches for the concept:

- SGAM
- SAREF, CIM, BIM
- EEBUS, SPINE, SHIP
- JSON, XML, JSON-LD, RDF
- KNX, M-Bus, Modbus, Zigbee, MQTT

The architecture will be implemented and demonstrated in 7 pilots. The architecture is initially applied to both energy and **buildings**. It could support other sectors such as other energy vectors (**gas, heat**), **transports**, **health**, …). The Information Layer, in particular information models / ontologies sub-layer, would be mostly concerned.

3.1.10 INTERRFACE *(ENERGY)*

INTERRFACE's data exchange architecture is called IEGSA: Integrated pan-European Grid Services Architecture (Figure 18). The IEGSA architecture defines a modular platform able to incorporate the multi-disciplinary nature of the involved tools and applications of the INTERRFACE project. Hence, INTERRFACE offers the creation of a common architecture which will enable the connection, data and information exchange with existing data hubs across Europe where TSOs, DSOs, market participants and customers are connected. The IEGSA platform is designed to facilitate access to real time data and derive more efficient development ensuring the secure and reliable operation of TSO and DSO networks. Concurrently, balancing and congestion schemes and procedures as well as novel energy trading concepts will be reviewed to enable a real-life application of future market design and services. The blend of all aforementioned assets, datasets, tools/ services and market models is envisioned to optimise operations and allow the introduction of new services to cover the needs of more stakeholders of the energy value chain.

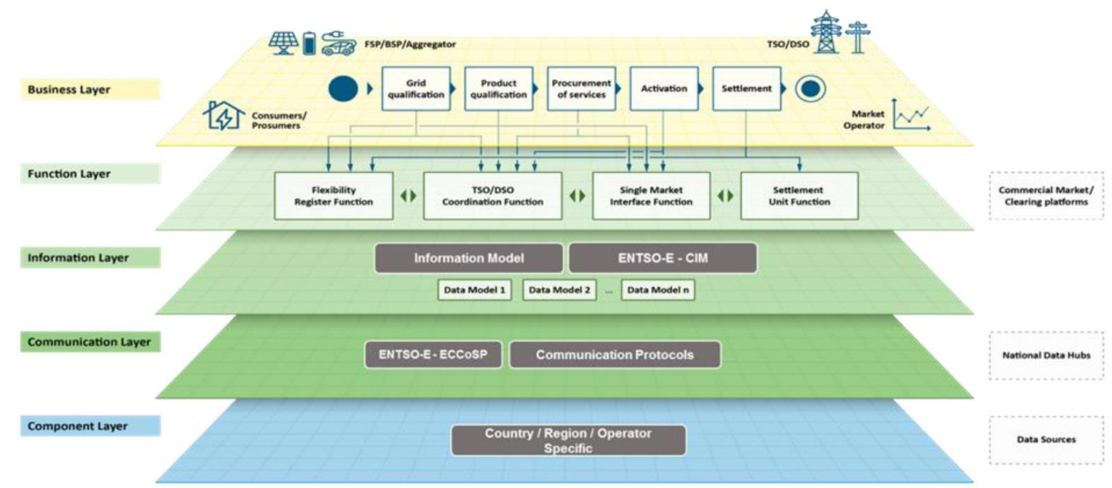


Figure 3 SGAM-based IEGSA architecture

Figure 18: IEGSA data exchange architecture [INTERRFACE, 2021]

The main functional blocks of IEGSA are Flexibility Register, TSO-DSO Coordination platform, Single Interface to Market, Settlement Unit, User Management Module.

Flexibility Register (FR) enables Flexibility Service Providers (FSPs) to bring their flexibility resources to markets. The software development of the Flexibility Register contains structural information on the location of connection points that can provide flexibility services to system operators. It aims to gather and share relevant information on potential sources of flexibility. It acts as a central repository, including technical information on resources that are connected to the joint area of responsibility of different SOs. FR processes that are performed within this module include: user management, resource/resource group registration, interaction with consent manager, product definition, trigger of product, grid and bid qualification. FR module can be accessed by all users of IEGSA such as FSP, Market Operator (MO) and the System Operators (SOs). Each of them has different rights when accessing it. Several UI functionalities reside in FR to ease resource registration (i.e. view and update existing, add new), resource groups definition (i.e. view and update existing, add new), qualification status tab (preview resources and resource groups qualifications status), product definitions and product qualification requests.

TSO-DSO Coordination platform acts as the gateway through which the system operators (TSOs and DSOs) can access the IEGSA platform. It allows data exchange with operators through well-defined and interoperable APIs. Thus, it facilitates coordination between TSOs and DSOs. This module hosts and interacts with the bid and grid qualification services and market-related processes (e.g., merit-order list documents) via the flexibility register. Subsequent UI functionalities are implemented to support SOs to view resources and resource groups. Regarding Resources the SOs may proceed with changes on the qualification status. A dashboard for the merit order lists of all IEGSA integrated markets is also available for SOs, which also may allow the activation of certain bids directly from IEGSA. Activated bids can be previewed on the “Trades” environment of the TSO-DSO Coordination platform.

Single Interface to Market is essentially a backend component that acts as the gateway to connect marketplaces with IEGSA, essentially allowing the exchange of market-related data. This module consists of a set of standardised RestAPIs, which handle the communication of IEGSA with the various markets that it is connected with. This component lies on the back-end, and there is no dedicated User Interface. The APIs that comprise the Single Interface to Market are responsible for the transfer of data that facilitates all the processes in IEGSA that surround the market integration. The scalable and standardised design of the APIs allows the agnostic connection to different market platforms and the seamless data exchange. Thus, IEGSA can exchange bids, Merit Order Lists, and Activation

Orders with all interconnected markets. The connection to different markets gives a more holistic overview of the available offers and bids to the System Operators, allowing the more efficient and secure grid management.

Settlement Unit performs the energy settlement of all trades. It facilitates the gathering of all data that are related to the energy imbalance settlement communicating with all responsible actors (e.g., FSPs, SOs, BRPs).

User Management Module (Privacy Preserving Framework) performs the energy settlement of all trades. The FSP may upload documents related to metered and/or sub-meter readings along with activated volumes for all the metering points affiliated with the particular resource object for all metering points.

Main business processes enabled by the platform:

- Grid qualification Process
- Product qualification Process
- Procurement Process
- Bid qualification Process
- Activation Process
- Settlement Process

Main data management functionalities:

- Data integration
- Data logging
- Data storing
- Data sharing
- Meta-data processing and sharing
- Authentication of data users
- Authorisation for publishing data
- Consent management
- Role based access control / data security

Existing relevant standardised approaches for the concept:

- Role models – HEMRM has been considered in the development of the IEGSA platform and certain recommendations have been proposed for extensions.
- In terms of data formats various data exchanges are based on CIM compliant profiles.
- Internal data exchanges for the communication of core IEGSA components with custom APIs are performed with JSON formats.
- All communications with external systems are based on restful APIs.

The IEGSA platform is designed in modular manner so that it can be applicable to a wide range of application cases, including those of the seven INTERRFACE pilot cases. IEGSA is applied only in the electricity sector. IEGSA architecture could be extended and enhanced so that it can cover and facilitate the cross-sector integration, thus being beneficial for system operators and flexible end-users for the co-operation of electricity sector with **gas, heat or water** sectors. The most important layers of SGAM shall be the business layer which should determine the core common business processes (determining the business flow and cross-sector integration objectives), and the function layer which shall designate the mutual processes for the sectors to be connected focusing particularly on data functional processes. Last but not least, the information layer of IEGSA can serve as the basis to extend the data modelling to adhere the other sector’s information.

3.1.11 MERLON (*ENERGY*)

MERLON architecture (Figure 19) has been proposed in alignment with well-known references (such as SGAM, COSMAG, etc.) and relying on pre-existing partner components and modules. On the data sharing part for the architecture, MERLON central Interoperability and Data Management Platform includes six modules, namely the **Data Collection Configuration Manager, the Data Ingestion Manager, the Data Handler, the Data Storage, the Data Management Orchestrator and the Real-time Data Messaging Pipeline**. MERLON Interoperability and Data

Management framework comprises a message-oriented-middleware infrastructure, to facilitate the information exchange between all components of the MERLON system with heterogeneous interfaces and communication protocols.

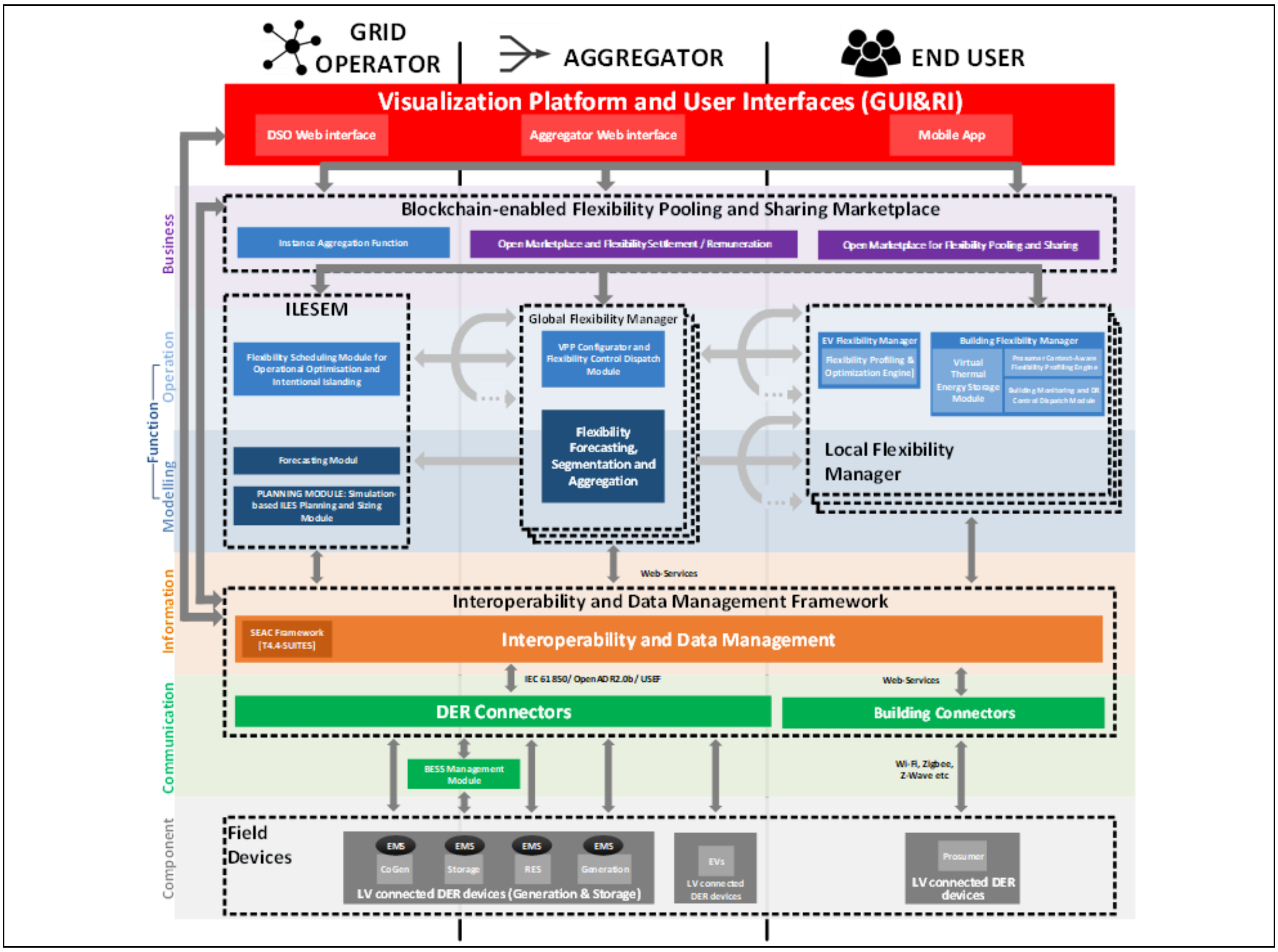


Figure 19: MERLON architecture [MERLON, 2019]

Field devices form the bottom layer of MERLON architecture, as they provide the endpoint source of information or actuation points. It is expected that each pilot will provide specific equipment and communication access methods for this field devices to be integrated. The important thing to stress here is that, regardless the equipment to be monitored or controlled, field devices should be accessible and actionable (in case of need) following the Use Case restrictions.

Interoperability and Data Management Framework. This is the software component to ensure communication and information exchange with all system components defined in the architecture. It acts as the core communication layer of the MERLON architecture and information exchange messenger for all MERLON components, following the main data principles of the MERLON Information Model as defined in the project. In addition, the role of the component is to store the information required for the different applications delivered in the project.

Local Flexibility Manager is the component that continuously monitors the status of DERs and assesses the local flexibility available to the ILES (Integrated Local Energy System). This is performed at specified time steps and for various applicable time horizons. They communicate the demand flexibility at building-level to the Global Flexibility Manager (GFM) for aggregation at the aggregator's side. In terms of the opposite information flow direction and after the reception of a building-level DR (Demand Response) signal from the GFM, the LFM is responsible for its further break down into individual control strategies to be applied to intra-building DER devices. The Local Flexibility Manager (LFM) refers to "demand flexibility" and is classified into two sub-components based on the "demand flexibility resources" included in MERLON ILES. Namely, the local flexibility manager comprises the Building Flexibility Manager (BFM), representing residential/ commercial assets, and the EV Flexibility Manager (EVFM), representing ILES electromobility assets.

Global Flexibility Manager (GFM) is responsible for the definition of the high-level flexibility control strategies to be deployed over selected clusters of demand flexibility sources. The component receives flexibility requests from the ILESEM components, which are issued according to ILES grid requirements and/or ancillary services intended to be offered to the overlay network. Based on an existing pool of LFMs that provide the demand flexibility of prosumers' controllable domestic loads and EVs under the terms of smart-contract agreements, the component performs (1) Flexibility Aggregation, (2) Flexibility Segmentation and clustering, (3) Flexibility Forecasting and (4) Formation of VPPs in order to realise ILES optimisation strategies through DR requests of the ILESEM.

The **ILESEM** (Integrated Local Energy System and Energy Market) is a holistic tool suite for DSOs which involves different functionalities. It is composed of the following sub-components:

- Simulation-based ILES planning and sizing module: this module must understand the behaviour of the local energy system, operate in an optimal way and calculate the amount of flexibility required.
- Forecasting module: this module develops advanced substation load forecasting algorithms to calculate the amount of flexibility needed in each half-hour period.
- High-level flexibility scheduling module: this module uses scheduling algorithm that will be updated with the forecasting for each network node. Also, it receives commercial and technical information of all controllable assets.
- Monitoring and flexibility dispatch to aggregators: through this module, DSOs send through the ILESEM flexibility requests to activate Demand Response signals to the Global Flexibility Manager of each Aggregator.
- Instance Aggregator module: it aggregates ILESEMs to assist the transmission level and for enhancing the security of supply at a local level.

Blockchain flexibility pooling and sharing marketplace is the layer of the architecture that is responsible for the management of the flexibility provided by the different assets to the different business needs through the established marketplace. The component receives flexibility offers from the DER owners, following specific requests from Aggregators. Following a negotiation process, and once a contractual agreement has been established, the amount of flexibility is further available for exploitation from the GFM as presented above. On the other hand, once a flexibility contract is activated, the fair settlement and remuneration should be performed in order to ensure market transparency and fairness among the different business entities.

Visualisation platform. This is the software component to act as the gateway of prosumers, DSOs and Aggregators in the MERLON framework. Informative visualisation and active participation at the different services and models is included here, as defined in the project.

Main business processes enabled by the platform:

- **Local distribution network management**. This business model category aims at realising the economic value of a Local Energy System (LES) in supporting the economic operation and development of the local distribution network, by limiting power flows and thus mitigating thermal and voltage constraints of the network, reducing network losses, and more importantly avoiding or deferring capital-intensive network reinforcements.
- **Provision of security of supply during emergency conditions**. This category aims at enhancing security of supply for the local consumers by minimising the required load shedding and the associated inconvenience costs during emergency conditions.
- **Provision of balancing services to the TSO**. This category aims at realising the economic value of LES by enabling the participation of their distributed flexibility resources in balancing markets organised by the TSO (specifically markets for primary, secondary and tertiary reserves) and subsequently enhancing the competitiveness of these markets and reducing the balancing costs of the system.
- **Participation in energy market**. This business model category aims at reducing the energy costs for the LES consumers and increasing the energy profits for the LES prosumers and includes two, potentially related, instances of business models: i) responding to the time-varying energy tariffs of electricity retailers, and ii) establishing local energy trading among the LES participants.

Main data management functionalities:

- **Data Collection Configuration Manager**. The scope of this module is to handle the appropriate configuration files that specify the model parameters required for acquisition and then storage of data to the MERLON Interoperability & Data Management platform. The role of this configuration process is twofold: (a) to clearly specify the list of parameters (as available from the DER connectors) that will be made available to the MERLON Interoperability & Data Management platform either via the Data Ingestion Module or the Real Time Message Pipeline and (b) to provide the specifications for the data model mapping to the MERLON Information Model, ensuring the smooth and well-structured "data collection" of application data.
- The **Data Ingestion Manager** provides the necessary functionality for the timely and successful retrieval of data from various sources in the MERLON Interoperability & Data Management platform. MERLON data can be generally retrieved from DER connectors and other data sources (e.g. MERLON applications) through data retrieval from APIs that have been exposed by the 3rd parties/external or MERLON applications. Once the data are retrieved, they are temporary stored in a data lake for further processing.
- The **Data Handler** is responsible for performing the necessary data processing and transformation operations to ensure the full alignment of the data that have been ingested (through the Data Ingestion Manager or the Real-time Data Messaging Pipeline) to the MERLON common information model.
- The **Data Storage** is responsible for data persistence and archiving of the volumes of data generated in the MERLON project. Once the data handling process is over, the transformed data are stored in a non-relational (NoSQL) database in the Data Storage component. The NoSQL approach has been preferred over a relational database, as it is scalable by default and thus allows optimised management of heterogeneous datasets. In addition to the permanent data storage, a data indexing engine is put into use in order to facilitate search and data retrieval.
- The **Real-time Data Messaging Pipeline** is responsible for real time message/data exchange among the different applications of the MERLON project. One of the main requirements of the project is to ensure real time connectivity of the applications to the available data sources.
- The **Data Management Orchestrator** is responsible for the orchestration and execution of the services, associated with data ingestion, handler, storage. In addition, the orchestrator effectively interfaces with all system modules and supports all the message exchanges associated with the different tasks to be performed. In parallel, the orchestrator is responsible to ensure that the data processes are allocated with enough resources for their execution. Last but not least, the Orchestrator is tracking the operational status of each module; acting that way as a logging system for the different states of the MERLON Interoperability & Data Management Platform.

Existing relevant standardised approaches for the concept:

- IEC CIM is the backbone for the modelling work about DSO operations with the recently established IEC 61968-5 to define the details of the DERMS (Distributed Energy Resources Management System) operation.
- At the Aggregator side, OpenADR (recently defined as an IEC standard 62746-10-1:2018 "Systems interface between customer energy management system and the power management system - Part 10-1: Open automated demand response") is the dominant standard though additional efforts are available at regional level.
- From a business point of view, USEF (Universal Smart Energy Framework) standard has been defined to set the market rules for the participation of the Aggregator in different market schemas.
- Finally, standards associated with the participation of the different MERLON stakeholders in the energy markets are considered in MERLON, including IEC 61968-8 and EN 50491 (prosumers), ZigBee, Bluetooth Low Energy, Z-Wave, EnOcean, INSTEON, SAREF, IEC CIM, SmartM2M, EFI, SPINE and IEC 62056 (Buildings), OSCP (Open Smart Charging Protocol), OCPP (Open Charge Point Protocol), IEC 61850-90-8, Open ADR 2.0/ IEC 62746-10 and ISO/IEC 15118 (Electric Vehicles).

MERLON architecture is currently being developed and implemented in two different demo sites (Austria and Spain). Apart from the interactions MERLON has with other sectors (**buildings** and **electric vehicles**), the architecture is not intended to be replicated elsewhere.

3.1.12 OneNet (*ENERGY*)

OneNet system is based on a novel concept of decentralised data exchange scheme. Figure 20 depicts high level vision of the OneNet reference architecture.

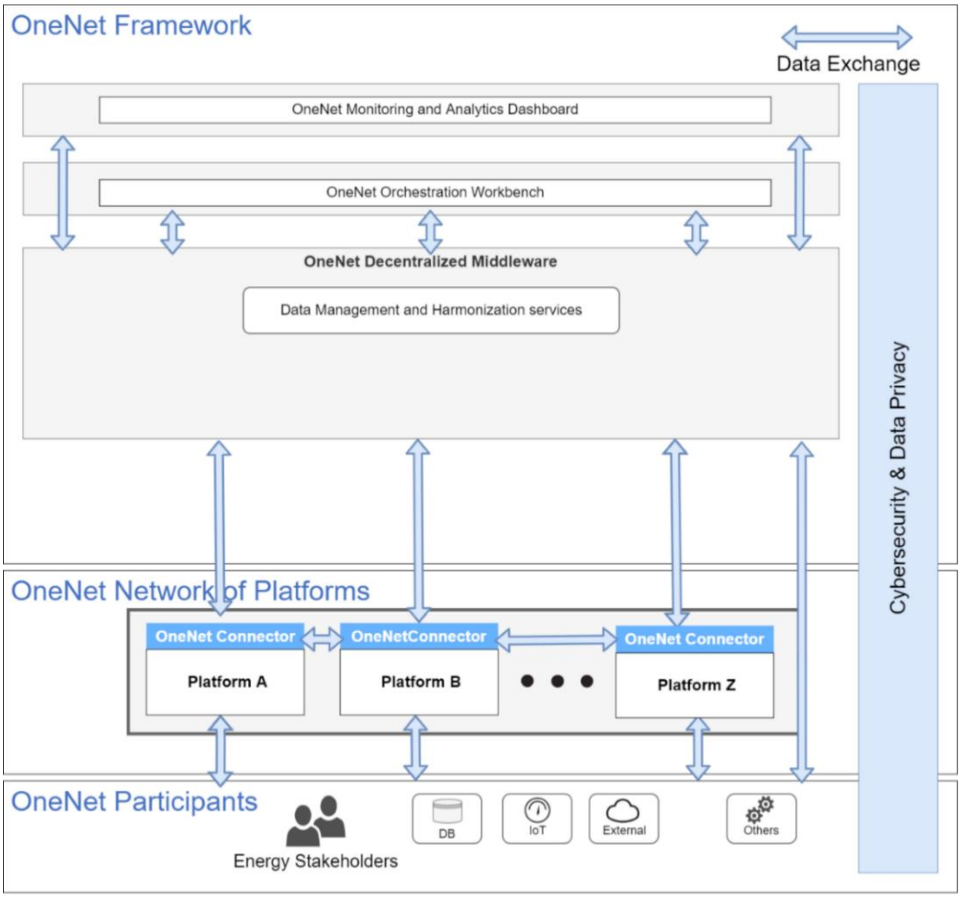


Figure 20: OneNet High Level Architecture [OneNet, 2021]

OneNet Decentralised Middleware main components are *Broker Service Provider, Clearing House, Identity Provider, Vocabulary Provider, FIWARE Broker.* Those components and the subsequent objectives of OneNet are to enable the cross-platform data exchange, ensure a standardised connection of different platforms, allow the discovery of data sources and services, define common vocabularies for improving interoperability, manage data exchange in a secure and trusted way, create a data-driven business ecosystem, allow for data providers to define data prices and usage rules, attract data consumers by facilitating the search mechanisms of data sets and ensuring a detailed and clear description of data structures, share cross-border information related to weather forecast in case of extreme events, manage alarm system in case of data or security breach in power grids.

AI, BigData, IoT Data Orchestration for cross-platform services enable AI, BigData and IoT data orchestration for cross-platform services as well as tracking the performance of the cross-platform services.

Integration of devices and other data sources to OneNet using FIWARE is enabled by using standardised FIWARE components. FIWARE context Broker is adapted and evolved for providing a data-model agnostic connector based on NSGI-LD.

The OneNet middleware does enable the communication and data exchange among multiple actors creating a European-wide data exchange ecosystem that enables a range of cross-platform and cross-country services in the energy value chain. The OneNet middleware will essentially support the connection of multiple data exchange platforms and actors for multiple cross-platform data-driven services. Therefore, the business processes in this regard may refer to data ownership, data provision and data consumption as well as the data brokerage designation.

Main data management functionalities (addressing mainly the requirements of data exchange between platforms:

- Data Modelling
- Data Process Flow mapping capability
- Data Quality
- Security & Trust
- Data Cleaning & Wrangling
- Integration Support
- Service Flexibility
- Tracking & Auditing

Existing relevant standardised approaches for the concept:

- Role models will be harmonised based on HEMRM. The main actors of OneNet will be data provider, data consumer and data owner.
- The majority of data exchanges are currently envisioned to take place following the CIM/IEC guidelines. Therefore, all OneNet participants will have to work along the development of the vocabulary provider.
- In terms of communication protocols data exchanges are foreseen to perform with restful APIs.

There will be several demonstration cases within the project. Within the project it is not foreseen to include cross-sector integration. However, since the overall orchestration of OneNet middleware will be based on FIWARE and IDSA frameworks, it would be feasible to accommodate **cross-sector** data exchanges as well. It might be beneficial for system operators and end-users to consider other energy sectors integration such as **heat and gas**.

3.1.13 OPEN DEI (*CROSS-SECTOR*)

OPEN DEI Reference Architecture Framework (RAF) (Figure 21) combines knowledge and tools to foster effective sharing and assessment of experiences and lessons learned on how systems supporting Digital Transformation (DT) can be architected, crossing the boundaries of specific applicative sectors. It is not intended to be implemented in a concrete Digital Platform, but aims to provide a common blueprint to compare existing approaches and solutions.

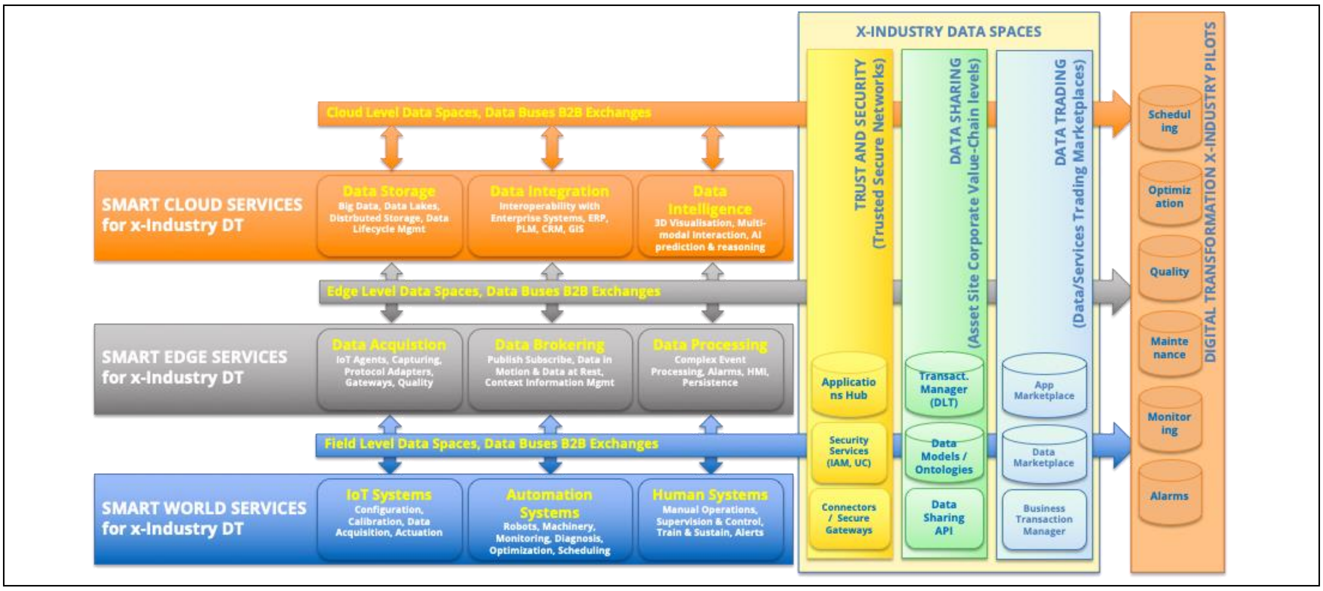


Figure 21: OPEN DEI reference architecture for cross-domain digital transformation [A. Marguglio, 2020]

Field Level Data Spaces includes the Smart World Services able to collect data and support the interaction with the IoT Systems (configuration, calibration, data acquisition, actuation, etc.), Automation and Smart Assets (robots, machinery, and related operations) and Human Systems (manual operations, supervision, and control, etc.).

Edge Level Data Spaces defines the typical edge operations from the data acquisition (from the logical perspective) to the data processing through the data brokering. The edge services will play a key role also for data analytics (i.e., validating and improving models for data analysis).

Cloud Level Data Spaces includes data storage, data integration and data intelligence operations on the cloud. The cloud services will process big data, deploy algorithms, integrate different source platforms and services, provide advanced services such as AI prediction and reasoning.

X-Industry Data Spaces support data exchanges in a trusted and secure environment following the Data Sovereignty principles, strongly connected to the IDS security mechanisms. **X-Industry Data Buses** implement an Asset Site Corporate Value-Chain level for enabling the data transfer in the corporate value chain as Data Bus for the OPEN DEI RAF. **Digital Transformation X-Industry Pilots** enable applications (sometimes sector specific) for supporting business scenarios from experiments.

The goal is to harmonise and coordinate different DT approaches under a common RAF. The RAF does not support directly business-specific processes, but tries to keep a more abstract level.

The three-layer services structure is able to describe data management functionalities implementing a bottom-up approach from the real world assets to the cloud in order to establish digital transformation pathways to exploit the value of data-driven services and cross-sector data-sharing capabilities.

The RAF doesn't describe specific data formats or protocols since given its framework nature the objective is to provide high level "guidelines" for the Digital Platforms and Reference Architectures in the OPEN DEI domains.

OPEN DEI RAF can be mapped to the most common Digital Platforms by adopting easy tools intended to highlight the important functional building blocks common to data-driven Digital Platforms across industries. This is not a concrete implementation, but more a concretisation process in order to be able to compare multiple approaches to building digital platforms. OPEN DEI RAF focuses on the experiences and relevant standards available four basic industrial domains: **manufacturing, agriculture, energy, healthcare**.

3.1.14 PHArA-ON *(HEALTH)*

PHArA-ON project uses existing technologies and platforms and connects theses according to the needs of the 6 pilots in health sector. The reference architecture (Figure 22) is largely based on existing standards and work, e.g. IEEE 2413-2019 – IEEE Standard for an Architectural Framework for the Internet of Things (IoT) [BOG/CAG - Corporate Advisory Group, 2019], CREATE-IoT 3D RAM.

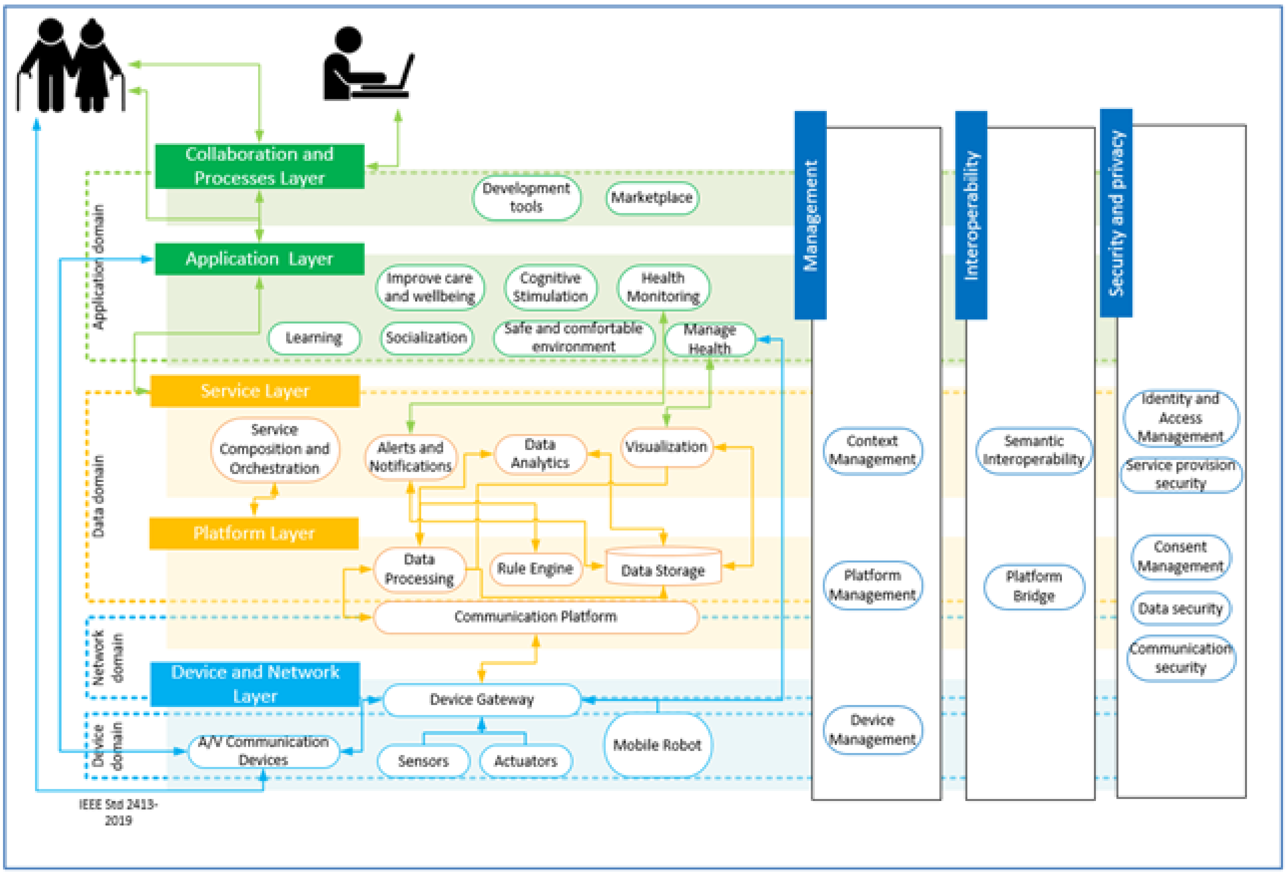


Figure 22: PHArA-ON reference architecture [PHArA-ON, 2021]

Main business processes enabled by the platform:

- Improve telecare systems
- Reduce social isolation and loneliness
- Supporting wellbeing
- Promote social cohesion
- Improve quality of life for older adults living at home

Main data management functionalities:

- Data acquisition
- Data processing (aggregation, fusion, transformation, annotation)
- Data storage
- Data analysis
- Data usage
- Data destruction

Existing relevant standardised approaches for the concept:

- Protocols like MQTT, HTTPS
- Data formats like JSON

Pilots to implement the architecture are in progress in 4 countries and first deployments are coming to life. This architecture is not so specific for healthcare and can easily be used in smart home, smart buildings, and can easily be extended according to new needs.

3.1.15 Platone *(ENERGY)*

The Platone solution consists of a two-layer architecture named Platone Open Framework (Figure 23). The Platone project develops a new architecture for testing and implementing a data acquisitions system based on a two-layer approach that will allow greater stakeholder involvement and will enable an efficient and smart network management.

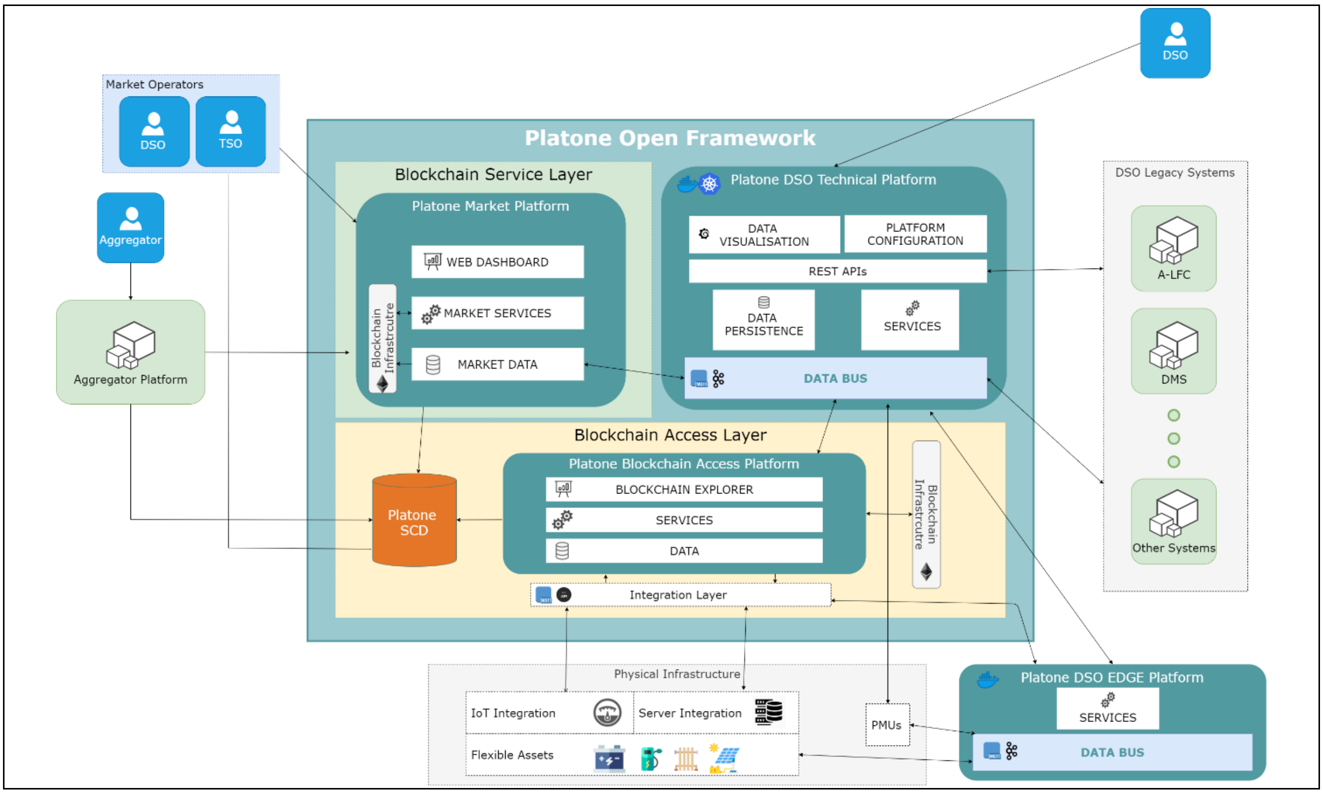


Figure 23: Platone Open Framework [Platone, 2020]

Blockchain Service Layer enables the deployment of different blockchain-based components, providing a blockchain infrastructure and Smart Contracts services. In the context of Platone, the Platone Market platform is an example of blockchain-based platform deployed on it. **Platone Market Platform** allows the support of wide geographical area flexibility requests from TSOs and local flexibility requests from DSOs. These are matched with offers coming from aggregators, resolving conflicts according to pre-defined rules of dispatching priorities. All the market operations are registered and certified within the blockchain service layer, ensuring a transparency, security and trustworthiness among all the market participants.

Blockchain Access Layer adds a further level of security and trustworthiness to the framework. It is an extension of the physical infrastructure and performs multiple tasks, among which are data certification and automated flexibility execution through Smart Contracts. It includes the Blockchain Access Platform and the Shared Customer Database. **Platone Blockchain Access platform** implements all the functionalities offered by the blockchain technology through smart contracts and provides an interface for the integration of the data coming from the physical infrastructure. **Platone Shared Customer Database** contains all the measurements, set points and other needed data collected from customer physical infrastructure. It allows the other components of the Platone Open Framework to access data in an easy way and without compromising security and privacy.

Platone DSO Technical Platform: it allows DSOs to manage the distribution grid in a secure, efficient and stable manner. It is based on an open-source extensible microservices platform and allows to deploy, as Docker containers, specific services for the DSOs and execute them on Kubernetes. The Data Bus layer, included on the DSO Technical Platform, allows integration both of other components of the Platone framework and of external components (e.g. DSO Management System) with a direct connection to the classical supervisory control and data acquisition (SCADA) system adopted by the DSO and served by standard communication protocols.

Main business processes enabled by the platform:

- Flexibility Management
- Congestion Management
- Voltage Management

- Grid Control
- Grid State Estimation
- Local Flexibility Management
- Flexibility Marketplace

Main data management functionalities:

- Data Collection
- Data Certification (via blockchain)
- Consent Management (via blockchain)
- Data sharing

Existing relevant standardised approaches for the concept:

- Role Models – HEMRM
- Information models – CIM, IEC 61859
- Data Formats – XML, JSON
- Protocols – HTTP/S, MQTT/S

The Platone Open Framework was integrated into three different demo architectures: Italian Demo, German Demo and Greek Demo. Each demo plans to demonstrate the benefits of the Platone Open Framework within different scenarios. The Demos Use cases and scenarios are public available here: https://smart-grid-use-cases.github.io/docs/. No other sectors are foreseen so far. The Blockchain Access Layer component could be extended to be applied to **other sectors** due to its flexible and generic approach on the data management.

3.1.16 QU4LITY (*MANUFACTURING*)

QU4LITY is developing a range of digital enablers that will enable the implementation of Zero Defect Manufacturing (ZDM) systems that comply with the QU4LITY Reference Architecture (Q-RA). Specifically, these digital enablers will empower the functionalities of the QU4LITY systems at different levels of the three-tier architecture pattern, including several cross-cutting functions that are applicable to all functional domains of the Q-RA (Figure 24). The objective of QU4LITY is to demonstrate, in a realistic, measurable, and replicable way an open, certifiable and highly standardised, SME-friendly and transformative shared data-driven ZDM product and service model for Factory 4.0.

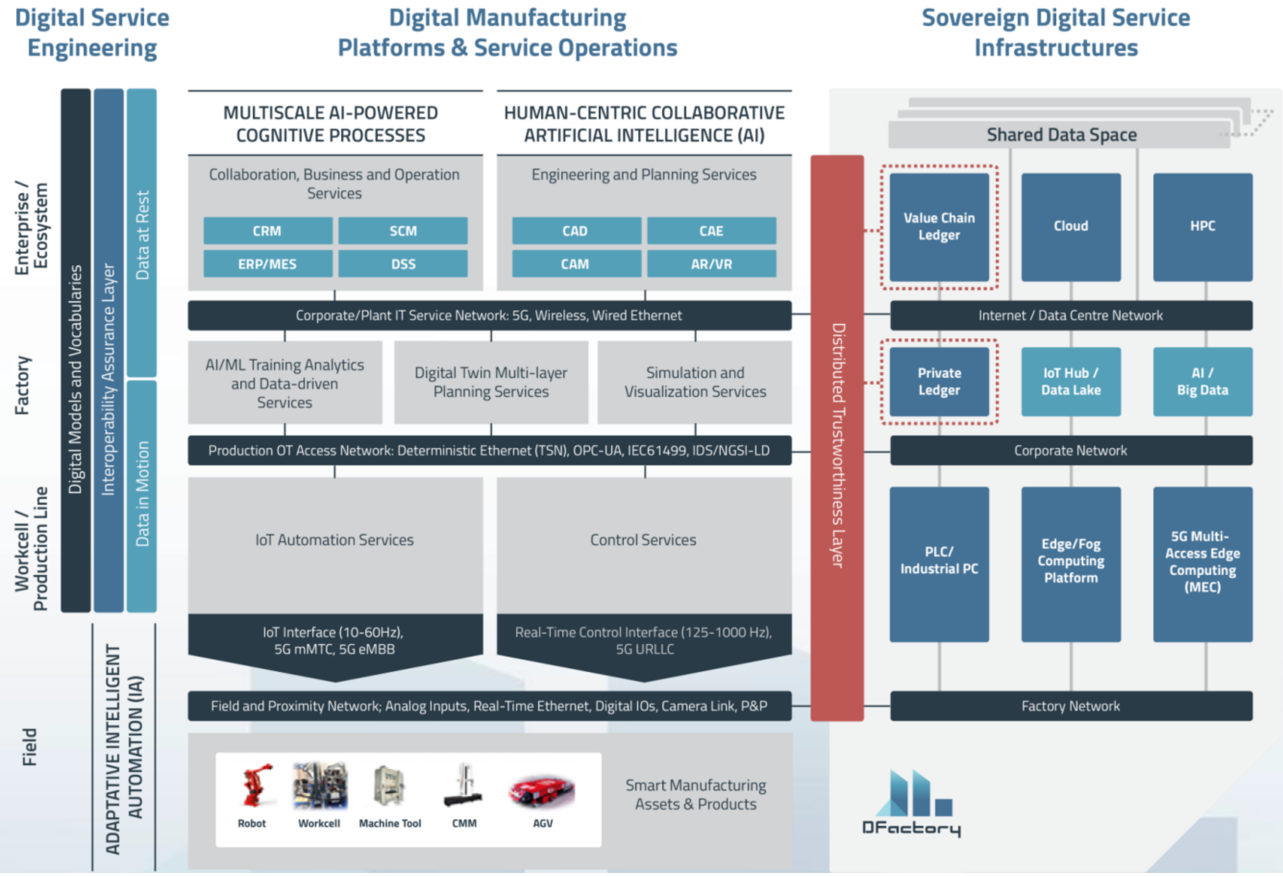


Figure 24: QU4LITY reference architecture: Digital Reality in Zero Defect Manufacturing [Lazaro, 2021]

The Q-RA can be described by 4 main Viewpoints which highlight different aspects and roles of the architecture.

Functional Viewpoint: a technology-agnostic view of the functions necessary to form a QU4LITY-based system. This view describes the distribution of and dependencies among functions for support of ZDM processes and activities. It's represented using Orange boxes in the Q-RA.

Information Viewpoint: this view monitors, controls and analyses connected entities and sub-systems, remaining within a "domain" or being exchanged between "domains". Both raw and processed information is used by the different ZDM services and applications to fulfil intended task for a given activity in the system. It's represented using Green boxes in the Q-RA.

Networking Viewpoint: this view describes the principal communications networks which are involved and the entities with which they connect. It's represented using Blue boxes in the Q-RA.

System Deployment Viewpoint: this view describes how the system components can interact or be networked together, for example, key physical components and runtime environments (Cloud, HPC – High Performance Computing, Edge devices, etc.) and the topology of the interconnectivity of the components. It's represented using Light Blue boxes in the Q-RA.

Main business processes enabled by the platform:

- significantly increase operational efficiency
- scrap reduction
- prescriptive quality management
- energy efficiency
- defect propagation avoidance
- improved smart product customer experience
- foster new digital business models

Main data management functionalities:

- “AI/ML Training Analytics and Data-driven Services” manages complex analytics pipeline and other data-driven processes on heterogeneous data sources, providing access, modelling and processing capabilities.
- “Shared Data Space” building block of Q-RA enables the secure and trustworthy sharing of data across industrial systems within the factory and across factories, creating easy link to connect to trusted data-driven ecosystem exploring the benefits of ZDM technologies of even cross-domain.

Based on the requirements of each pilot determined using an interoperability matrix, built with the help of the Degrees of Interoperability, in QU4LITY projects, standards, protocols and related frameworks have been considered, analysed and finally selected to implement the components as specified in Q-RA.

QU4LITY is being implemented in 14 different lighthouse pilots across 7 different sectors: 9 production factories’ pilots on processes, 5 plug & control manufacturing equipment pilots. Q-RA inherits most relevant outcomes of other Research and Innovation activities focussing on 7 different manufacturing sectors: White goods & Appliances, Plastic injection, Metal machining, Ceramic pressing, Aerospace, Automotive & Electronics, Additive manufacturing.

3.1.17 RENAISSANCE *(ENERGY)*

RENAISSANCE architecture has been proposed in alignment with well-known references (such as SGAM, COSMAG – Comprehensive Architecture for Smart Grid, etc.) and relying on pre-existing partner components and modules. On the data sharing part for the architecture, RENAISSANCE leverages on Atos FUSE innovation platform, which is an ICT Platform that is intended to provide advanced services to a wide variety of stakeholders through a range of end-user applications, including web & mobile browsers, native mobile apps, and IoT & field devices. It is a hybrid multi-cloud solution achieving high availability and low latency at the edge while improving the scalability of the overall solution. The solution exposes several APIs and message brokers to integrate with other applications and services, where requests and messages are handled by executing different business logic, retrieving information from an amount of datastores.

The **Physical layer** aims to fulfil two goals. Firstly, the included devices will provide the platform with real-time data (e.g. consumption, generation, emissions, power coefficient, thermal/electricity storage), extracted from smart or other edge devices. It is responsible to control the distribution of loads, thus controlling the micro grid. Finally, their configuration will be partially dynamic and partially static, controlled by the manager/end-user of the facility. For instance, dynamic configuration revolves around user’s comfort settings, such as desired luminance, temperature levels etc. Static configuration revolves around system constraints, e.g., mapping assets to physical ports.

The **Data layer**’s objective is to serve, on the one hand, as an interface for external systems providing adaptors for edge devices and, on the other hand, to provide a unified interface for advanced energy services, abstracting them from data management functionalities, such as harmonisation, context broking or mid-to-long term storage.

The **Data Modelling and Forecasting Layer** will use raw data collected by the information platform, in order to provide guidelines for the decision-making process. It consists of two (2) submodules, the Flexibility and Energy Forecasting module and the Energy Market Price Forecasting module

The **Decision support system** will be responsible for taking quick and efficient decisions regarding the facilitation of the energy portfolio, by analysing data received from the flexibility and forecasting layer, as well as the ROP’s database. It consists of three (3) submodules, the Grid Stability Simulation Engine, the Self-Portfolio Energy Balancing and the Asset Handling.

RENAISSANCE **Social Engine** will serve the interaction between the involved stakeholders of the grid. Its purpose is to generate a digital environment that will offer communication tools, as well as rewards and personalised suggestions for a more beneficial usage of the micro-grid. In order to do so, three (3) submodules are developed, Collaborative Platform, Award-Enabled Service and Personal Assistant.

The **Trading Supervision System** enables effective communication between the RENAISSANCE Information Platform and the smart contracts deployed in RENAISSANCE’s blockchain network, ensuring their correct execution. This is achieved by dynamically establishing the limits of these smart contracts depicting agreements between prosumers in order to guarantee stable operation of the grid.

Main business processes enabled by the platform:

- **Grid Stability**. It will monitor the entire portfolio in terms of stability potential for issues at the physical level (power, voltage, etc.) and will run various simulation scenarios feeding the platforms decision support system with potential risks, including assets that are in the portfolio.
- **Self-Portfolio Energy Balancing**. It controls and retains the stability within the available portfolio, by providing the DSS (Decision Support System) with the appropriate signals, in order to inform grid stakeholders to proceed with the appropriate actions.
- **Asset Handling** focuses on the analysis and distribution of control signals, in order to maintain stability, both in terms of cost as well as in energy.

Main data management functionalities:

- **Device adaption**. The main purpose of this module is to establish connections between the energy assets and the RENAISSANCE Information Platform. Depending on the technology used, several adaptors are provided to ensure smooth communication with RENAISSANCE devices generating data or being controlled in the physical layer.
- **Common Information Model.** This module is in charge of the data harmonisation of all information received from devices on the field. This harmonisation is done based on standard and well-known ontologies on the ICT and energy domains, resulting in a common structure for data being fed to the ROP that can be easily mapped to these base ontologies.
- The **Context Broker** manages the context information (using standards such as NGSI) regardless of the data source type. In this module, all data being streamed from devices is processed, and the current state of the entities representing those devices in the platform is updated accordingly.
- The **ETL module** stores batch data within the RENAISSANCE Data Platform. As its name implies, this module extracts, transforms and loads (ETL) the data originating from buffered or historical data sources. Accordingly, these data will also benefit from being served through a unified API.
- The **Data Platform** is a scalable, highly available and distributed data warehouse that is equipped with search, filtering and aggregation engines that allow to access data in a fast and convenient manner. Likewise, this module provides tools for visualising and performing basic analytics on the persisted data.
- The **Unified API** is an abstraction layer built to harmonise the way advanced energy services request data and send commands to underlying energy devices. This API module will ensure interoperability with all RENAISSANCE functional services by means of matching their needed interfaces.

Existing relevant standardised approaches for the concept:

- The architecture for RENAISSANCE, and its foundation as FUSE platform is open source, and based on well-known standards and approached.
- Uses FIWARE generic enablers as baseline for data storing, processing and persistence.
- Provides a number of APIs to connect to data streams in different protocols, including OPC, Modbus, FTP, etc.
- Adapted and complemented with SGAM to make the link between ICT and Energy domains.
- As per the Common Information Model, RENAISSANCE platform considered CIM, SAREF and NGSI as primary inputs.

RENAISSANCE architecture is currently being developed and implemented in four different demo sites (Belgium, Greece, the Netherlands and Spain). Apart from the interactions RENAISSANCE has with other sectors (**buildings** and **electric vehicles**), the architecture is not intended to be replicated elsewhere.

3.1.18 TRINITY (*ENERGY*)

TRINITY provides a set of applicative solutions for enhancing cooperation and coordination among the Transmission System Operators of South-Eastern Europe (SEE) in order to support the integration of the electricity markets in the region, whilst promoting higher penetration of clean energies. In order to ensure a common approach to the analysis of all use cases of TRINITY by all involved partners, the IEC 62559-2 methodology was employed for the description of the use cases and modelled in SGAM. All the application provided in the TRINITY demonstration phase were independent applicative solutions prior to the start of the project and that have been selected for the project to be interconnected and enhanced during all the project duration. See Figure 25 for high-level intercommunication diagram explaining the main information exchanged between them.

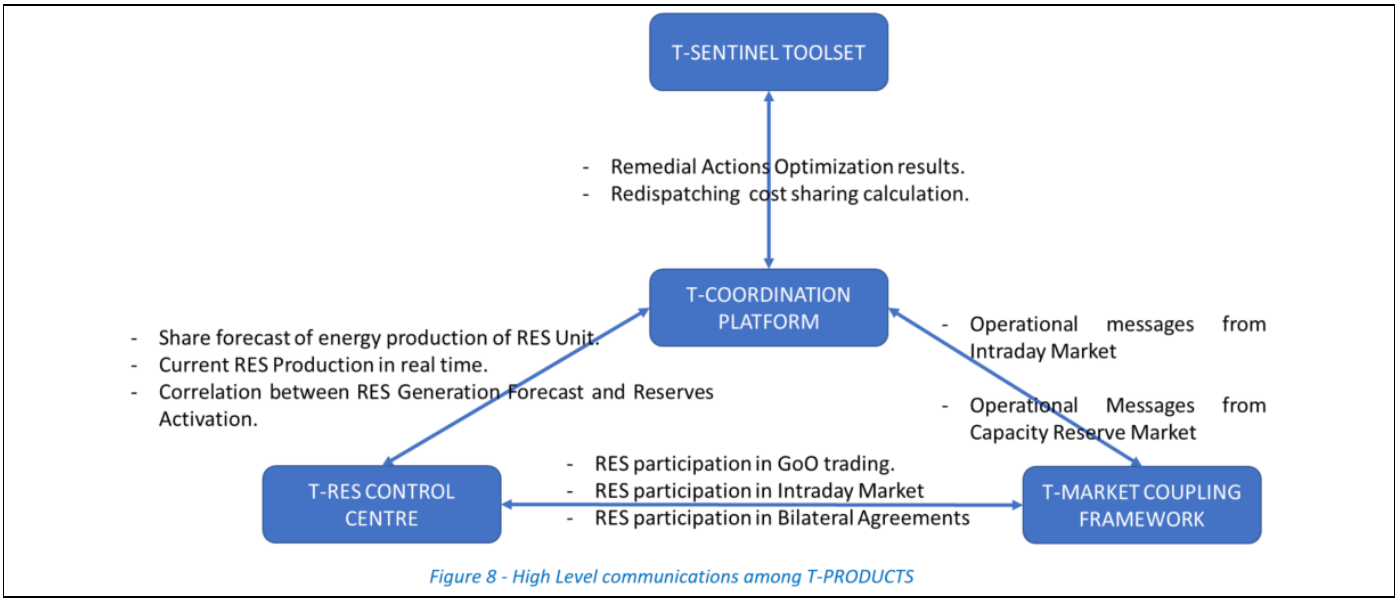


Figure 25: TRINITY architecture [TRINITY, 2021]

TRINITY will develop and demonstrate in real conditions in the South-East Europe area the following four Products:

- **T-MARKET COUPLING FRAMEWORK** will propose coordinated intra-day and capacity markets between countries in the region, considering EU and non-EU countries;
- **T-SENTINEL TOOLSET** will enable remedial action optimisation at regional level and develop novel algorithms for improvement of Reliability Margins calculation;
- **T-RES CONTROL CENTRE** will help the optimisation of usage for RES producers with an interactive map providing information for analysis of the RES potential in partnership with the TSOs of the SEE region;
- **T-COORDINATION PLATFORM** will provide a common application for communication and coordination between partners in the SEE area: coordinate and validate proposed actions among TSO, RSC (Regional Security Coordinator) and RES producers (for example proposal of remedial actions issued from the CSA – Coordinated Security Analysis); exchange relevant information (for example availability of the results of computation by business tools) and edit relevant report & KPIs. The integration of other existing RSC and TSO tools are also implemented to enhance security and coordination between the involved end-users.

Main business processes enabled by the platform:

- Market operation – intra-day electricity trade, regional capacity reserve trade, bilateral trade, and Guarantees of Origin (GoO) auction trading
- System Operation – power system operational security forecasting and monitoring, capacity calculation, redispatching cost-sharing, adequacy assessment and emergency and restoration processes
- Enhanced RES integration – real-time supervision and control of large RES production units, interactive map analysis for RES results and future investments
- Enhanced coordination and cooperation – between the TSO, RSC, RES Producers and promoters, NEMO (Nominated Electricity Market Operator) in a scenario of high penetration of renewables and high market integration

Main data management functionalities:

- Data aggregation
- Data computation for providing higher level information

- Limited data access (not opened but limited to the user rights and authorisations)

Existing relevant standardised approaches for the concept:

- Role model – standard actors from European Network Code and Harmonised Role Model and adds some actors relevant for our actions.
- Information model – ENTSO-E Transparency platform data model, ENTSO-E EDI (Electronic Data Interchange) data model, IEC 60870-5-104, ICCP (Inter Control Center Protocol) data model, IEC 61968-100, smart metering DLMS (Device Language Message Specification) data model, UCTE (Union for the Coordination of the Transmission of Electricity) data model
- Notification Data Model used by the T-COORDINATION platform is provided by the OpenSource Let's Coordinate project from the LF Energy and could be considered as public data exchange model
- Data formats – XML, XLSX, JSON
- Data format standards – ISO 8601:2014 (Data elements and interchange formats – Information interchange – Representation of dates and times), RFC4122 (A Universally Unique IDentifier (UUID) URN Namespace)
- Communication protocols – HTTPS, sFTP, XMPP (RabbitMQ), REST API, SCADA Protocols

TRINITY as demonstration project will put in real life the different developed applications described in the TRINITY architecture. The project is completely focused on the Electricity Market in the SEE area and in line with the objectives of the Clean Energy Package. However, some of the technologies developed are agnostics from the electricity specificities, like the T-COORDINATION Platform that is developed using Operator Fabric and Let's Coordinate Open Source Projects of LF Energy (Linux Foundation for Energy). The principle of having a common tool for exchanging important information and coordinating activities between different partners could be **reused in other sectors** or activities. It could be either used in TSO-DSO cooperation or even in SMART GRID integration to allow fast and tracked decisions. It would be a useful tool for cross-sector sharing.

3.1.19 TwinERGY (*CROSS-SECTOR*)

TwinERGY is in the process of developing a new data exchange architecture for their Data Management Platform, stepping on relevant developments from previous H2020 big data projects (in the energy domain) and in full compliance with SGAM and relevant specifications provided by BRIDGE, BDVA-DAIRO and GAIA-X.

Initial provisions on the data (exchange) architecture, involve **Data Collection service**, to manage the ingestion of data into the platform, the mapping to the CIM and the curator/cleaning rules; **Data Governance**, to manage the overall job processes and the management of the CIM; **Security and storage**, responsible for storing securely data and metadata, indexing the data, backup and restore features and storing the CIM; **Open APIs** for data retrieval. The list of components will be refined once the final version of the architecture is released.

Main business processes enabled by the platform:

- Data governance
- Data security and privacy
- Data interoperability

Main data management functionalities:

- Data Ingestion
- Mapping to Common Information Model
- Data cleaning and quality assurance
- Data storage
- Metadata definition
- Query building and search over big datasets
- Data retrieval and dynamic API creation based on query parameters

Existing relevant standardised approaches for the concept:

- Information models – CIM, IEC 61850, OpenADR2.0b, USEF, SAREF (SAREF4ENER, SAREF4BLDG)
- Data formats – CSV, JSON, XML, Parquet, PNG/JPEG

- Protocols – HTTP/HTTPS, REST, TCP, AMQP

The TwinERGY Data Management Platform will be demonstrated in four demo sites as part of the relevant activities of the project. The architecture is generic enough and **easily adaptable in other domains**. As part of TwinERGY the architecture will be applied in the **building** sector, while there are relevant plans applying it in the future (by enriching the ingestion methods and applying the relevant sector-specific data models) in the **manufacturing** and **aviation/transport** sectors.

3.1.20 X-FLEX (*ENERGY*)

X-FLEX applies existing architecture for data exchange platform (Figure 26). The architecture of the X-FLEX Platform was built upon the work of previous H2020 projects such as Wisegrid and Compile.

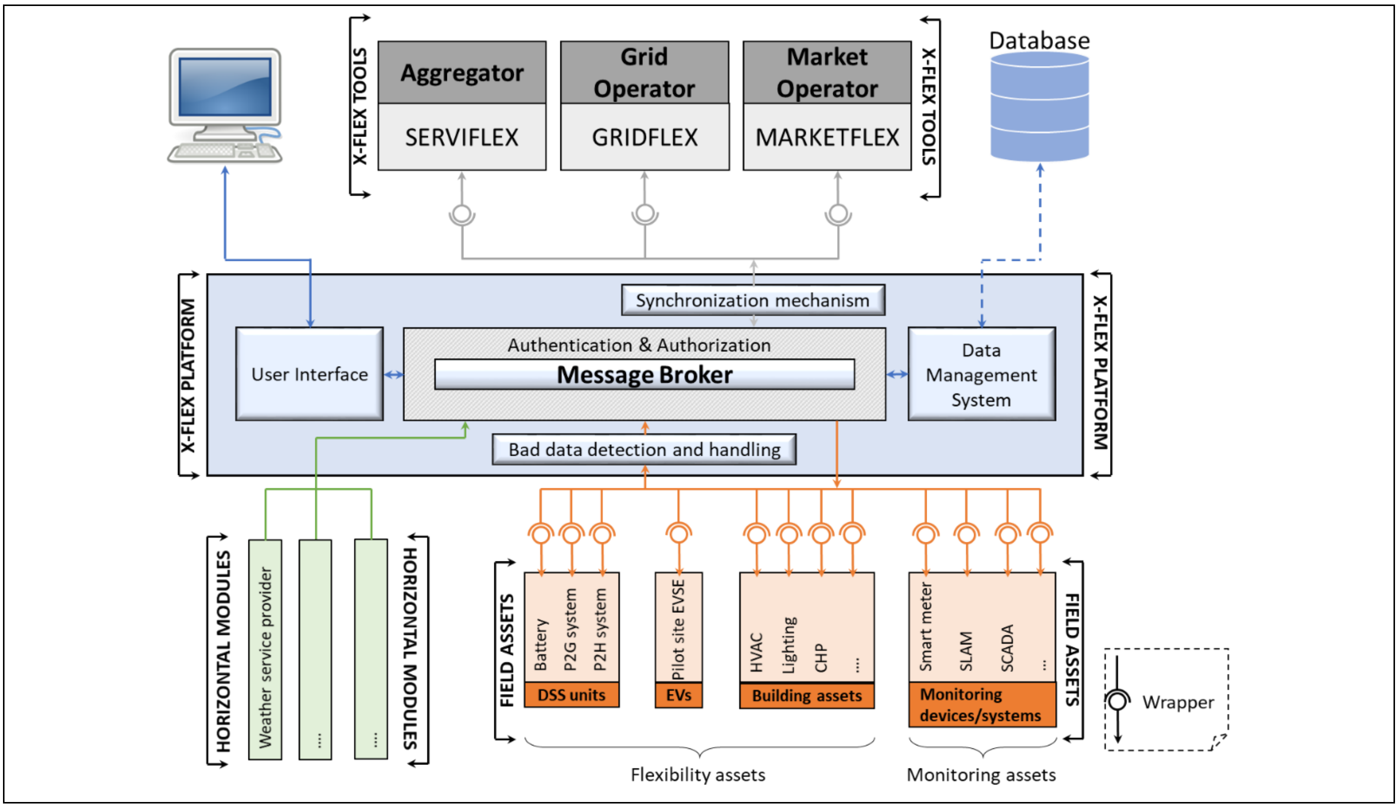


Figure 26: X-FLEX architecture [X-FLEX, 2022]

Message Broker: At the core of the platform a **message broker** will be adopted for the managing of messages flows.

Authentication and Authorisation control: Different software modules will exchange data through the X-FLEX platform and appropriate mechanisms should be put in place to control the access over the information exchanged. Authentication and authorisation component will serve as the security infrastructure of the platform.

Bad data detection and handling: According to the requirements, bad data (wrong metering data) coming for metering equipment should be detected as soon as possible and handled appropriately.

Synchronisation mechanism: According to the requirements, a synchronisation mechanism of all the tools is required to keep always all of them updated with the latest information.

Data Base/ Data Management System: The data base will serve as the central data repository of X-FLEX project in which a heterogeneous set of data coming from the energy network will be stored, managed and processed. This data base will also act as DER registry containing information about the technical and operational limitations of the different assets as well as information about its nominal parameters.

Wrapper: Translates from internal data model to the agreed data model.

Horizontal modules: General purpose components that will be reused among different X-FLEX applications (Weather service provider, etc.).

Field assets: X-FLEX flexibility assets (DEG units, DSS units, EVs, etc.) and monitoring assets (smart meters, SLAMs, SCADA, etc.).

Main business processes enabled by the platform:

- Provision of services for all energy actors
- Ensuring more secure, stable and clean energy supply
- Facilitation of cross-network and cross-entity interoperability

Main data management functionalities:

- Interoperability framework that enables the integration and deployment of various systems and services coming from the energy sector
- Modular architecture that allows future integration of new services and data models

Existing relevant standardised approaches for the concept:

- Communication protocols: MQTT (Message Queuing Telemetry Transport), AMQP (Advanced Message Queuing Protocol), HTTP (Hypertext Transfer Protocol)
- Data formats: CIM (Common Information Model), USEF (Universal Smart Energy Framework), UFTP (USEF Flex Trading Protocol)

X-FLEX platform will be implemented in project's demonstration activities". There is an intention to apply the architecture in **heat**, **building** sectors. It could be theoretically applied in **other sectors**.

3.2 Mapping of projects' architectures to DERA

Figures 27-31 depict the attempts to map few projects described in chapter 3.1 to DERA 2.0.

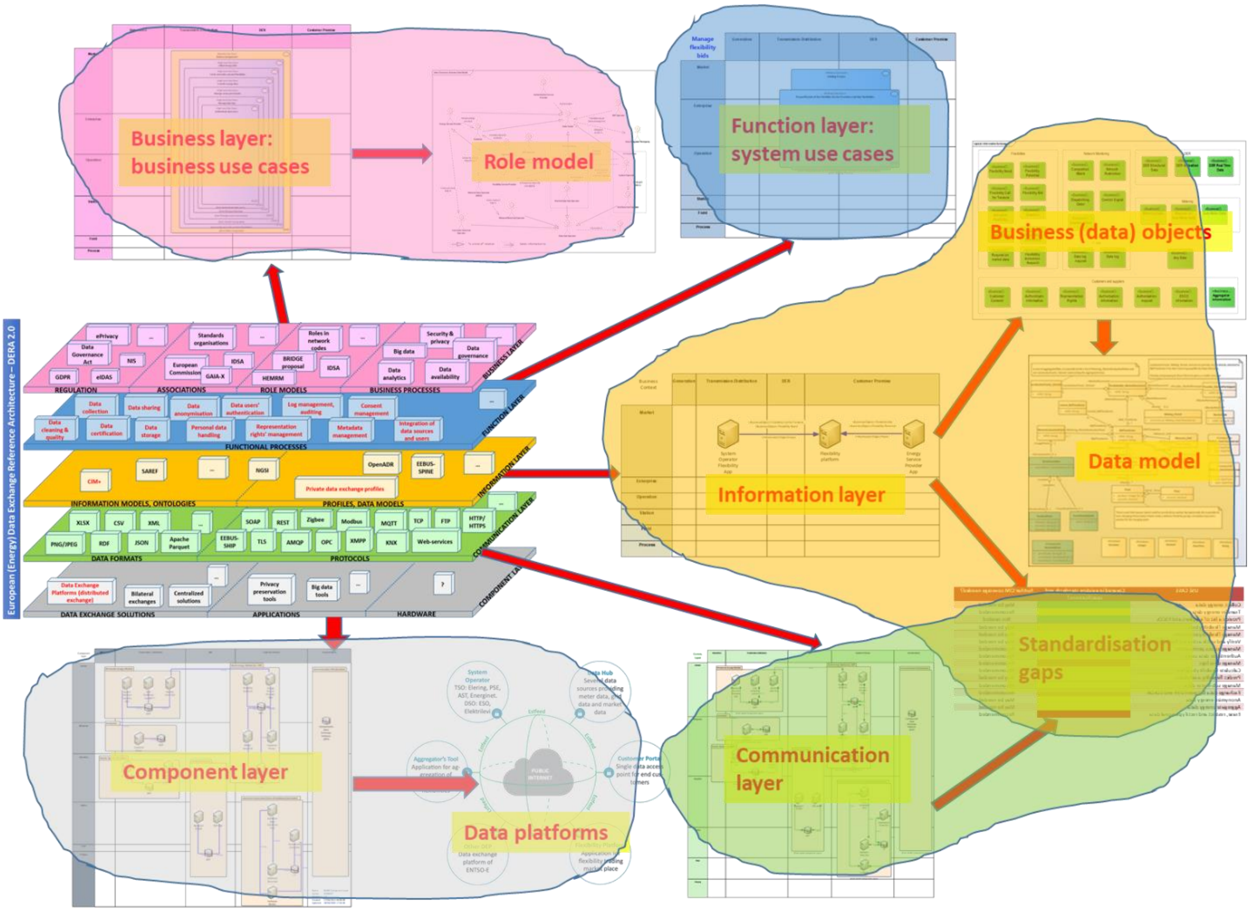


Figure 27: Mapping of EU-SysFlex architecture to DERA 2.0

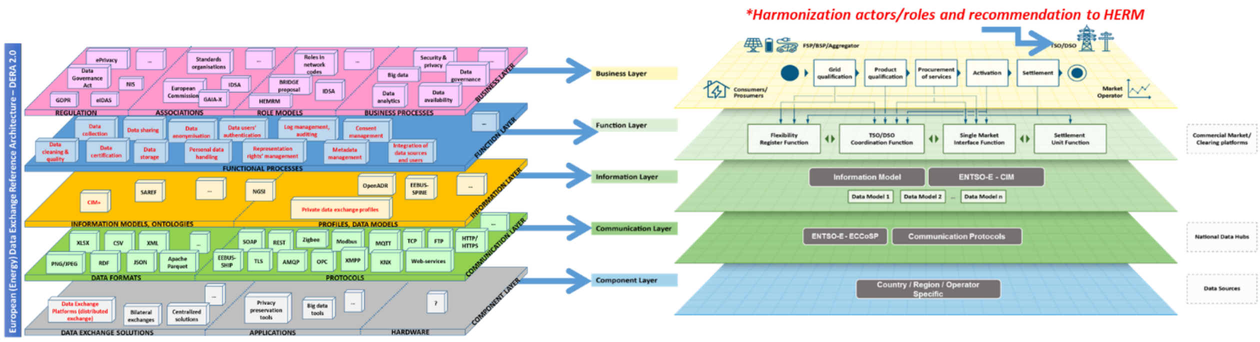


Figure 28: Mapping of INTERRFACE architecture to DERA 2.0

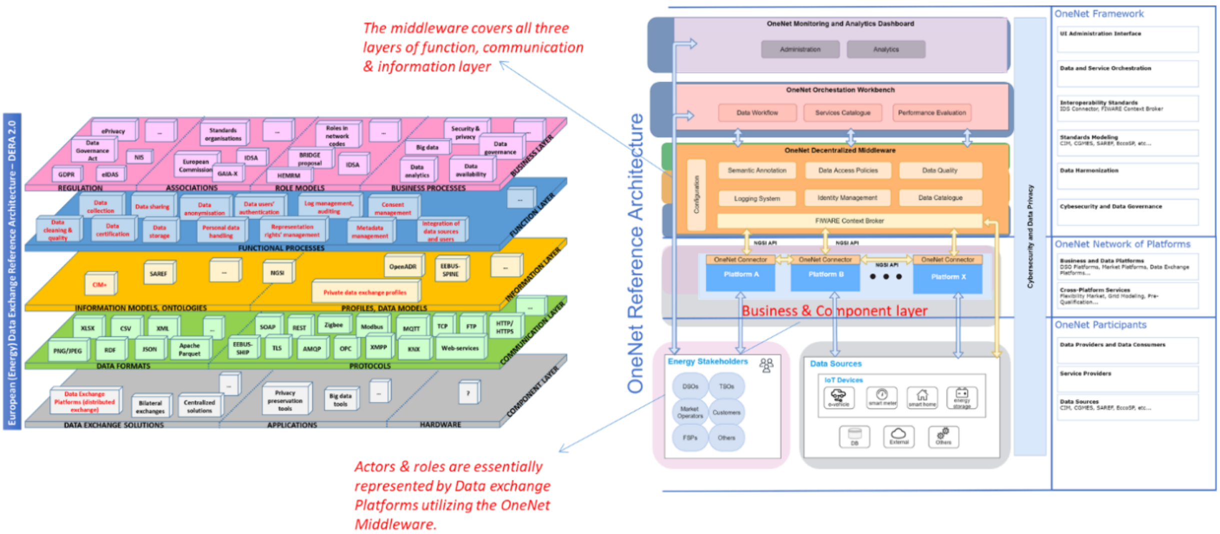


Figure 29: Mapping of OneNet architecture to DERA 2.0

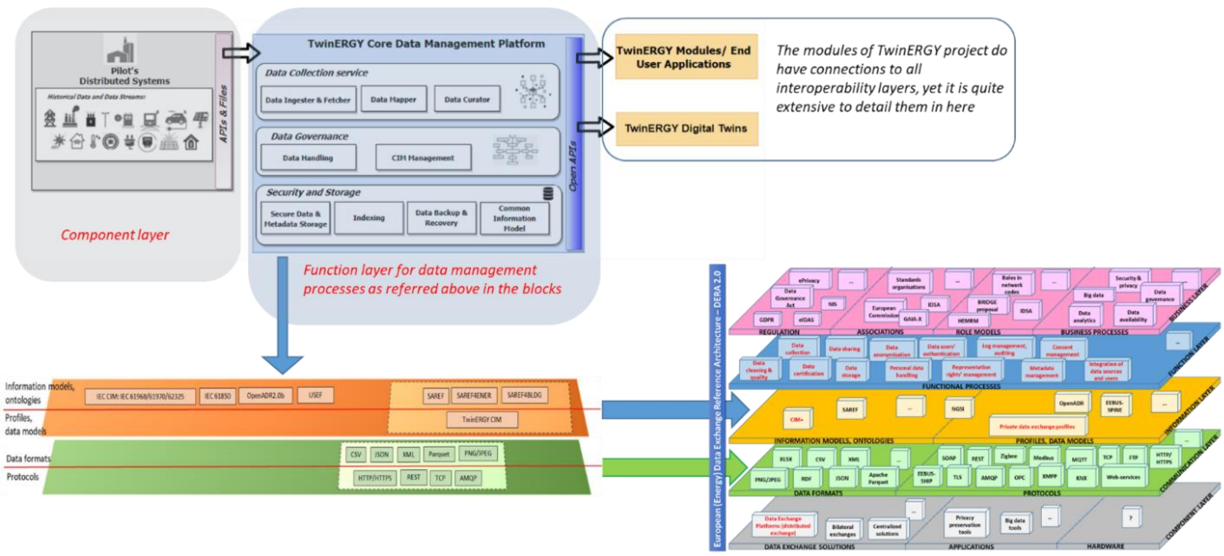


Figure 30: Mapping of TwinERGY architecture to DERA 2.0

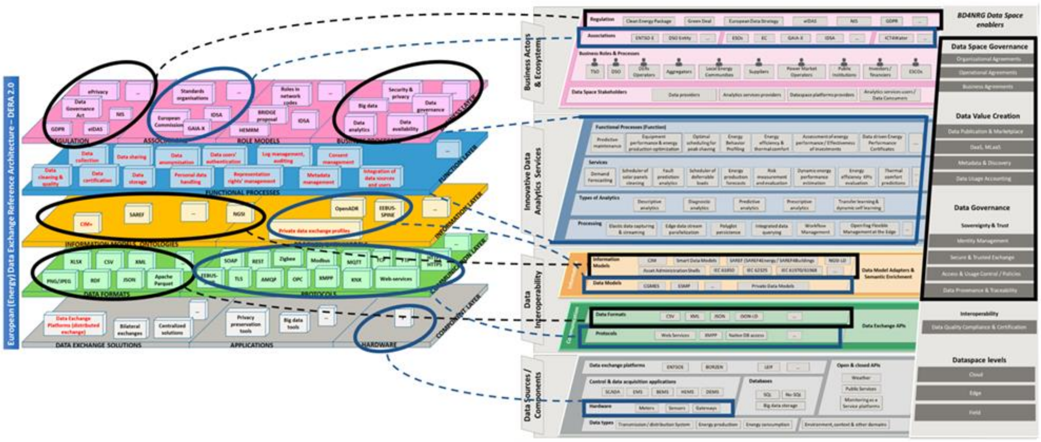


Figure 31: Mapping of BD4NRG architecture to DERA 2.0

4. Summary of pilot implementation

4.1 Scoping

The goal for 'pilot implementation' was initially defined as follows: By means of MVP (minimum viable product) implement (cross-sector) reference architecture based on the recommendations given in the report. Between interested BRIDGE projects – this assumes agreement from at least 2-3 projects willing to participate in such MVP. Best candidates for MVP would be projects which focus on data exchange anyway, specifically across sectors and country borders.

Eventually the projects participating in the discussions included ebalance-plus, OneNet, EU-SysFlex, INTERRFACE and TwinERGY. Figure 32 provides the visual overview of the architectures of these projects, clustering systems into levels and possible paths for cross-sector data exchanges.

Scoping steps:

- Identify the concerned platforms, systems
- Methodology: Follow the reference architecture by selecting small number of elements to be implemented
    - On Business layer – roles
    - On Function layer – data sharing use case with 2(3) scenarios: bilaterally between 'local' platforms, utilising 'cross-platform' middleware, (connecting two 'cross-platform' middlewares)
    - On Information layer – business objects
    - On Communication layer – not addressed yet
    - On Component layer – local platform, cross-platform DEP
- Define common use case(s)
- Mapping to SGAM (e.g. using SGAM Toolbox): to be left for future actions
- Data modelling, profiling: to be left for future actions
- Implementation/development: to be left for future actions

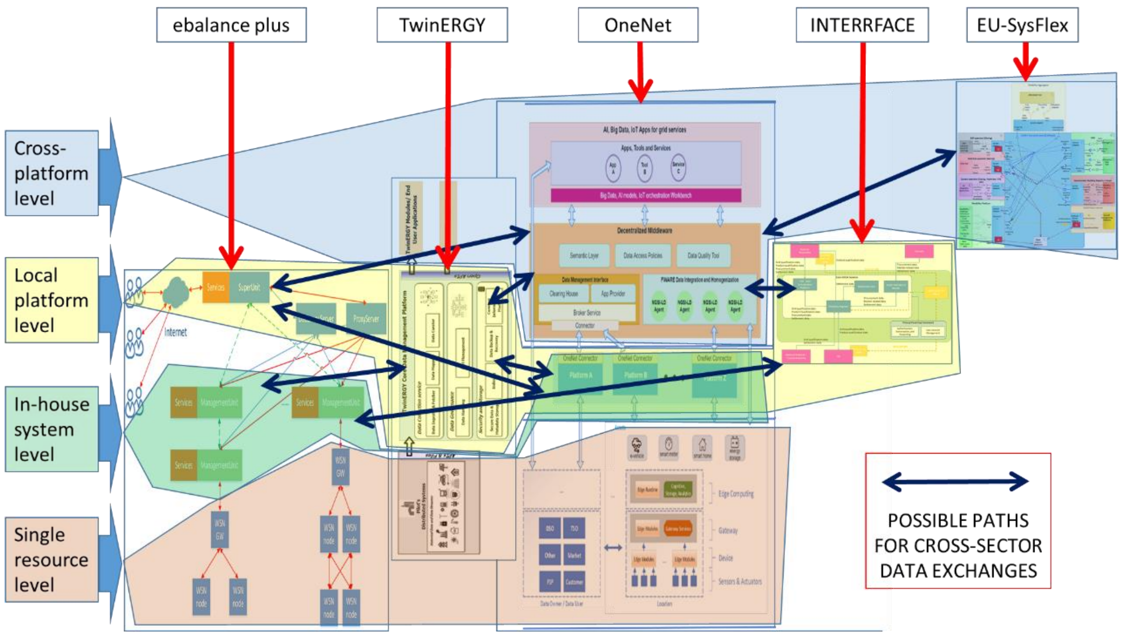


Figure 32: Possible scope for DERA 2.0 pilot implementation

4.2 Use case

Transfer (energy) data

Based on IEC 62559-2 edition 1

Description of the use case

Name of use case

Use case identification		
ID	*Area(s)/Domain(s)/Zone(s)*	*Name of use case*
	Data management	Transfer (energy) data

Version management

Version management				
Version No.	*Date*	*Name of author(s)*	*Changes*	*Approval status*
1	11.11.2021	Kalle Kukk (Elering)	Based on EU-SysFlex system use case	
2				
3				

Scope and objectives of use case

Scope and objectives of use case	
Scope	Transfer of different types of energy related and non-energy data. The system use case describes the data flow from the data provider (data hub or any other data source) to data owner or data user (third party application like supplier, aggregator, ESCO), who has consent or legal mandate to use the data. The flows may take place directly (bilaterally) or through a specific middleware (data exchange platform – DEP).
Objective(s)	To enable free flow of data and interoperable cross-sector data exchange on European scale.
Related business case(s)	

Narrative of Use Case

Narrative of use case
Short description
Two scenarios are considered where data transfer is facilitated by a data exchange platform (DEP): 1) Sharing data owner's data with other stakeholders 2) Data owner's access to own data 3) To be decided: a scenario for bilateral data exchange between two 'local platforms' and/or a scenario whereby 'in-house' systems will be connected to a common 'local platform'
Complete description
Summary of use case ➢ **Request data through DEP API and publish data to subscribed applications** Description: Data can be sent to an application if the application has requested for the data through DEP API or if it has subscribed to publications of this data. ▪ Request data Description: An application requests for data from a Data Source.

- Check authorisation from data owner to request specific data
  Description: An application can receive authorisation (consent) from a Data Owner to request data from a Data Source.
- Authorisation check
  Description:
- Authorisation check
  Description:
- Forward request for data
  Description: The Data Exchange Platform forwards to the Data Source the request for data.
- Check the request for data
  Description: The Data Source checks whether there is valid authorisation for the requesting application.
- Process the request for data
  Description: The Data Source makes data available to the requesting application, in a "publish-stream" mode.
- Publish data to authorised applications
  Description: The Data Source publishes data to all applications with valid authorisation.
- Forward data
  Description: The Data Exchange Platform forwards the published data to authorised applications.

➢ **Download data through DEP customer portal**
Description: An authenticated user can check and download the data through DEP from any Data Hub, depending on the type of data (to be defined).

- Process the request for data
  Description:
- Authenticate to DEP
  Description: Data users authenticates to Data Exchange Platform via a web-based customer portal or through 3rd party application.
- Verify authentication information
  Description: The Data Exchange Platform verifies the authentication information and the representation rights.
- Request data
  Description: Data users request for data via a DEP web-based portal or through 3rd party applications.
- Process request
  Description: If the Data User and the Data Source are not in the same country, the Data Exchange Platform forwards the request to the Foreign Data Exchange Platform.
- Process the request for data
  Description: The Data Source can create different kinds of file (e.g. Excel, PDF, XML).

Use case conditions

Use case conditions	
Assumptions	
1	Data owners/providers are responsible for data quality
2	Data may come from different data sources (incl. data hubs)
3	The communication channel is protected
Prerequisites	
1	The data owner and user are properly authenticated
2	Consent mechanisms are in place for transferring private data
3	No legal obstacles for cross-border data exchange
4	The selected data are available

5	The granularity and the completeness of the selected data is adequate

Diagrams of use case

Diagram(s) of use case


Actors

Actors			
Actor name	*Actor type*	*Actor description*	*Further information specific to this use case*
Data Exchange Platform	System	Data exchange platform (DEP) is a communication platform the basic functionality of which is to secure data transfer (routing) from data providers (e.g. data hubs, flexibility service providers, TSOs, DSOs) to the data users (e.g. TSOs, DSOs, consumers, suppliers, energy service providers). DEP stores data related to its services (e.g. cryptographic hash of the data requested). The DEP does not store core energy data (e.g. meter data, grid data, market data) while these data can be stored by data hubs. Several DEPs may exist in different countries and inside one country.	
Data Source	System	Any kind of system used to store data (including Data Hub and Flexibility Platform).	
Application	System	Any kind of system connected to a Data Exchange Platform and used by a market participant who wishes to receive data.	
Data User	Business	Any person who uses data. Can be a Data Owner or a Data Delegated Third party.	
Foreign Customer Portal	System	Customer Portal for another country. Can also mean a separate portal in the same country.	
Customer Portal	System	Customer Portal manages data users' authentication, access permissions and data logs. Customer Portals store data related to its services (e.g. authentication information, representation rights, access permissions, data logs).	
DEP Operator	Business	Data exchange platform operator owns and operates a communication system which basic functionality is data transfer.	
Consent Administrator	Business		

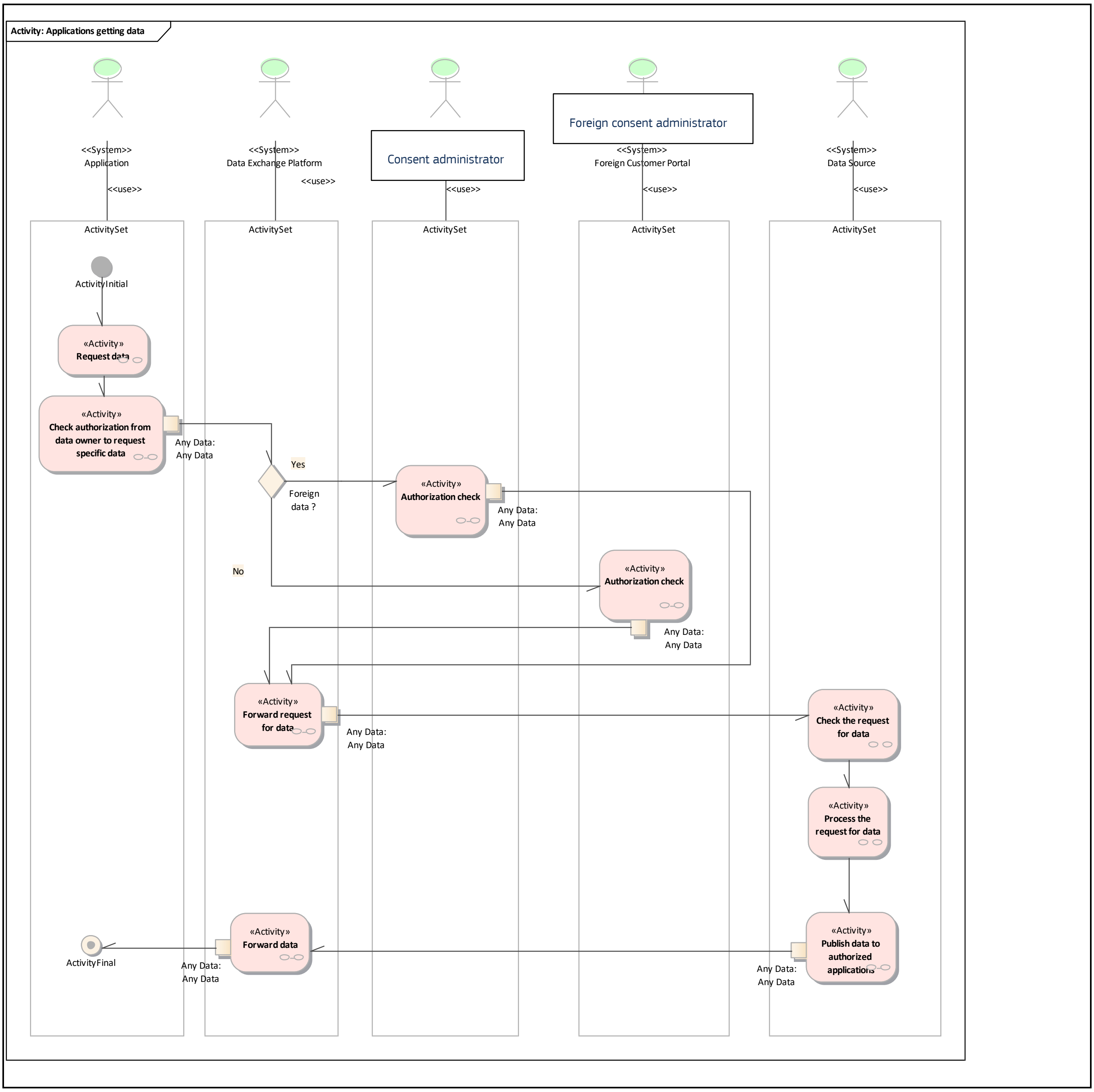
Step by step analysis of use case

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Request data through DEP API and publish data to subscribed applications	Data can be sent to an application if the application has requested for the data through DEP API or if it has subscribed to publications of this data.				
2	Download data through DEP customer portal	An authenticated user can check and download the data through DEP from any Data Hub, depending on the type of data (to be defined).				

Scenario 1: Request data through DEP API and publish data to subscribed applications

Data can be sent to an application if the application has requested for the data through DEP API or if it has subscribed to publications of this data.

Requirement list (refer to "Requirement" section for more information)	
Requirement R-ID	**Requirement name**
Cat1.Req1	Access Citizen Right
Cat1.Req2	Portable Citizen Right
Cat2.Req3	DT-REQ1
Cat2.Req4	DT-REQ3
Cat2.Req5	DT-REQ4
Cat2.Req6	DT-REQ2



Scenario step by step analysis

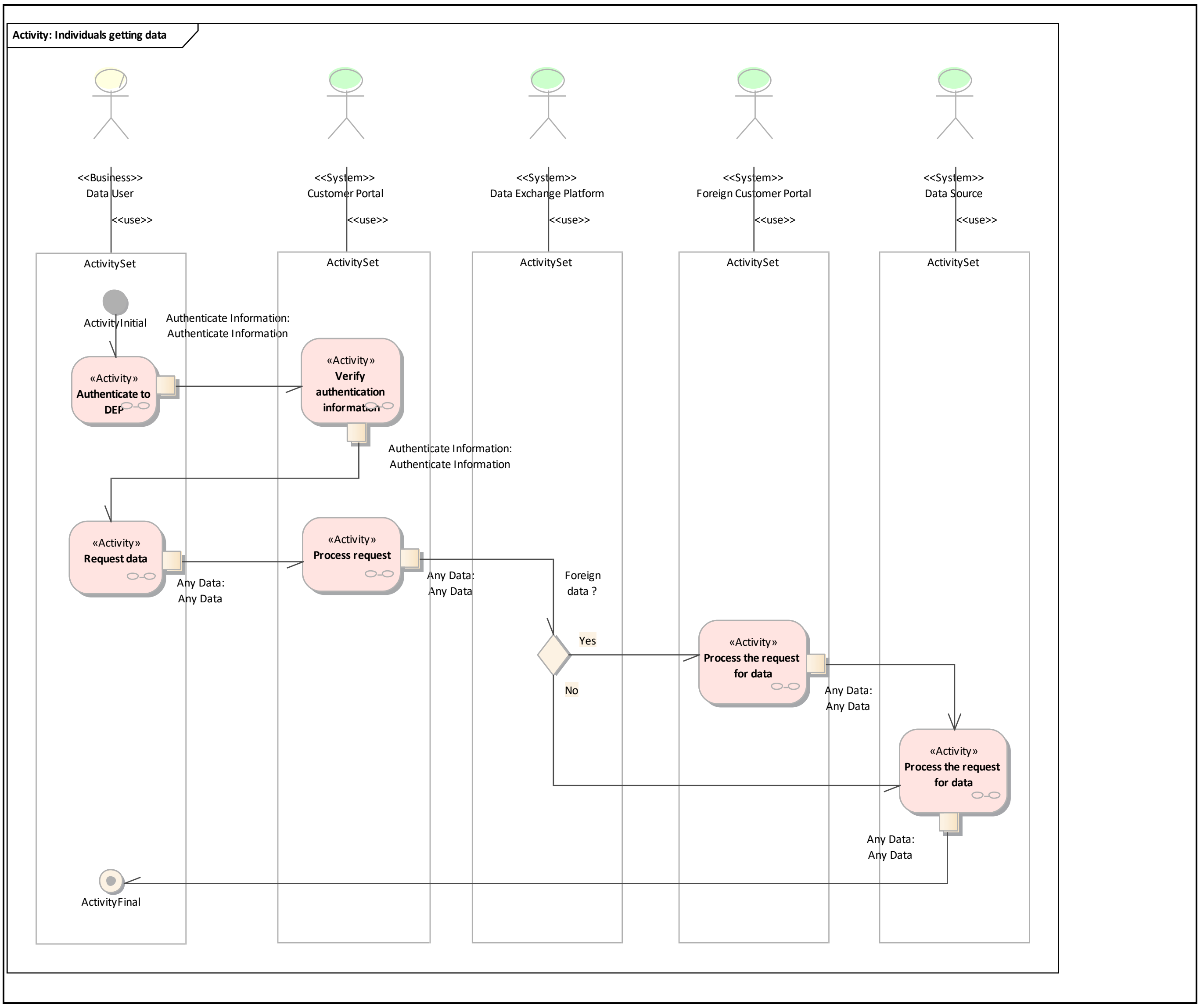
Scenario								
Scenario name	Request data through DEP API and publish data to subscribed applications							
Step No	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirement, R-IDs***
1.1		Request data	An application requests for data from a Data Source.		Application			
1.2		Check authorisation from data owner to request specific data	An application can receive authorisation (consent) from a Data Owner to request data from a Data Source.		Application	Customer Portal, Foreign Customer Portal	Info1-Any Data	

1.3		Authorisation check			Consent Administrator	Data Exchange Platform	Info1-Any Data	
1.4		Authorisation check			Foreign Consent Administrator	Data Exchange Platform	Info1-Any Data	
1.5		Forward request for data	The Data Exchange Platform forwards to the Data Source the request for data.		Data Exchange Platform	Data Source	Info1-Any Data	
1.6		Check the request for data	The Data Source checks whether there is valid authorisation for the requesting application.		Data Source			
1.7		Process the request for data	The Data Source makes data available to the requesting application, in a "publish-stream" mode.		Data Source			
1.8		Publish data to authorised applications	The Data Source publishes data to all applications with valid authorisation.		Data Source	Data Exchange Platform	Info1-Any Data	
1.9		Forward data	The Data Exchange Platform forwards the published data to authorised applications.		Data Exchange Platform	Application	Info1-Any Data	

Scenario 2: Download data through DEP customer portal

An authenticated user can check and download the data through DEP from any Data Hub, depending on the type of data (to be defined).

Requirement list (refer to "Requirement" section for more information)	
Requirement R-ID	***Requirement name***
Cat1.Req2	Portable Citizen Right
Cat1.Req1	Access Citizen Right
Cat2.Req3	DT-REQ1
Cat2.Req4	DT-REQ3
Cat2.Req5	DT-REQ4
Cat2.Req6	DT-REQ2



Scenario step by step analysis

Scenario								
Scenario name	Download data through DEP customer portal							
Step No	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirement, R-IDs***
2.1		Process the request for data			Foreign Customer Portal	Data Source	Info1-Any Data	
2.2		Authenticate to DEP	Data users authenticates to Data Exchange Platform via a web-based customer portal or through 3rd party application.		Data User	Customer Portal	Info2-Authentication Information	
2.3		Verify authentication information	The Data Exchange Platform verifies the authentication information and the representation rights.		Customer Portal	Data User	Info2-Authentication Information	

2.4		Request data	Data users request for data via a DEP web-based portal or through 3rd party applications.		Data User	Customer Portal	Info1-Any Data	
2.5		Process request	If the Data User and the Data Source are not in the same country, the Data Exchange Platform forwards the request to the Foreign Data Exchange Platform.		Customer Portal	Data Source, Foreign Customer Portal	Info1-Any Data	
2.6		Process the request for data	The Data Source can create different kinds of files (e.g. Excel, PDF, XML).		Data Source	Data User	Info1-Any Data	

Information exchanged

Information exchanged			
Information exchanged, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Info1	Any Data		
Info2	Authentication Information		

Requirements

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Cat1	Personal data	
Requirement R-ID	***Requirement name***	***Requirement description***
Req1	Access Citizen Right	Right to secure direct access of own personal data and to any processing, storage or sharing details
Req2	Portable Citizen Right	A copy of the data held may be requested by the individual in a portable format

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Cat2	Functional	
Requirement R-ID	***Requirement name***	***Requirement description***
Req3	DT-REQ1	Transfer of data must be secured, by means of encryption or communication protocol
Req4	DT-REQ3	Data owner's access to data through DEP (and foreign DEP)
Req5	DT-REQ4	Application's access to data through DEP (and foreign DEP)
Req6	DT-REQ2	Data portability (applies to personal data - Article 20 of the GDPR)

5. Next steps

Possible BRIDGE activities related to data exchange reference architecture planned for 2022/2023:

- Continue pilot implementation of the reference architecture, including the steps like
  - Mapping to SGAM (e.g. using SGAM Toolbox);
  - Data modelling, profiling;
  - Implementation/development.
- For improved visualisation model the reference architecture, e.g. by applying Unified Modelling Language (UML).
- Follow the implementation of individual recommendations related to reference architecture as presented in chapter 2.3.
- Add data governance layer to the reference architecture.
- Engage closely new projects funded through Horizon Europe call on Energy Data Spaces.
- Contribute to Digitalisation of Energy Action Plan (DoEAP)
  - On strategic level – ensure the inclusion of cross-sector perspective, interoperability of sectorial data spaces and governance aspects;
  - On operational level – benefit from BRIDGE data exchange reference architecture and make the link with other BRIDGE activities related to use case repository, smart energy standards user group and asset interoperability framework. The methodology for describing Generic Business Processes and the repository for storing use cases can be leveraged by using the same approach for other electricity sector (i.e. not only flexibility market processes related) data exchanges as well as for cross-sector data exchanges. Also there are possible synergies with developing the data interoperability implementing acts as mandated in electricity market directive. Future BRIDGE projects should take these as starting point for their activities.

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Annex I. Glossary

Term	Definition	Source
Architecture	Fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution.	CEN-CENELEC-ETSI [2012] with reference to ISO/IEC/IEEE 42010
Canonical data model	A semantic model chosen as a common dialect for a data exchange.	
CIM standards	CIM standards aim to: • simplify integration of components and expand options for supply of components by standardising information exchanges; • reduce complexity with clear consistent semantic modelling among different points of integration; • clarify data mastership across any domain; • establish data flow between components without directly coupling their design.	[Britton]
Data format	Data format in the meaning of file format is a standard way that information is encoded for storage in a computer file. It specifies how bits are used to encode information in a digital storage medium.	Wikipedia
Data model	An abstract model that organises elements of data and standardises how they relate to one another and to the properties of real-world entities.	Wikipedia
Information model	A representation of concepts and the relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse. Typically it specifies relations between kinds of things, but may also include relations with individual things. It can provide sharable, stable, and organised structure of information requirements or knowledge for the domain context. An information model provides formalism to the description of a problem domain without constraining how that description is mapped to an actual implementation in software. There may be many mappings of the information model. Such mappings are called data models, irrespective of whether they are object models (e.g. using UML), entity relationship models or XML schemas. The information model now serves two purposes. First, to aid future software design in creating robust data models, for example by supporting different customer address types. Secondly, to enforce a common terminology across the system landscape and in the documentation	Lee [1999] Wikipedia McNamee [2018]

Term	Definition	Source
Interoperability	The ability of two or more devices to exchange information and use that information for correct cooperation to perform the required functions. In other words, two or more systems are interoperable, if they are able to perform cooperatively a specific function by using information that is exchanged.	SGTF EG1 [2019], IEC 61850-2010 [2012]
Ontology	A representation, formal naming and definition of the categories, properties and relations between the concepts, data and entities that substantiate one, many or all domains of discourse.	Wikipedia
Profile	Specifies standards for particular business problems. Defines how the semantics of an interface relate to the Canonical Data Model.	[Britton]
Protocol	Communication protocol is a system of rules that allow two or more entities of a communications system to transmit information via any kind of variation of a physical quantity. The protocol defines the rules, syntax, semantics and synchronisation of communication and possible error recovery methods. Protocols may be implemented by hardware, software, or a combination of both.	Wikipedia
Reference architecture	A Reference Architecture describes the structure of a system with its element types and their structures, as well as their interaction types, among each other and with their environment. Describing this, a Reference Architecture defines restrictions for an instantiation (concrete architecture). Through abstraction from individual details, a Reference Architecture is universally valid within a specific domain. Further architectures with the same functional requirements can be constructed based on the reference architecture. Along with reference architectures comes a recommendation, based on experiences from existing developments as well as from a wide acceptance and recognition by its users or per definition.	CEN-CENELEC-ETSI [2012] with reference to ISO/IEC42010
(Reference core) process model	A representation of harmonised processes for information exchange within the energy sector so that these processes may be implemented as such or as the basis for a customised version according to regional/national business needs.	SGTF EG1 [2019]
(Reference) information model	A representation of concepts and the relationships, constraints, rules, and operations to specify data semantics for the energy sector.	SGTF EG1 [2019]
Role model	A model representing core functions/responsibilities in the energy sector and their interdependence.	SGTF EG1 [2019]

Term	Definition	Source
Semantics	Understanding of the concepts contained in the message data structures. Understanding of the information that needs to be accessed/exchanged. The semantic aspect refers to the meaning of data elements and the relationship between them. It includes developing vocabularies and schemata to describe data exchanges, and ensures that data elements are understood in the same way by all communicating parties.	SGTF EG1 [2019], European Interoperability Framework [EC, 2017]
Semantic model	A structured description of the semantics of a set of information, using some information modelling language (e.g. UML). A semantic model is 'metadata' – 'data about data'. Many different semantic models are possible for the same semantics, even within one modelling language. Semantic modelling only represents information content – it does not include formatting/encoding (syntactical) specifications.	[Britton]
Semantic transformation	A procedure for converting a given semantics from one semantic model representation to another. This should be distinguished from a syntactic transformation that converts from one format to another (e.g. CSV to XML).	[Britton]
Syntactics	Understanding of data structure in message exchanged between systems. Technical aspects (e.g. formats, technologies used) of the information that needs to be accessed/exchanged. The syntactic aspect refers to describing the exact format of the information to be exchanged in terms of grammar and format.	SGTF EG1 [2019], European Interoperability Framework [EC, 2017]
Use case	A list of actions or event steps typically defining the interactions between a role (known in the Unified Modelling Language (UML) as an actor) and a system to achieve a goal. The actor can be a human or other external system.	Wikipedia

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