European Commission

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European energy data exchange reference architecture

Data Management Working Group

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Bridge WG/TF Chairmanship

- Olivier Genest – *Chair*

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List of Acronyms and Abbreviations

AC	Alternating Current
ADMS	Advanced Distribution Management Systems
AI	Artificial Intelligence
AMQP	Advance Message Queuing Protocol
API	Application Programming Interface
ASP	Authentication Service Provider
BO	Business Object
BRP	Balancing Responsible Party
BUC	Business Use Case
CDPSM	Common Distribution Power System Model
CEC	Citizen's Energy Community
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CEP	Clean Energy Package
CG-SEG	Coordination Group Smart Energy Grid (CEN-CENELEC-ETSI)
CGM	Common Grid Model
CGMES	Common Grid Model Exchange Specification
CIM	Common Information Model
CMU	Customer Management Unit
COSEM	Companion Specification for Energy Metering
CSV	Comma-Separated Values file
CVR	Conservation Voltage Reduction
DB	Database
DC	Direct Current
DEP	Data Exchange Platform
DEPO	Data Exchange Platform Operator
DER	Distributed Energy Resources
DFIG	Double-Fed Induction Generator
DHO	Data Hub Operator
DLMS	Device Language Message Specification
DNO	Distribution Network Operator
DSF	Demand Side Flexibility
DSO	Distribution System Operator
EaaS	Energy-as-a-Service
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
ECP	Energy Communication Platform
ECUG	European CIM User Group
EDA	Energy Data Exchange Austria
EFET	European Federation of Energy Traders
EFI	Energy Flexibility Interface
EG	Expert Group
EHV	Extra High Voltage
EIC	Energy Identification Code
eIDAS	EU regulation on electronic IDentification, Authentication and trust Services
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ESB	Enterprise Service Bus
ESCO	Energy Service Company
ESESUG	European Smart Energy Standard User Group

ESMP	European Style Market Profile
ESO	European Standardisation Organisation
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
FSP	Flexibility Service Provider
FSSF	File System Shared Folders
FTP	File Transfer Protocol
GDPR	General Data Protection Regulation
HDFS	Hadoop Distributed File System
HEMRM	Harmonised Electricity Market Role Model
HERM	Harmonised Energy Role Model
HTTP	Hypertext Transfer Protocol
HV	High Voltage
I2SP	Incidents' Information Sharing Platform
ICCP	Inter Control Center Protocol
ICT	Information and Communications Technology
IDSA	International Data Spaces Association
IEC	International Electrotechnical Commission
IEM	Internal Energy Market
IG	Induction Generator
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organisation for Standardisation
JSON	JavaScript Object Notation
IT	Information Technology
JRC	Joint Research Centre
KPI	Key Performance Indicator
LV	Low Voltage
LVGMU	Low Voltage Grid Management Unit
MDA	Metered Data Administrator
MDC	Meter Data Company
MDO	Metered Data Operator
MDR	Metered Data Responsible
MO	Market Operator
MQTT	Message Queuing Telemetry Transport
MS	Member State
MV	Medium Voltage
MVP	Minimum Viable Product
NGSI-LD	Context Information Management API (see [ETSI, 2020]
NIS	EU directive on security of Network and Information Systems
OH	Overhead
OWL	Web Ontology Language
P2P	Peer to Peer
PQ	Power Quality
PV	Photovoltaics
R&D	Research & Development
RBAC	Role Based Access Control
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
SGAM	Smart Grid Architecture Model

SGTF	European Smart Grids Task Force
SGU	Significant Grid User
SME	Small and Medium-sized Enterprise
SRD	System Reference Document
SUC	System Use Case
SyC	System Committee
TC	Technical Committee
TCP	Transmission Control Protocol
TR	Technical Report
TS	Technical Specification
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
UG	Underground
UML	Unified Modelling Language
USEF	Universal Smart Energy Framework
WG	Working Group
WP	Work Package
WWTP	Wastewater Treatment Plant
XMI	XML Metadata Interchange
XML	Extensible Markup Language
XMPP	Extensible Messaging and Presence Protocol
XSD	XML Schema Definition

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.

Practical outcomes associated to this report are:

1. Proposal for the definition of a common European reference architecture
2. Setting up European CIM (Common Information Model) user group and CIM repository
3. Repository of data roles and updates to HEMRM (Harmonised Electricity Market Role Model)

During the BRIDGE General Assembly of February 2020, the Parallel Session 5 focused on the data management aspects of TSO-DSO coordination. Several topics for further investigation were identified. This report combines the topics related to the EU wide conceptual data exchange reference architecture, CIM and HEMRM.

Based on the conclusions of this Parallel Session 5, the main objectives hereby are to:

- Develop conceptual European data exchange model, involving elements like functionalities, governance, data access, open source, standardisation needs.
- Define "interoperability of platforms" and identify platforms with European ambition and potential for replicability and scalability.
- Ensure GDPR compliance and data owner's control over their data.
- Elaborate new data roles, harmonise approach to role definitions and recommend these to be included in HEMRM.
- Apply CIM standards in TSO-DSO coordination as well as cooperate in suggesting extensions to CIM.

For the purpose of this report the work was organised in three workflows, respectively for reference architecture, CIM and data roles. Several questionnaires were developed and input asked from BRIDGE members. A separate survey was elaborated for the representatives of other sectors outside BRIDGE/electricity. Before finalising the report it was consulted with external stakeholders like ebIX, representatives of ENTSO-E and DSO community, ICT4Water, representatives of European standardisation organisations, OPEN DEI.

Main findings are as follows:

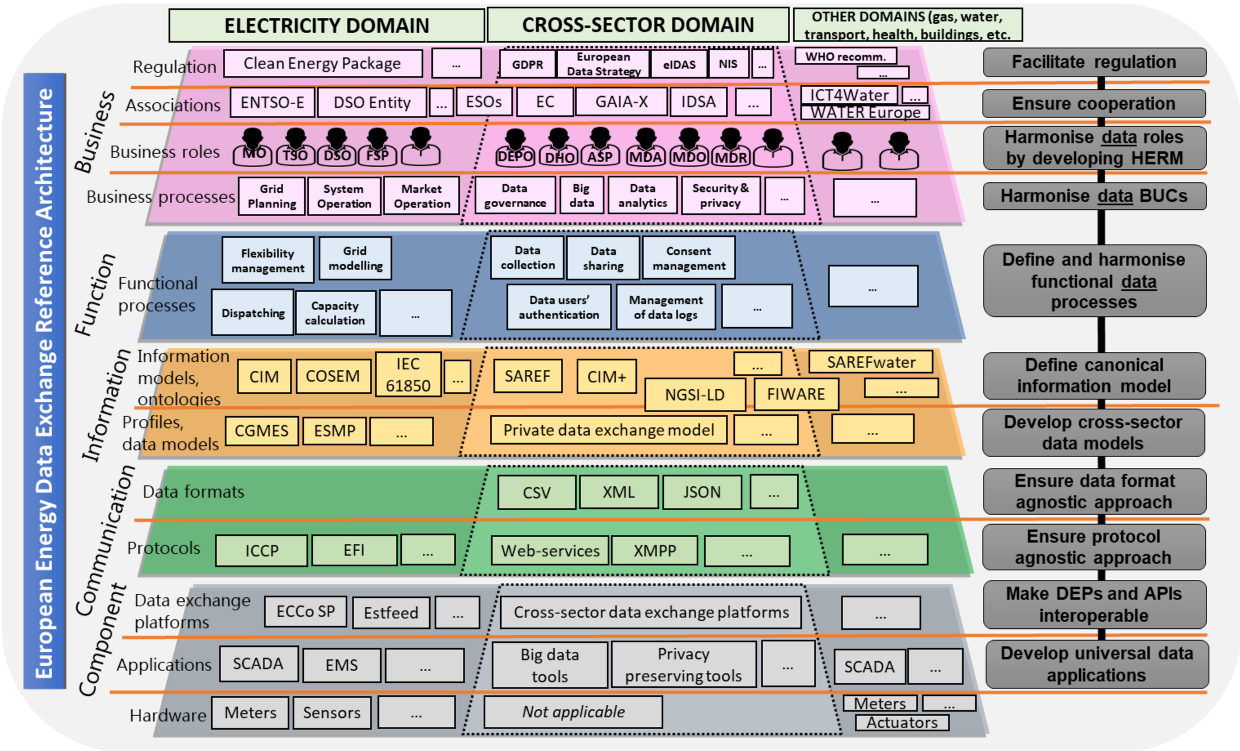
- CEP (Clean Energy Package) and GDPR (General Data Protection Regulation) are most often mentioned by projects – CEP (i.e. electricity market directive) in the context of meter data access and GDPR for personal data handling.
- Several bottom-up initiatives are emerging to support cross-sector (and cross-border) data exchange – GAIA-X, FIWARE, Data Bridge Alliance, IDSA, OPEN DEI.
- BRIDGE projects are using several data exchange business roles which are missing in HEMRM (Harmonised Electricity Market Role Model). It should be ensured that consistent set of business roles (both role names and definitions) are used by projects.
- Given the exploration of cross-sectoral architectures, it was derived that there are dependencies of the electricity with other vectors of energy sector. 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).
- The analysis of obtained responses from both BRIDGE projects for the electricity as well as from the cross-sector interaction highlights that the key transformation of both electricity domain and the cross-sector domain is the data exchange and management.
- The Canonical Data Model is used to define the Business Objects (information exchange requirement).
- 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.
- Projects are using a variety of data formats and communication protocols for data exchange.

- BRIDGE projects are increasingly using business process agnostic data platforms, e.g. ECCo SP, Estfeed, IEGSA, Atos FUSE, Enterprise Service Bus, Cloudera etc.

Summary of recommendations:

- Leverage Smart Grid Architecture Model (SGAM) usage and study its extension to other sectors.
- Facilitate regulation for cross-sector exchange of any type of both private data and public data, e.g. through the means of regulation for data spaces and data interoperability implementing acts.
- Ensure cooperation between appropriate associations to work on cross-sector and cross-border data management.
- Propose to ENTSO-E, ebIX and EFET new roles and classes to be included and definitions to be adapted in existing HEMRM. Develop mechanism for proposing new roles by BRIDGE projects.
- Harmonise data roles across electricity and other energy domains by developing HERM – Harmonised Energy Role Model. Look for consistency with other domains outside energy based on this HERM – cross-sectoral roles.
- Create a central repository for roles used by BRIDGE (and other) projects as part of 'Use Case Repository' and/or 'CIM repository'.
- Harmonise the development and content of data exchange business use cases for cross-sector domain.
- Define and harmonise functional data processes for cross-sector domain.
- Define 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. Study the benefit to use ontologies to support cross-sector interactions.
- Develop cross-sector data models and profiles.
- Ensure protocol agnostic approach to cross-sector data exchange.
- Ensure data format agnostic approach to cross-sector data exchange.
- Set up and manage a CIM repository for BRIDGE projects and beyond.
- Set up a European CIM User Group and eventually a Smart Energy Standard User Group.
- Define the strategy to disseminate advantages and benefits that CIM usage provides as well as develop a systematic approach in provision of education and consulting to all interested parties across Europe.
- Make CIM UML model(s) and associated profiles available following a clear procedure.
- Make DEPs (Data Exchange Platforms) 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.
- Develop universal data applications which can serve any domain.

The figure below depicts high-level SGAM based reference architecture for European energy data exchange as proposed in this report.



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. This includes identifying high-level reference architecture, information modelling and role modelling. It is a natural follow-up step to the previous BRIDGE study which investigated data management aspects of TSO-DSO coordination [2019].

BRIDGE Data Management WG recognizes 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'[1] 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.

Reference architecture workflow started with the following key points:

- Interoperability of the variety of existing (and planned) solutions (platforms), incl. used and planned by BRIDGE projects
- Enable free flow of data between platforms (interoperability)
- Enable cross-border data exchange
- Accommodate any type of data, incl. real-time, sub-meter, TSO-DSO, etc.
- Ensure GDPR compliance and data owner's control over their data
- Enable sector coupling – gas, heating & cooling, water, buildings, health, etc.
- Open source
- SGAM based approach
- Standardisation needs
- Exchange data across projects

[1] In SGTF EG1 2019 report the term 'Core Reference Model' was suggested (see recommendation #6 of the report). However, while developing 'data interoperability implementing acts the term was changed to 'Reference Model' simply. This change does not imply any changes in the conceptual approach.

As a reminder and as starting point for this report, Figure 1 summarizes different platforms which were referenced in [BRIDGE, 2019]. It should be noted, however, that the focus of this report is on data platform only (and not on market platforms).

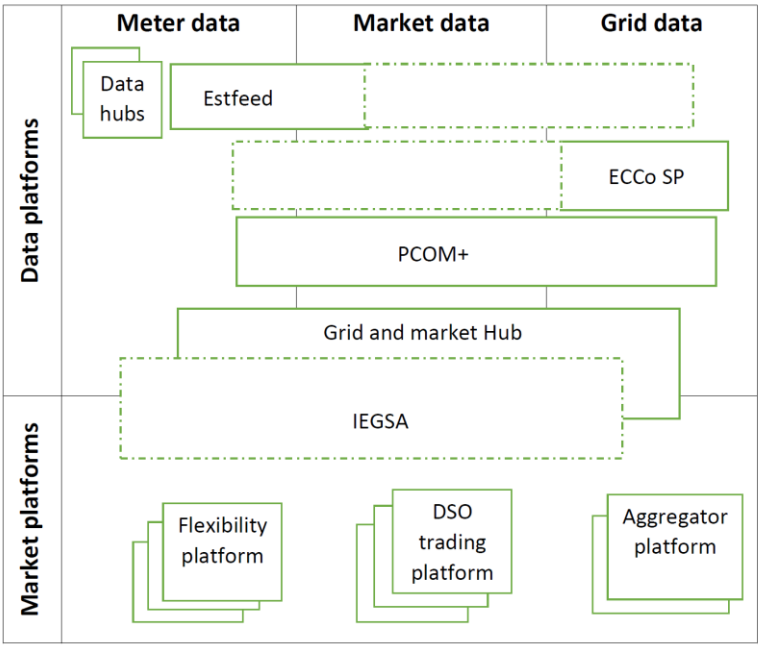


Figure 1: Landscape of existing and new energy sector specific data platforms [BRIDGE, 2019]

Information model workflow is aligned with EC's Smart Grid Task Force (SGTF) aims, which is to reach and maintain interoperability. A building block of the Reference Model is IEC (International Electrotechnical Commission) Common Information Model (CIM), which was adopted by ENTSO-E (European Network of Transmission System Operators for Electricity) in 2009 and elaborated since then through network codes and guidelines:

- Connection codes
  - Demand Connection (EU) 2016/1388
  - High-voltage direct current connections (EU) 2016/1447
  - Requirements for generators (EU) 2016/631
- Market codes
  - Capacity Allocation and Congestion Management (EU) 2015/1222
  - Forward Capacity Allocation Regulation (EU) 2016/1719
  - Electricity Balancing (EU) 2017/2195
- Operation codes
  - Emergency and restoration (EU) 2017/2196
  - System Operation (EU) 2017/1485

Several profiles have been standardised by IEC, which are supporting network codes and guidelines. These profiles are named CGMES (Common Grid Model Exchange Specification) and ESMP (European Style Market Profile). Figure 2 illustrates CIM standards which are supporting European network codes and guidelines.

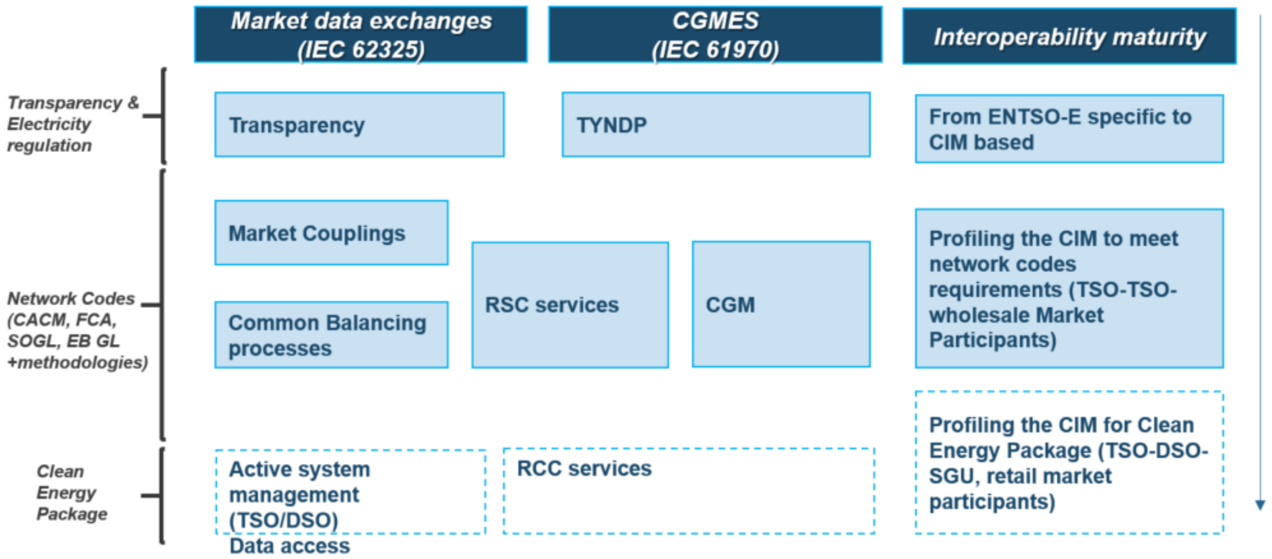


Figure 2: Development of network codes, guidelines, and standards [ENTSO-E, not published]

CIM can be used in three business domains:

- Power grid and network studies
- Utility application integration
- Market

The aim for Information Model workflow is to:

- Manage a CIM repository
- Set-up a European CIM user group

Role model workflow was a joint action with Regulation WG whereas the latter was leading the action. Data Management WG provided the input to the joint report [BRIDGE Regulation WG, 2021], the content is summarized and more detailed background provided in this report.

High-level approach of the role model workflow:

- Collect data exchange specific (business) roles used by projects. Engage all projects in Data Management WG. Align with „Use case repository“ sub-group. Create a central repository for data roles.
- Propose new roles to be included in HEMRM.
- Identify gaps between USEF (Universal Smart Energy Framework) and HEMRM, and others.

Structure of the report:

- Chapter 2 provides overview of the state-of-the art energy data exchange architectures, including motivation for common European architecture, reminders from BRIDGE report on TSO-DSO Coordination, other initiatives and frameworks addressing reference architecture topic, introduction to the discussion on Data Exchange Platforms (DEPs), information models, and models for data roles.
- Chapter 3 is in-depth analysis of data exchange platforms based on projects' experience, starting with the introduction of the questionnaires distributed to BRIDGE projects and explaining main findings of the survey. Finally, a questionnaire was developed to get input from other sectors outside electricity in order to look at the energy data exchange reference architecture from a cross-sector perspective.

- Chapter 4 explains the usage of Common Information Model based on questionnaire and as answered by BRIDGE reports. The chapter also elaborates the ideas around topics on CIM repository, setting up a European CIM user group, education and promotion of usage of CIM in electricity domain, and handling of code components in IEC standards and its impact on CIM usage.
- Chapter 5 is for data exchange roles, summarizing the results of jointly developed report with BRIDGE Regulation WG and providing some further insights, e.g. in terms of mapping different role models used by BRIDGE projects.
- Chapter 6 outlines the European energy data exchange reference architecture, makes recommendations and proposes next steps.
- Annexes include glossary, questionnaires and full information about roles collected from projects.

2. State-of-the-art energy data exchange architectures

2.1 Towards common European reference architecture

2.1.1 Motivation for common European architecture

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, utilizing 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.

A fundamental element towards the definition of a reference architecture is the proper designation of interoperable data exchange solutions. 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 Harmonized 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. Hence, those are set in place in several H2020 projects, involved also in BRIDGE.

2.1.2 BRIDGE report on TSO-DSO Coordination

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). However, this sub-chapter summarises the main findings and recommendations related to data management from TSO-DSO Coordination report [BRIDGE, 2019] as it was the starting point and motivation for the current report.

Main data management related findings from TSO-DSO Coordination report:

- There are few dedicated platforms for energy data exchanges existing or developing.
- Half of the projects demonstrate interoperability between platforms, while only few demonstrate cross-sector interoperability.
- Half of the projects apply standardised approach to use case description and majority of the projects are in favour of having access to a use case repository[2].
- Some new data roles have been proposed.
- CIM standard is not addressing all aspects implicitly relevant for TSO-DSO coordination.

Summary of data management related recommendations in TSO-DSO Coordination report:

- Develop conceptual European data exchange model, involving elements like functionalities, governance, data access, open source, standardisation needs.
- Define “interoperability of platforms” and identify platforms with European ambition and potential for replicability and scalability.
- Ensure GDPR compliance and data owner's control over their data.
- Cooperate while developing use cases and an easily accessible use case repository.
- Elaborate new data roles, harmonize approach to role definitions and recommend these to be included in HEMRM.
- Apply CIM standards in TSO-DSO coordination as well as cooperate in suggesting extensions to CIM.

2.1.3 Initiatives, frameworks and standards for reference architecture

Clean Energy Package, Data Interoperability Implementing Act

The primary legal act of Clean Energy Package (CEP) of interest is the new electricity market directive [Directive (EU) 2019/944]. According to article 23, Member States are responsible to specify the rules on the access to data of the final customer by eligible parties. The concerned data includes metering and consumption data as well as data required for customer switching, demand response and other services. Access to and sharing of data shall be easy, free of cost for final customers regarding their own data, efficient, secure and respectful of data protection requirements, incl. those of GDPR [Regulation (EU) 2016/679].

According to article 24 of the directive, the EC shall adopt implementing acts for interoperability requirements and non-discriminatory and transparent procedures for access to these data. Those requirements and procedures shall be based on existing national practices. In 2020 EU SGTF EG1 was relaunched to advise EC with its expert knowledge and propose interoperability requirements as well as transparent and non-discriminatory procedures for access and exchange of electricity (and gas) data in the EU.

SGTF EG1 report on data interoperability

The current activity of SGTF EG1 builds upon the group’s previous report Towards Interoperability within the EU for Electricity and Gas Data Access & Exchange [2019]. There were some recommendations which could be clustered as *content* related and other as *process* related.

Content related recommendations by SGTF EG1 [2019]:

- Specify information exchange in terms of exchange between harmonised roles.
- Building on available role models, adopt and use a common European role model.
- To facilitate interoperability adopt and use a common information model for semantics, for example consider building on the available IEC CIM model.
- Adopt and use a core process model, which should allow for national specificities and stay open for further interoperability over time.
- Business requirements shall be the basis for interoperability and must remain technology-neutral.

[2] Currently under construction by another BRIDGE activity.

- Adopt and use available European standards as a basis to improve interoperability.
- Process related recommendations by SGTF EG1 [2019]:
- On the way to interoperability of national practices for accessing and exchanging data, all relevant stakeholders must get involved, discuss and negotiate.
- Monitor the gap between each national practice and the reference core model. Consider means for maintaining this at European level.
- Bear in mind that legal aspects in national markets can be a limiting factor to full interoperability.
- Aiming for interoperability should not be conditional to a cost/benefit analysis. However, how to reach it and maintain it (in terms of context and timing) could be analysed and optimised through Cost/Benefit Analyses and Risks/Opportunities Assessments.
- Bear in mind that reaching and maintaining interoperability is a step-by-step exercise requiring a roadmap that needs to be duly monitored and accordingly adapted.

Smart Grid Architecture Model

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 21 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.

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 technical specification (TS) IEC TS 63200 ED1: System Reference Deliverable SRD: Definition of Extended SGAM Smart Energy Grid Reference Architecture [2021]. This System Reference Document (SRD) defines the framework elements, associated ontology, and modelling methodology for designing the Smart Energy Grid Reference Architecture using the SGAM.

CEN-CENELEC-ETSI gap analysis of CEP

CEN-CENELEC-ETSI Working Group Clean Energy Package drafted a report [2018] that intends to address the key legal propositions of CEP which are considered as most relevant for standardisation. Four priority topics related to data interoperability were captured:

- Data Management, format and interoperability
- Real time access to consumption data and connectivity to the smart metering infrastructure
- Interoperability with Consumer Energy Management systems
- Operational data exchange between grid operators and grid users

European strategy for data

Data strategy adopted in February 2020 [EC, 19.02.2020] looks into several problems like availability of data, data interoperability, data governance, data infrastructure, empowering individuals to exercise their rights. It should be ensured that data can flow within the EU and across sectors, data protection rules are fully respected, the rules for access to and use of data are fair, practical and clear, there are clear and trustworthy data governance mechanisms in place. All this is valid for different domains, including energy. The actions serving single market of data address:

- A cross-sectoral governance framework for data access and use. In November 2020 EC announced the Proposal for a Regulation on European data governance or so-called Data Governance Act [EC,

25.11.2020] as the first of a set of measures to implement European strategy for data. The regulation lays down the conditions for the re-use of certain categories of data held by public sector bodies as well as notification and supervisory framework for the provision of data sharing services.
- Enablers: Investments in data and strengthening Europe's capabilities and infrastructures for hosting, processing and using data, interoperability. In the period 2021-2027, the Commission will invest in a High Impact Project on European data spaces and federated cloud infrastructures. Concretely, the Commission intends to fund the establishment of EU-wide common, interoperable data spaces in strategic sectors.
- Competences: Empowering individuals, investing in skills and in SMEs (Small and Medium-sized Enterprises).
- Common European data spaces in strategic sectors and domains of public interest. This includes a Common European energy data space, to promote a stronger availability and cross-sector sharing of data, in a customer-centric, secure and trustworthy manner, as this would facilitate innovative solutions and support the decarbonisation of the energy system.

ENTSO-E report on state of play of data exchanges in Europe

The report on Data Exchange in Electric Power Systems: European State of Play and Perspectives [ENTSO-E, THEMA, 2017] stated that data exchange platforms (DEPs) are a tool for improving coordination and market functionality. In the building of an efficient integrated European electricity market, information exchange and data management are becoming more connected. Increased information access and exchange not only leads to substantial efficiency gains in grid operation and planning, but also lowers market access barriers, ensures transparency in consumers' usage and creates new market opportunities (e. g., energy services companies). An increasing harmonisation of standards and formats across Europe may make it easier for companies to provide services across several countries. Data stored and exchanged will grow beyond mere metering values to include market data, like weather forecasts or spot prices, grid congestions, unavailability of assets or possibly even grid-planning data where this is relevant for other stakeholders besides system operators. Efficient data exchange is also necessary for achieving a seamless integration between wholesale and retail markets.

Facilitating customers energy data management and interoperability – DSOs' perspective

E.DSO position paper [2020] highlights the interoperability and consent management as basis for data exchange. It also explains two approaches to data management, either as centralized data exchange via a single DEP or decentralized data exchange carried out bilaterally between actors. From the European wide interoperability perspective the report lists three options to support cross-border data exchange:

- Harmonization of all necessary layers to achieve interoperability (especially data formats and protocols)
- Create comparability of national solutions: mapping of Member States processes and information models towards a core reference model
- Implementation of cross-border DEPs: connecting the national data systems (centralized or decentralized) and translating the national specifics

Another DSO association, GEODE, elaborates data management approaches by adding hybrid model (beside decentralized and centralized models) which would be a combination of the two previous models – all market participants can communicate in a decentralized manner, but in some use cases (e.g. compliance monitoring for services like supplier switching, supervision of trading activities or integration functionality for e.g. smaller parties), there are task-specific central structures [2020].

DG CNECT funded study on interoperability for demand side flexibility

Specifically for the electricity domain the increasing importance of data interoperability has become obvious through the emergence of flexibility market. The study on interoperability for demand side flexibility [EC, DNV GL, ESMIG, TNO, 2018] has investigated the need for alignment among the communication standards from the Utility, Telecom and Home appliances industries. This is highly relevant for the data needed for demand side flexibility (DSF) which needs to flow seamlessly through an IT infrastructure that connects Smart Meters, Consumer Energy Management Systems, Smart Appliances and Gateways between the home and external networks. Nine standards were selected that have been compared with the reference ontology SAREF (Smart Appliances REFerence ontology) and its extension for the Energy domain, SAREF4ENER. It was concluded that alignment between DSF standards is needed and that SAREF/SAREF4ENER can be used as the overarching ontology to facilitate this alignment. The study has shown that SAREF/SAREF4ENER can be used to reach interoperability on data level and as the ontology for the interfaces that are relevant for DSF applications.

DG ENER funded study: Assessment and roadmap for the digital transformation of the energy sector towards an innovative internal energy market

The assessment and roadmap for the digital transformation of the energy sector towards an innovative internal energy market [EC, PwC, Tractebel, 2019] highlighted several key issues and related actions (recommendations) concerning the provision of flexibility services at the distribution level. Key issues related to data interoperability:

- The access to consumption and production data – implementation of the Directive on the IEM (Internal Energy Market) to establish the right of customers and third eligible parties to receive all relevant consumption and production data, in an understandable format, the development of interoperability requirements at the EU level, implementation of the new Directive on the IEM with respect the access and exchange of customers' consumption and production data, development of EU recommendations/guidelines on interoperability standards at the EU level, adoption of binding (EU) interoperability requirements.
- Customer privacy and data protection – implementation of the Directive on the IEM including the provisions related to data protection of smart meters' data in the smart metering system deployment, implementation of the new Directive on the IEM with respect to smart meters data management model, development of EU recommendations/guidelines for setting principles that need to be complied by all data management models for smart meters in place or currently under design.
- Interoperability between connected devices – implementation of the Directive on the IEM to define smart metering systems interoperability, adoption by the Commission of common guidelines to MSs (Member States) for the adoption of standards and best practices for smart metering systems interoperability, adoption by the Commission of Implementing Acts to determine interoperability requirements and nondiscriminatory and transparent procedures for access to data, adoption of binding (EU) interoperability requirements supported by the introduction of relevant parameters (KPIs – Key Performance Indicators) for products and parts.

ASSET study on data format and procedures

The report on Format and procedures for electricity (and gas) data access and exchange in Member States [ASSET Project, 2018] analysed European national practices. Based on this fact-finding exercise, differences among MSs and barriers even within MS were identified when it comes to access and exchange of data. A number of recommendations were formulated, some of them very relevant for this BRIDGE study as well:

- The national regulator should enforce compliance with a single national format. This is especially the case in decentralised data management systems and in countries where energy policy is a regional competence.

In particular, the national regulator should verify whether national formats are general enough to accommodate differences in regional policy choices.

- The national regulator increases transparency at MS level, by making publicly available on a website the role models, the data formats and all standard as well as non-standard procedures for processes such as supplier switching and billing. Furthermore, the EC could consider setting up a European website where national procedures are collected and centrally published in at least one common EU language.
- Standardisation organisations update existing international standards, like CIM, as a pivot language ensuring the compatibility of national communication choices. Clearly defined national formats and procedures are a pre-condition for an efficient mapping.
- The existence of a transparent consent management for giving, and especially revoking access should be the first priority to be addressed by MS deploying smart metering systems.

There are many further frameworks and standards influencing the landscape of energy data exchange architecture, some of them referenced in detail in this report: CIM, FIWARE[3], IDSA[4] (International Data Spaces Association), SAREF, DLMS-COSEM (Device Language Message Specification – Companion Specification for Energy Metering), IEC 61850, HEMRM, USEF[5], OPEN DEI[6], national data hubs and platforms (like EDA – Energy Data Exchange Austria, Energy Data Exchange Framework in Netherlands, Estfeed in Estonia), ICT4Water[7], GAIA-X[8], Data Bridge Alliance, EC communication on European Interoperability Framework [EC, 23.03.2017], EC's annual Rolling Plan for ICT Standardisation[9].

2.2 Data exchange platforms and common European architecture

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 optimize. 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 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.

Several papers [E.DSO, 2020; GEODE, 2020; Elering, Pöyry, 2019] have described the benefits of different data exchange models (decentralized, centralized, hybrid, distributed). The focus of this BRIDGE report is on data exchange platforms. Interoperable DEPs aim to improve data exchange processes between the different parties (e.g. system operators, aggregators, market operators etc.) connected to the electricity system and market. The

[3] https://www.fiware.org/
[4] https://www.internationaldataspaces.org/
[5] https://www.usef.energy/
[6] https://www.opendei.eu/
[7] https://ict4water.eu/
[8] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[9] https://ec.europa.eu/growth/single-market/european-standards/ict-standardisation_en

upcoming adoption of data exchange platforms and their functionalities are certainly designated to different regimes and practices throughout Europe. Some recent studies and reports [ENTSO-E, THEMA, 2017] have covered the development of data exchange platforms primarily from a retail market perspective. However, as it will be presented in Chapter 3, lately there have been R&D projects addressing both retail and wholesale markets.

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].

However, as data exchange platforms bundle not only processes but also versatile actors, it is vital to view the energy system as a unique system instead of several separate systems such as TSO grids, DSO grids, etc. The power system as a whole can be perceived where all parties involved should work together in achieving a safe and reliable electricity system and social welfare optimisation via regulatory oversight.

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.

2.3 Information models

Former EC Mandate M/490 [EC, 2011] has developed a reference architecture methodology between 2008 and 2012 which was then standardised by IEC. The Use Case methodology and associated standards were developed (IEC 62559 series, IEC 62913 series), the SGAM model was further developed and standardised [IEC 63200, 2021]. The Information Layer of SGAM is a placeholder of IEC Common Information Model, standardised by IEC in IEC 61970-301 [2020], IEC 61968-11 [2013], IEC 62325-301 [2018] information models.

Figure 3 reminds the methodology based on SGAM interoperability layers.

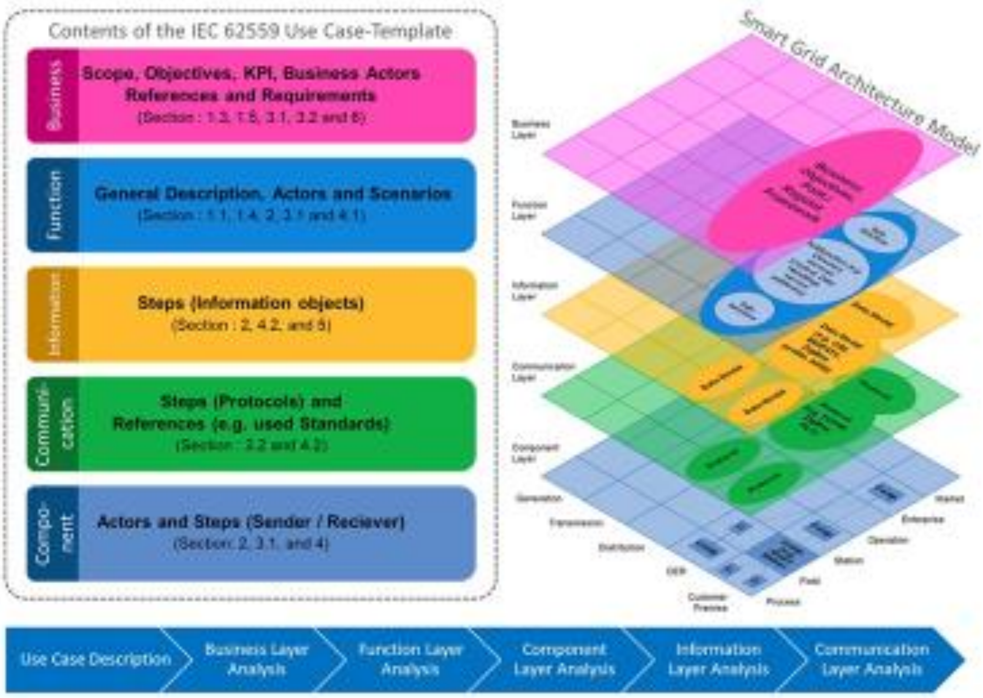


Figure 3: SGAM and Use Case Template sections' relationships [TDX-ASSIST Deliverable 1.14, 2020]

Figure 4 zooms on the methodology and relationship between Use Case definition, Business Object definition (Data Flow content definition) and Profile definition. The left part describes the Use Case methodology, which helps to define requirements of information exchanges. Data flow content definition on the right part of the figure can be named "Business Objects", which express semantic requirements. Business Objects lead to the definition of profiles. A profile is derived from information model like IEC CIM, or any kind of Information Model.

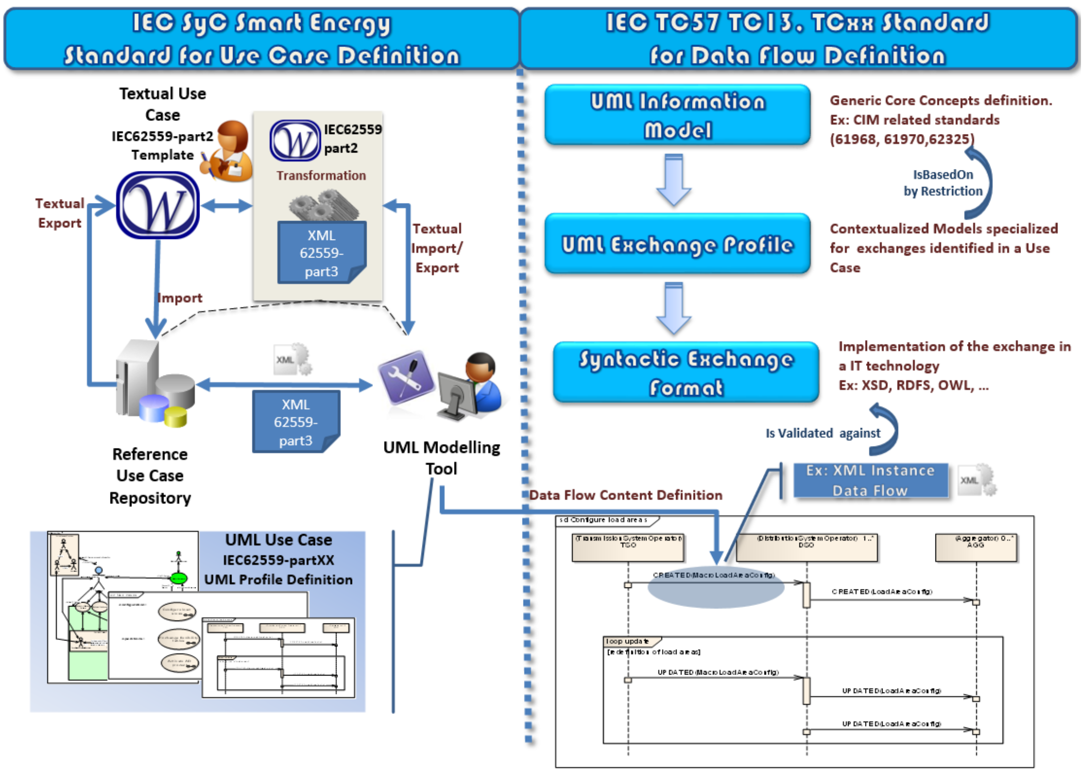


Figure 4: Use Case and Profile methodology relationship [TDX-ASSIST Deliverable 1.2, 2018]

Figure 5 illustrates Business Objects associated to System Use Case definition managed in TDX-ASSIST UML repository.

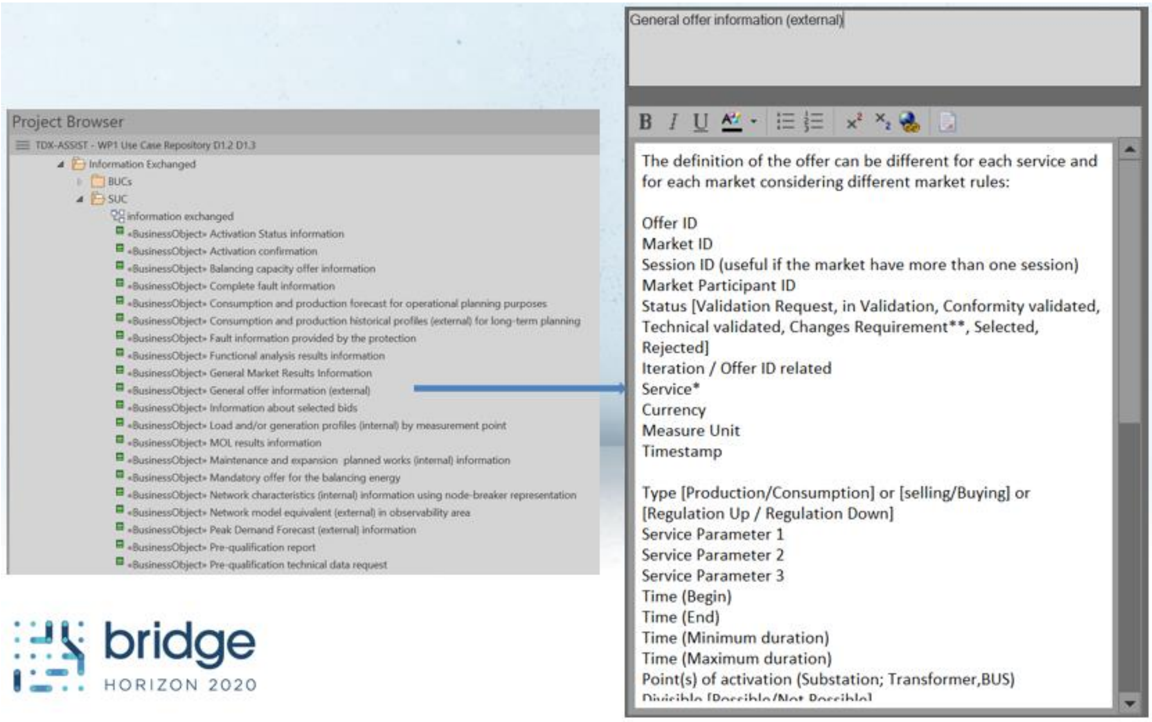


Figure 5: Business Object semantic description example [TDX-ASSIST Deliverable 1.12, 2020]

One of the reference models' building block is the information model (recommendation #6 of [SGTF EG1, 2019]. 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 as described in Introduction (Figure 2).

IEC CIM is one of the three core information models identified by IEC Smart Grid Standardisation Roadmap [IEC 63097, 2017] as illustrated in Figure 6. 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].

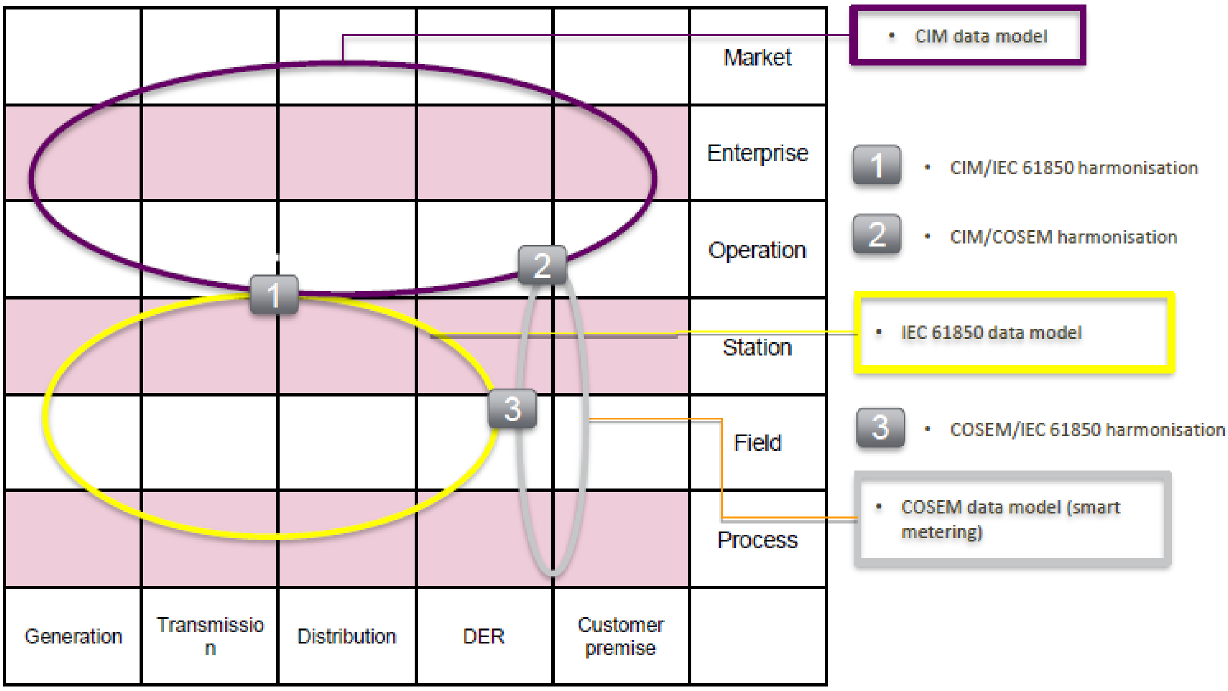


Figure 6: IEC core information models: CIM, IEC 61850, COSEM [IEC 62357-1, 2016]

2.4 Models for data roles

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'.

Five role models applied by few Horizon2020 projects were identified and compared for this report, whereas EU-SysFlex and PHOENIX are project-specific models and HEMRM, IDSA and USEF are more generic frameworks.

<u>The Harmonised Electricity Market Role Model [ebIX, EFET, ENTSO-E, 2020]</u>

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".

"To build a Role Model diagram the UML class diagramming technique has been used. The diagram makes use of two UML symbols, the "actor" symbol (not to be confused with a party on a marketplace) is used to represent a role and the "class" symbol is used to define an object."

'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.

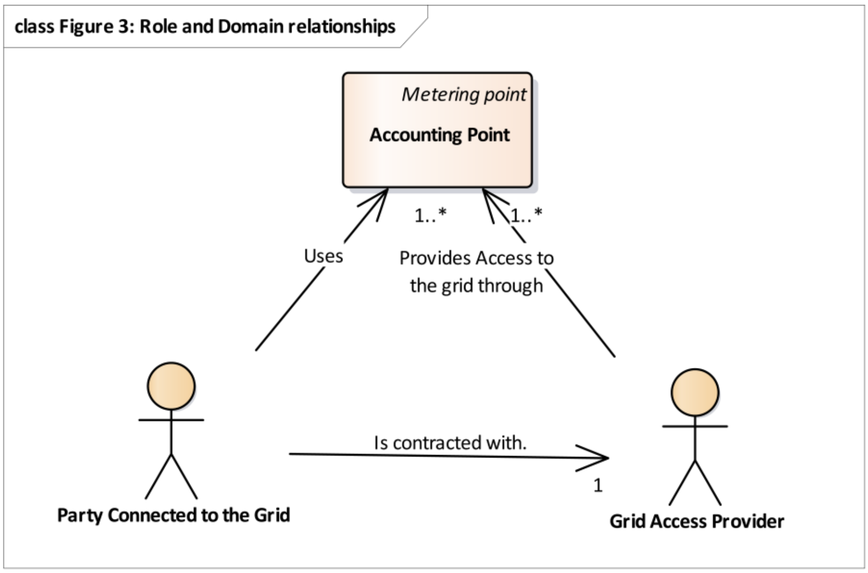


Figure 7: Role and Object relationships, example [HEMRM, 2020]

HEMRM is well recognised by European Commission and seems to be the most widely used role model, incl. by Horizon2020 projects. According to TSO-DSO Coordination study [BRIDGE, 2019] six projects out of 14 followed HEMRM in explaining data roles.

<u>THE FRAMEWORK EXPLAINED [USEF Foundation, 2015]</u>

“To the extent possible, USEF has chosen to align the names of the roles used in its model with the existing business roles commonly accepted throughout Europe and defined by ENTSO-E.” The only data exchange related role in USEF model is the Meter Data Company (MDC) which “is responsible for acquiring and validating meter data. The MDC plays a role in USEF’s flexibility settlement process and the wholesale settlement process”.

<u>Reference Architecture Model [IDSA, 2019]</u>

The Business Layer of the Reference Architecture Model defines and categorizes the different roles the participants in the International Data Spaces may assume. Furthermore, it specifies basic patterns of interaction taking place between these roles. It thereby contributes to the development of innovative business models and digital, data-driven services to be used by the participants in the International Data Spaces.

There are four categories of roles:

- CATEGORY 1: CORE PARTICIPANT. Core Participants are involved and required every time data is exchanged in the International Data Spaces. Roles assigned to, this category are Data Owner, Data Provider, Data Consumer, Data User, and App Provider. The role of a Core Participant can be assumed by any organisation that owns, wants to provide, and/or wants to consume or use data.
- CATEGORY 2: INTERMEDIARY. Intermediaries act as trusted entities. Roles assigned to this category are Broker Service Provider, Clearing House, Identity Provider, App Store, and Vocabulary Provider. These roles may be assumed only by trusted organisations.
- CATEGORY 3: SOFTWARE / SERVICE PROVIDER. This category comprises IT companies providing software and/or services (e.g., based on a software-as-a-service model) to the participants of the International Data Spaces. Roles subsumed under this category are Service Provider and Software Provider.
- CATEGORY 4: GOVERNANCE BODY. The Certification Body, Evaluation Facilities, and the International Data Spaces Association are the Governance Bodies of the International Data Spaces.

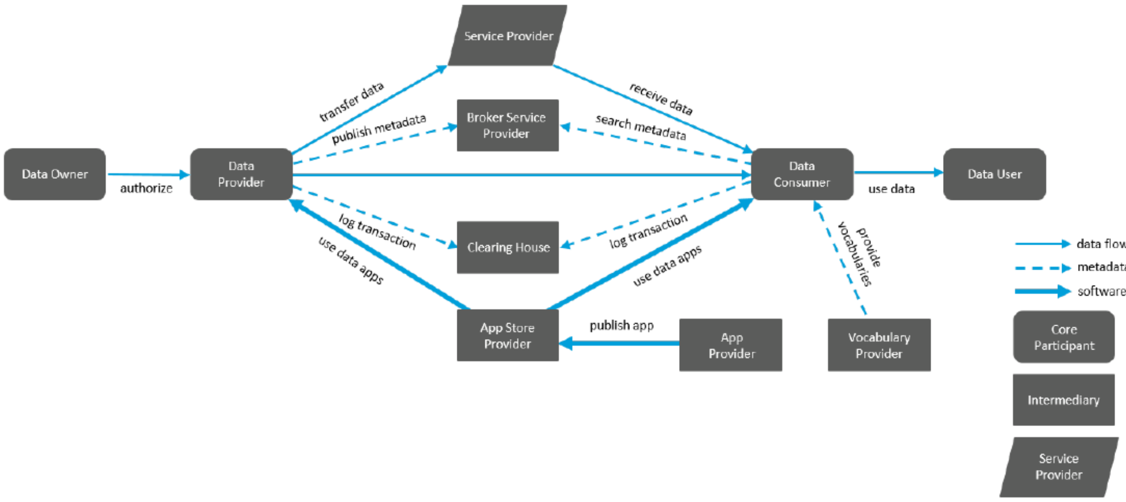


Figure 8: Roles and interactions in the Industrial Data Space [IDSA, 2019]

<u>EU-SysFlex role model [2020]</u>

The project developed data exchange SUCs as starting point. These SUCs focus on both business roles and systems. Systems are defined by a set of functionalities. Each system is operated by a Business Role whose responsibility must fit the functionalities of the system (e.g. a System Operator SCADA is operated by a System Operator). A system is used by the Business Role who operates it but can be used by other Business Roles (e.g. a Customer Portal is operated by a Customer Portal Operator and is used by Customers, Authentication Service Provider, etc.).

A business role model describes, in a static way, how Business Roles interact with each other and which data they exchange. Business Roles exchange data through systems, either because they use these systems or because they interact with them. This analysis led to the definition of a data exchange role model. The objective of data exchange role model is to:

- Relate Business Roles with one of the already existing role from the HEMRM,
- Identify new Business Roles motivated by business or IT needs.

<u>PHOENIX role model</u>

Phoenix project has endeavoured to define and describe the (business) roles that are related to data exchange. These roles adhere to the external logical boundaries of the PHOENIX data exchange pipeline. Most of them refer to the Incidents' Information Sharing Platform (I2SP), which is responsible for communicating processed Computer-Telephone Integration data to the eligible and interested parties (e.g CERT-EU).

In the light of this, the Authentication Service Provider is envisioned as a trusted authority whose role is to verify the identity of the interested and eligible entities. In addition, I2SP System and Operator is responsible for the management of authentication procedures. I2SP Dashboard Operator is responsible for making the available relevant data presentable to the interested parties through the I2SP dashboard.

The origin of the exchangeable data is mapped to the Data Owner (an Electrical Power and Energy Systems stakeholder). The I2SP Data User and Data Provider situates on the other end of the pipeline and is responsible of handling and managing the processed data and subsequently providing them to the eligible and relevant channels.

The business role model analysis is not part of any PHOENIX deliverable, thus the aforementioned business roles cannot be mapped to any relevant document.

3. Data exchange platforms

3.1 Objectives and structure of questionnaire

3.1.1 Introduction and objectives

Lately, the ambitions of European Commission to enable consumers and prosumers to take part in the energy transition, have been highlighted in several initiatives such as the Clean Energy Package [Directive (EU) 2019/944]. This should be realised through equipping end-users with proper tools and rights to access energy markets. The former has enabled consumers to access and assess their own energy data and share it among (contracted) third parties, under their consent. Along with novel commercial services based on data sharing, there are evolving services relying on demand-side flexibility.

This BRIDGE report attempts to collect information from EU R&D projects according to their conceptual and technical details towards EU wide data platforms. Such data platforms and data architectures have been lately investigated in several EU R&D projects driven by the recent regulatory developments that mandate increased coordination and aim to enable customers to participate actively in both the retail and wholesale energy markets. Hence, more demanding requirements for data exchange between all stakeholders are foreseen. Data exchange platforms can play a vital role in the overall electricity sector, particularly, towards an integrated pan-European wholesale-retail market. This report captures technical developments of data exchange platforms, architectures and functionalities, which can be efficiently leveraged for the definition of a common European reference architecture for the electricity domain.

Thus, a questionnaire was prepared and disseminated to projects that are actively participating in the Data Management WG of the BRIDGE Initiative (see Annex II). Each project is asked through the proposed questionnaire if a representation of an interoperable data platform concept has been agreed and is available, which may not be specific to but may include data aspects. Through the questionnaire, the main pillars of interoperable functionalities of implemented digital architectures are mapped in an iterative approach to constitute the general data exchange framework.

Within this section the common structural elements, methodological approaches and technologies adopted within several EU wide projects for the development of interoperable data exchange platforms are examined.

Both traditional retail processes and emerging 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. Data exchange platforms have been introduced in several European countries led by the need for effective processes and increased data quality and volume with minimal delay, initially in retail markets.

3.1.2 Structure of questionnaire

The proposed structure is comprised of three different types of questions as presented in Figure 9. The first type of questions aims to capture general information regarding the scope and the wider vision of each developed data exchange platform. In those questions, the main objectives, roles/actors, architectural and specific use cases are recorded. Following this, the project specific questions focus on more technical information concerning standardised processes and functionalities, the methodological approach followed to develop interoperable data exchange frameworks. Furthermore, the layer, the particular effort as well as the lack of focus along the SGAM framework are recorded. The standards and protocols are enlisted in order to determine the common practices deployed along the different R&D projects from a technological viewpoint. In the last part of the questionnaire, there are questions related to the benefits and the visions towards the establishment of a common European reference architecture for the electricity sector.

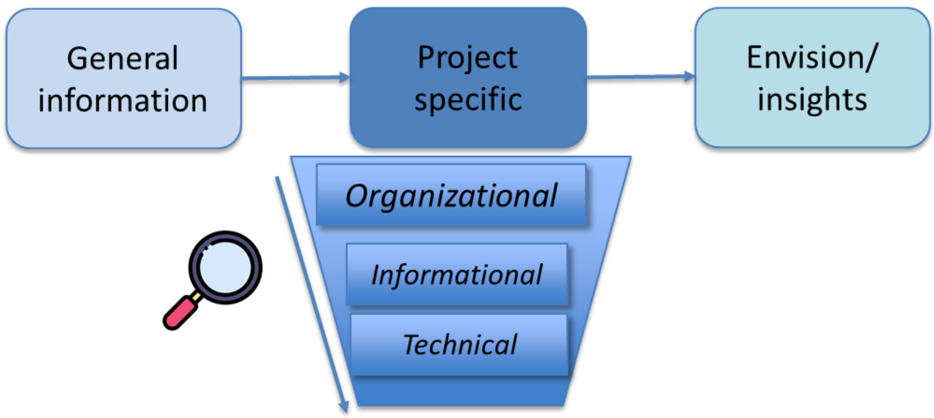


Figure 9: Structure of the reference architecture questionnaire

3.2 Main findings of survey

3.2.1 General project objectives and details

The increasing need of integrating DERs in the power systems is transforming the landscape in the energy sector and it is subsequently introducing new actors and roles in the power systems. This also introduces increased observability and management needs. The volume of data available nowadays is higher than ever; thus the need for efficient data platforms emerges more prominently. A multitude of 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. Through this questionnaire, a first attempt to identify the common objectives between those projects is being applied. In this section we will present those objectives, the roles that appear in the projects and the use cases that each project is implementing identifying similarities and commonalities and highlight the main focus areas.

Based on the feedback received from the 12 projects that answered the questionnaire it is established that the majority deals with data gathering, processing and exchange for the provision of different services. The projects participated in this survey (see Figure 10: Explored projects Figure 10) are INTERRFACE, EU-SysFlex, FLEXIGRID, GIFT, InterConnect, PLATOON, SYNERGY, CoordiNET, BD4OPEM, TDX-ASSIST, ebalance-plus, RENAISSANCE. In most cases, these services aim to assist the operation of TSO and DSO grids, but they also extend to fields such as achieving energy efficiency, comfort and energy savings. Access to markets is also frequently addressed in many projects by providing ways to communicate and exchange data with various market platforms in a standardised and structured way. Coordination between system operators is also a focus issue in some projects, by examining ways for the operators to exchange data in order to better coordinate their actions, resulting in a more reliable and efficient operation of the grid. Finally, analytics and big data processing in order to facilitate more efficient forecasting and more targeted services is also addressed by projects.

It is obvious that each project has a different focus area and there are numerous applications that are currently being examined. Nevertheless, a common need which translates into a core objective can be identified. This is the requirement to connect versatile actors, existing legacy and newly developed systems and devices in a way that allows the seamless exchange of data in a standardised and technology agnostic way. The need for interoperability is prominent.

It is encouraging that the majority of the projects are dealing with similar communication standards in their effort to reach an interoperable data platform. Only by adopting standardised solutions, it will be possible to achieve communication between versatile systems. The CIM model is being incorporated in many of the participating 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. Standardised solutions for establishing communication channels, such as ENTSO-E's ECCo SP platform was also frequently mentioned. 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.

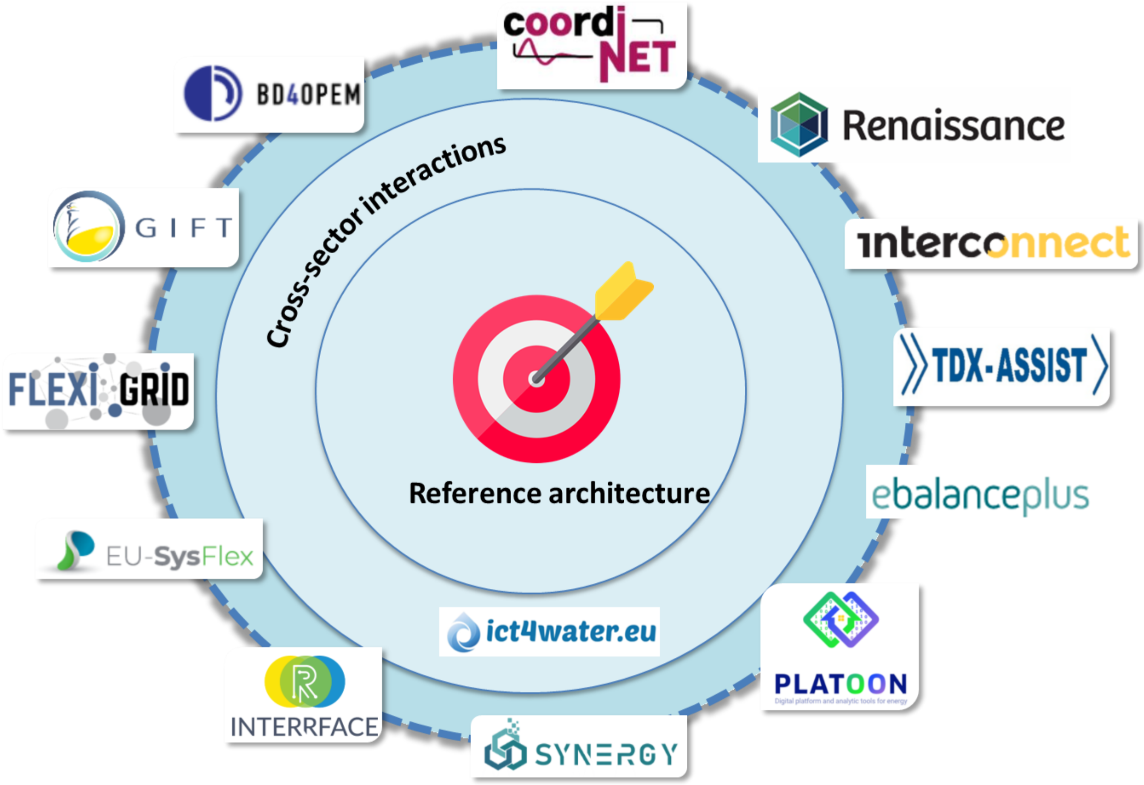


Figure 10: Explored projects for reference architecture

Regarding the roles that are being addressed, in most of the cases the core grid roles are present: Transmission System Operator, Distribution System Operator, Market Operator, Consumer and Producer/Generator are being addressed by most projects. Roles like the Aggregator, the Flexibility Service Provider and the Prosumer, ESCO (Energy Service Company) and Retailer are also gaining increasing focus. Nevertheless, when dealing with data platforms, and given the increasing complexity of data handling, new roles are emerging and are currently being examined by most R&D projects: Data Owner, Data User, Data Validator, Data Hub Operator are among those roles which are gradually being proposed. The need to include actors representing those roles is crucial, as the digitalization of the power systems is becoming a core objective of the energy transition. Roles related with the allocation of access rights and authentication are also becoming important, since data privacy is a really sensitive issue. Finally, many application-specific roles are being proposed by projects, such as the Flexibility Register Operator. Significant effort is required to standardise those roles, so that the responsibilities are clear and do not overlap.

The concepts of each explored data exchange platform of the participating R&D projects in this survey are summarized in Table 3.

Table 1: Explored Data Exchanged Platforms

Project name	Data exchange platform
INTERRFACE	IEGSA Platform, enabling coordination and the more robust operation of the power systems
EU-SysFlex	Platform scaling and replicating Estfeed distributed solution and agnostic to specific business processes
FLEXIGRID	FLEXIGRID DEP based on Atos FUSE
GIFT	Enterprise Service Bus based DEP
InterConnect	Platform focusing on semantic interoperability
PLATOON	PLATOON DEP – COSMAG compliant
SYNERGY	SYNERGY Big Data-driven Energy-as-a-Service (EaaS)
CoordiNet	CoordiNet Platform grid monitoring & operation, market operation and aggregation & disaggregation
BD4OPEM	DEP that leverages smart grid big data
TDX-ASSIST	Cloudera and ECCo SP platforms
ebalance-plus	Concept of distributed data storage (middleware) that is deployed on management units
RENAISSANCE	DEP based on Atos

3.2.2 Brief conceptual overview of proposed data exchange platforms

In this section there is a brief introduction provided pertaining the participating projects and developed data exchange platforms. Note that this is only a conceptual description of the interoperable data platforms and the projects as a whole. The derived common interoperable functionalities are framed within the results' analysis section.

INTERRFACE

An Interoperable European Grid Services Architecture will be developed, namely the IEGSA Platform. IEGSA platform will facilitate data exchange and communication between System operators, enabling coordination and the more robust operation of the power systems. It will also enable communication and data exchange between all involved actors enhancing transparency and allowing market access and participation of new actors, such as prosumers.

A conceptual illustration of IEGSA platform is provided in Figure 11. The illustration provides a comprehensive representation within the SGAM framework.

The roles involved are: TSO, DSO, MO (Market Operator), Aggregator, Flexibility Service Provider, Imbalance Settlement Responsible, Balancing Responsible Party, Consumer, Prosumer and new roles introduced by the project, such as: Flexibility Register Operator, TSO-DSO Coordination Platform Operator, Single Interface to Market Operator and Settlement Unit Operator. Several applications and usages of the IEGSA are described through demos. In Figure 12 the architectural components (Flexibility Register, TSO-DSO Coordination Platform, Settlement Unit) are illustrated.

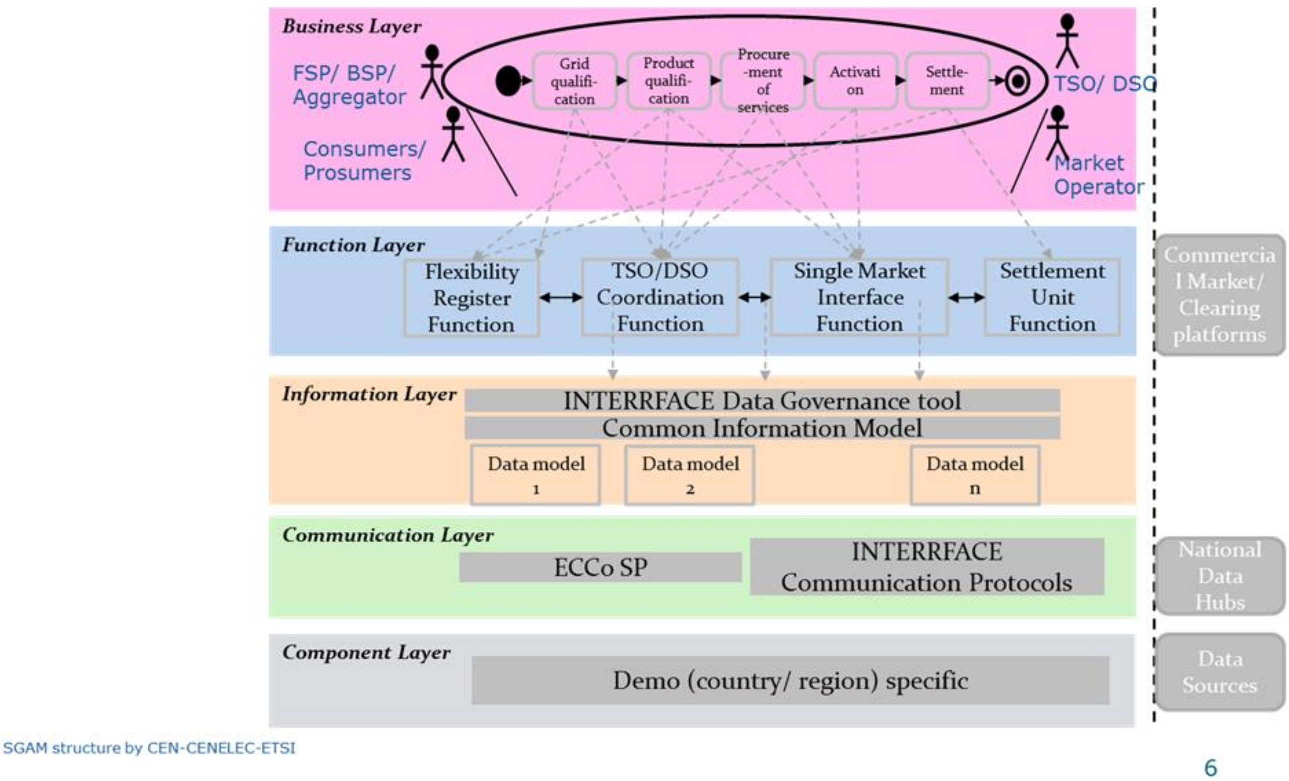


Figure 11: IEGSA mapping on SGAM framework [*provided in survey*]

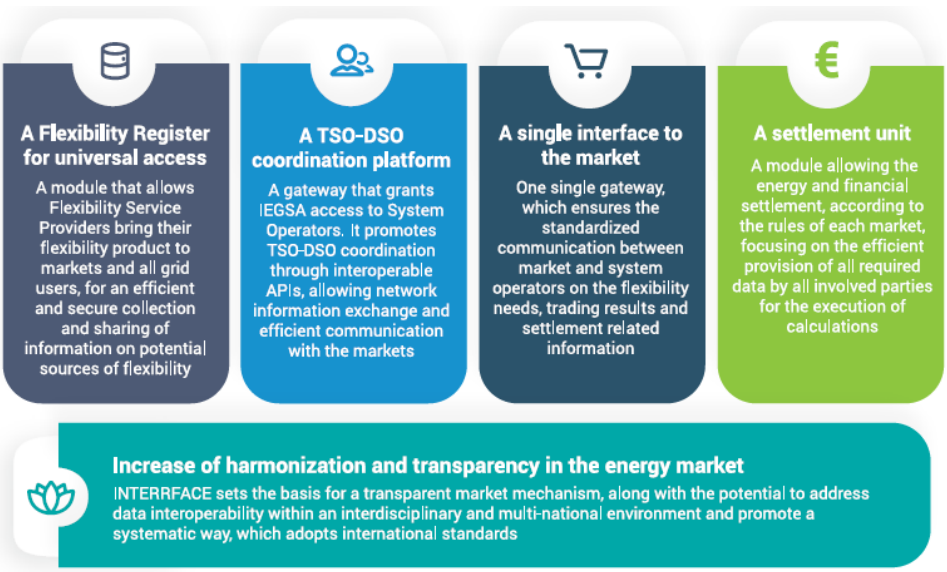


Figure 12: Architectural components of IEGSA [*provided in survey*]

EU-SysFlex

Estfeed platform [Cybernetica, 2018] was originally developed by Elering based on 'x-road' solution of Estonian government. It is a distributed solution and agnostic to specific business processes. Estfeed can interface with various data sources and these data can be used in the applications desired.

Data exchange involves 3 parties (see Figure 13):

- Application information system – consumer of data and services; communicates with the Estfeed system using Estfeed protocol;
- Source information system (data source) – provider of data and services; communicates with the Estfeed system using Estfeed protocol;
- Estfeed system – mediator of data and services between applications and data sources.

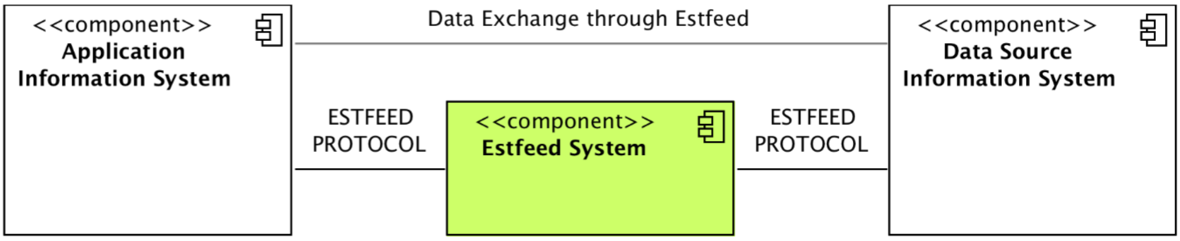


Figure 13: Estfeed protocol overview [Cybernetica, 2018]

Several functionalities require 'customer portal'. Currently Estfeed has its own portal. It gives the market participants access to their meter data and enables downloading the data. The client portal also provides the market participants an overview of all information concerning the participant found on the Data Hub: agreement deadlines, open suppliers, hourly meter data, the market participant's EIC (Energy Identification Code) code, and the EIC codes of the metering points linked to the market participant. All market participants can provide authorizations for accessing meter data from previous periods via the portal. The market participant's data can be accessed by market participants who have a statutory right to access the data or who have been given authorization to access the data by the market participant themselves. Customer Portal also enables to see the list of service providers. In addition, representation rights can be given and access to security logs is enabled.

The objective in EU-SysFlex is to scale and replicate the Estfeed solution - i.e. enable to exchange any type of data and enable to exchange it across country borders. Also, the interoperability with other data platforms will be tested. Relevant use cases built around Estfeed platform are listed in next question. The core actors (roles are Data Exchange Platform Operator and Customer Portal Operator but also other data management specific roles like Data Owner, Data User, Data Hub Operator, Authentication Service Provider, Metered Data Operator. In addition, several business process specific roles are present in these use cases - e.g. System Operator, Market Operator, Flexibility Service Provider.

FLEXIGRID

The project applications and demo sites will be combined in a common IT approach by using an interoperable architecture based on Atos FUSE and outlined in Figure 14.

ATOS FUSE is an open source platform that enables the integration of devices at the edge by fully exploiting data available from local and distributed energy resources. As shown, FUSE establishes a common framework or middleware for the applications to be executed sharing the access to the project information regardless of the underlying data models and structures, thus keeping them away from data management efforts and responsibilities. To achieve these concepts, a modular ensemble is available with different internal components:

- Service API: interfaces that expose the available data resources to the applications.
- Semantic repository: interoperability and replicability can be only achieved through the use of a common semantic model. FUSE follows the efforts developed in the CIM definition in ETSI, supported by SAREF and its multiple extensions.
- Data management services: modules dealing with data ingestion, preparation, analysis and exposition.
- Data API: interface for the integration of the external data sources, either grid infrastructure or other software platforms.
- Adapters: connection elements that enable external entities (grid or data inputs) to set bidirectional communication and benefit from the interoperability capability of the INTERPRETER middleware. Their architecture is based on FIWARE IoT Agents, adapted to the specific needs of the energy sector and connect the outer sources to the Data API.

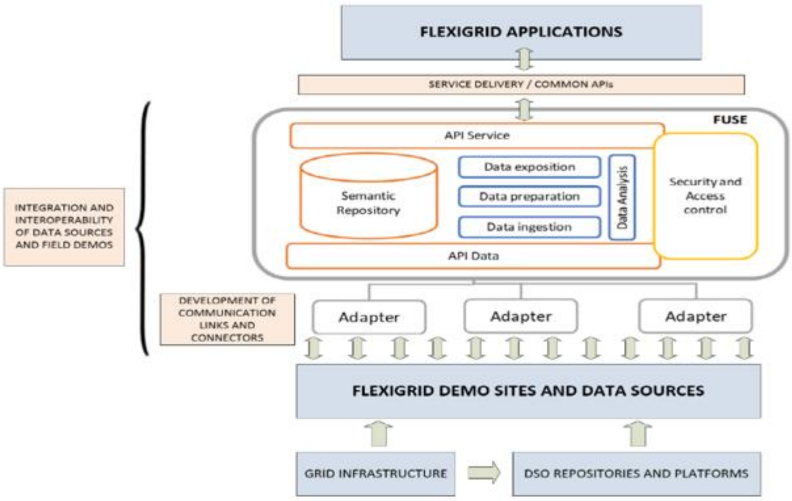


Figure 14: FLEXIGRID proposed data exchange platform [*provided in survey*]

These resources and their modularity pave the way for the integration of all FLEXIGRID demo sites and applications. This way, the data interoperability, acquisition and communication issues can be addressed separately from the grid infrastructure and the applications, nevertheless ensuring the overall performance of the final results coming from the combination enabled by FUSE.

Geographical Islands FlexibiliTy (GIFT)

The data platform used in the GIFT project is the Enterprise Service Bus (ESB), developed by Intracom SA Telecom Solutions. It collects the data from the aggregator, the grid observability system, the weather, energy supply and demand and price predictions systems, along with external information from DSOs, BRPs (Balancing Responsible Parties) and municipalities. It also communicates some data to the data repository for storage. Therefore, the ESB will enable the communication and data management for the whole GIFT system. This system will be used for congestion management and local energy communities' management. The developed data platform is illustrated in Figure 15.

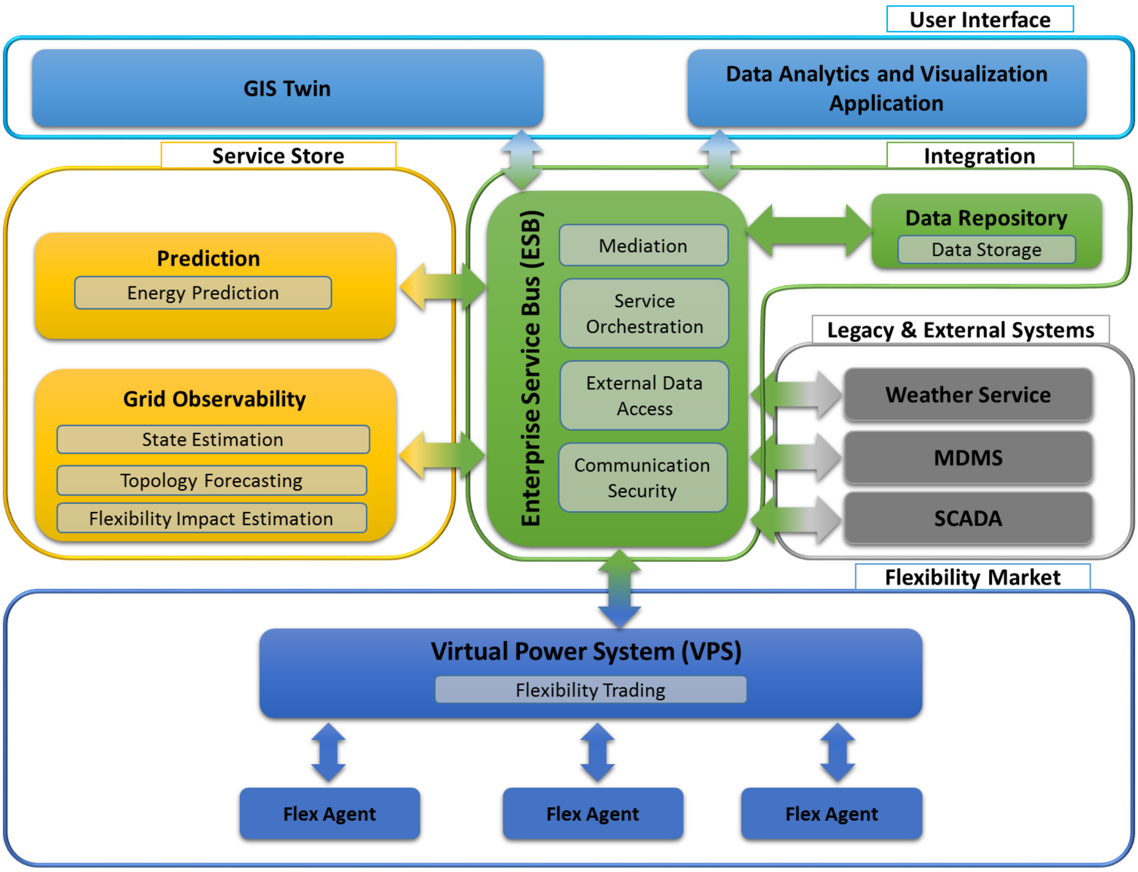


Figure 15: The data platform used in the GIFT project is the Enterprise Service Bus (ESB) [*provided in survey*]

InterConnect

The platform/framework that is being developed in InterConnect uses a semantic interoperability layer to ensure high levels of interoperability. This also enables different (vendor/technology) IoT platforms to be used in the platform instantiations. The main goal is to bring efficient energy management within reach of the end-users:

- Establish interoperability framework validating SAREF and semantic interoperability
- Large-scale pilot leading to market driven deployments
- Marketplace of integrated digital platforms and services bridging the gap between IoT and energy
- User centric energy and non-energy services

Main actor/device (areas) that the architecture identifies are: in building devices and sensors, outside building devices such as EV (Electric Vehicle), the User, the DSO, various supportive energy services (forecasting, local/technical aggregation, *etc.*), several non-energy and energy actors (comfort and smart living providers, energy service companies, aggregators, TSO *etc.*) and of course platform (solution) providers. Use cases consist in energy domain and non-energy domain, the latter is more user focussed on comfort, convenience, control/automation, security *etc.* The proposed platforms aims to unlock and channel the information flows related to: Devices, Sensors, Users, DSO (and local technical aggregator or forecaster supportive functions) via the platform and interoperability layers to energy and non-energy actors and services.

PLATOON

PLATOON will develop a COSMAG-compliant reference architecture for big data processing for the energy sector. PLATOON will develop interoperability layer based open standards (e.g. SAREF, CIM, NGSI-LD) to ensure compatibility with different platforms and legacy systems. There are several use cases employed to support the development such as Predictive Maintenance for Wind Farms, Electricity Balance Predictive Maintenance in power plants, Electricity grid stability, connectivity and life extension (i.e. Predictive Maintenance in Transformers Non-technical loss detection), Office building-operation performance thanks to physical models and AI algorithm, Energy Management System and spatial (multi-scale) predictive models in the smart city, Building Energy Management System Building Asset Energy Management System, Energy Efficiency and predictive maintenance in the smart tertiary building Hubgrade, Advanced EMS (Energy Management System) in Smart Tertiary Building Predictive Maintenance in Smart Tertiary Building, Energy Management of Microgrids.

SYNERGY

SYNERGY will attempt to unleash the data-driven innovation and collaboration potential across currently diversified and fragmented electricity actors, acting as a multiplier of the “combined” data value that can be accrued, shared and traded, and re-conceiving real-time data sharing against traditionally bilateral contracting applied in the electricity sector, to enable holistic optimization of the operation of electricity networks and the energy performance of their constituent components (RES plants, buildings, districts). The expected data ingestion, data curation, data sharing and data analytics functionality is delivered through different data-driven services bundles that have well-defined interfaces to ensure their seamless integration and operation within the SYNERGY integrated platform, as follows:

- Data Collection Services Bundle: During a 2-step process, the real-time and batch data assets are properly registered in the SYNERGY core platform.
- Data Security Services Bundle, that is responsible for safeguarding and securing any data asset (and trained analytics) that become available or pass through SYNERGY.
- Data Sharing Services Bundle, which lies at the core of the SYNERGY platform as it handles the adopted sharing / trading mechanisms, the effective remuneration approach and the multi-party data contracting lifecycle and is powered by blockchain technologies.
- Data Matchmaking Services Bundle, bringing a demand-driven mentality to the SYNERGY platform as opposed to the typical supply-driven operation of the data marketplaces.
- Data Analytics Services Bundle that essentially allows for exploratory data analysis, designing and monitoring analytics workflows and visualizing the analytics results in intuitive dashboards, and running pre-trained industrial / personal / edge analytics to generate new insights and knowledge for all energy stakeholders.
- Scalable Data Storage Services Bundle that provides different persistence modalities.
- Data Governance Services Bundle and Management Services Bundle which are responsible for the platform's auxiliary services, e.g. resources’ orchestration, provision of data usage analytics to data providers (in accordance with GDPR).

In particular, through the analytics services bundle, derivative data and intelligence will be generated, mainly focusing on baseline Personal Analytics (consumer energy behaviour, comfort preferences and flexibility) and Industrial Analytics (Building Energy and Predictive Maintenance analytics, RES plant Operations and Maintenance Analytics, DER (Renewable Energy Sources) Forecasting and Flexibility analytics, Grid Operation and Preventive Maintenance Analytics), along with Baseline Edge Analytics for the enhancement of intelligence at the local level towards automated control and optimization actions whenever needed (e.g. Smart Home/ Building Automation for the provision of critical flexibility services). In Figure 16 there is a conceptual representation of the proposed data processes.

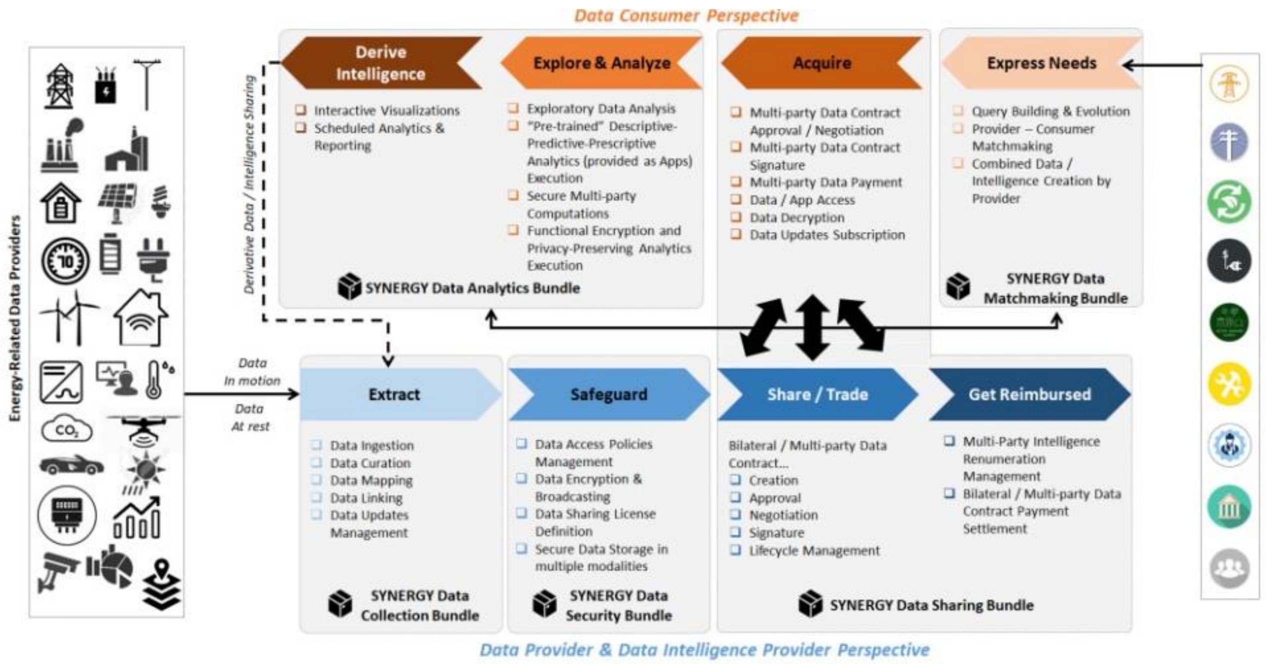


Figure 16: SYNERGY Big Data driven Energy-as-a-Service (EaaS) and proposed processes [https://www.synergyh2020.eu/about/the-project/]

CoordiNet

The project is defining a platform architecture to procure system services. The architecture is made up of three main blocks: grid monitoring & operation, market operation and aggregation & disaggregation. Information exchanges among the three blocks are being identified in order to standardise the interfaces among them. Moreover, the information that needs to be exchanged between TSOs and DSOs will also be investigated to also standardise it. Therefore, the actors involved include TSOs, DSOs, aggregators, flexibility service providers (owners of flexible assets) and operators of markets for system services (which may be TSOs and DSOs themselves). Figure 17 provides a representation of the proposed CoordiNet Platfrom.

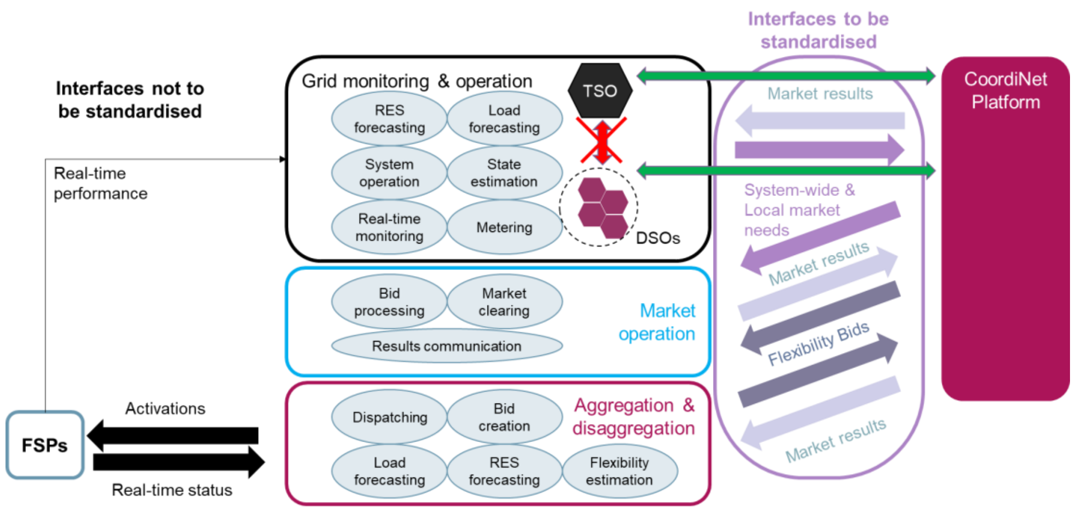


Figure 17: Coordinet platform [provided in survey]

The business use cases (BUCs) include combinations of services to be considered (balancing, congestion management, voltage control and controlled islanding), coordination schemes, timeframes and product types. In parallel, real platforms are being developed within the three demonstrators, which take this general view into account, but evolve over existing systems:

- In Spain, two platforms will be used:
    - The TSO is adapting existing systems to ensure a more efficient communication with the DSO when procuring balancing, congestion management and voltage control services.
    - The DSOs are developing a new platform to improve the communication with the TSO, to operate new local markets for congestion management and to allow for controlled islanding.
- In Sweden, a new platform is being developed to allow DSOs to operate new local and regional markets for congestion management and to facilitate the participation of DER into balancing markets. The Swedish platform will also include a blockchain environment for the validation of energy transactions in a P2P (Peer to Peer) capacity market.
- In Greece, a new platform is being developed to allow a coordinated TSO-DSO procurement of congestion management and voltage control services. The new platform is an interface that is intended to manage different interactions between the TSO, DSO and FSPs (Flexibility Service Providers), as well as enable the operation of local markets in order to procure local flexibility. The main functions to be performed by the platform are:
    - Data and information sharing between the TSO and DSO.
    - Gathering flexibility needs from both TSO and DSO.
    - Exchanging the flexibility of each potential FSP that can provide a specific service.
    - Gathering of market bids.
    - Performing market clearing functions.
    - Communicating the market results.
    - Submitting activation bids to service providers and grid operators.
    - Performing the settlement process.

BD4OPEM

The BD4OPEM project aims at developing a marketplace for advanced analytic services and solutions which will leverage smart grid big data. A wide range of services will be created in the fields of grid monitoring, operation and maintenance, network planning, fraud detection, smart houses/buildings/industries energy management, blockchain transactions and flexibility aggregation for demand-response. Crucial concepts of the platform are data sharing, publish & provision of services as well as the concept of open innovation for promoting the creation of new services based on the data available (or made available) via the platform. With regards to actors involved in the use cases, since there is a wide range of services provided via the platform, we have a wide ecosystem of business roles in the smart grid domain e.g. DSO, Prosumer, Flexibility Aggregator, Citizen's Energy Community (CEC) member. Furthermore, inspired by the work of International Data Spaces Association (IDSA), the basic roles on the data sharing domain were model (e.g. Data Owner / Provider / User / Consumer) as well as role relate to service provisioning and marketplace operation.

TDX-ASSIST

TDX-ASSIST experimented mainly two data exchange platforms: Cloudera and ECCo SP.

Cloudera Usage in TDX-ASSIST

The Cloudera Platform is designed as a multi-actor information and data access portal to enable business-to-business processes. It has the ability to develop interfaces that provided scalable and secure ICT infrastructure that gives access to a wider range of stakeholders as appropriate to power sector data. Also, it introduces a data-access portal using a cloud-based approach and based on the Role Based Access Control (RBAC). The platform is designed in WP3 for the interactions between TSOs, DSOs and market participants (e.g., consumers, grid users, producers, aggregators). The overall architecture of the data exchange cloud platform is shown in the Figure 18.

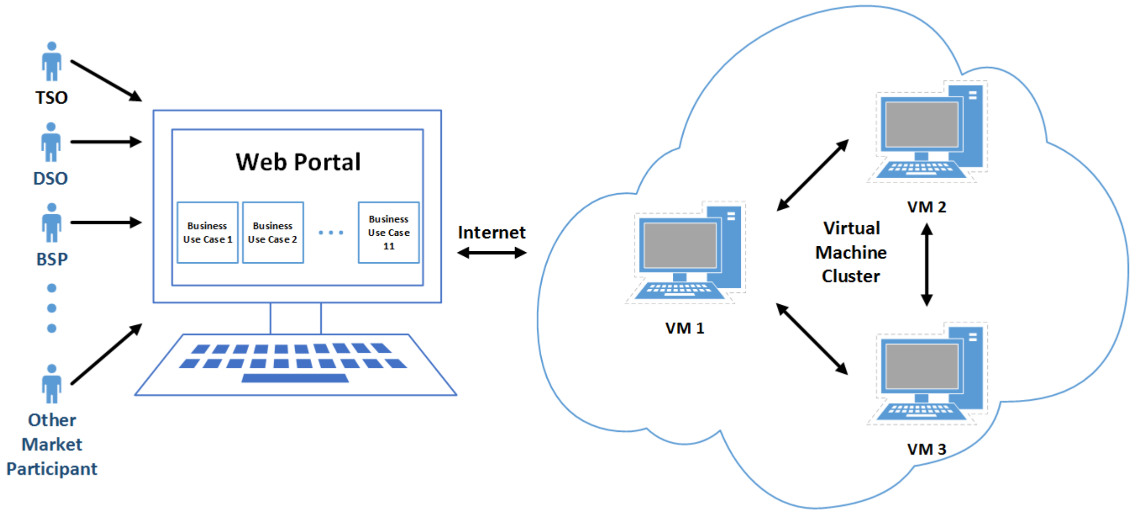


Figure 18: Overall architecture of the data exchange cloud platform [provided in survey]

ECCo SP Usage in TDX-ASSIST

In the scope of Slovenian demonstrator, two TDX-ASSIST BUCs have been demonstrated: “Activation of DSO-connected resources for balancing purposes in market environment” and “Coordination of long-term network planning between TSO and DSO”. The first BUC includes information exchange in near real-time while the second use case doesn’t have a strict constraints related to delivery time, but requires security and reliability. ECCo SP was used for information exchange in both demos, but using different interfaces.

In the first BUC, Elektro Gorenjska (Distribution Network Operator – DNO) exchanges information with ELES (TSO) related to the offering a product at the balancing market (using Conservation Voltage Reduction – CVR as a demand response mechanism). Information is serialized in CIM XML format using European Style Market Profile (ESMP). CIM XML files have been exchanged through AMQP (Advance Message Queuing Protocol) interface of ECCo SP. Machine readable format of data and AMQP interface enabled automatic information exchange between applications (for demo purposes only), without human intervention. During activation of the balancing product in the distribution grid, voltage profile is monitored through the power quality (PQ) meters that send voltage and power measurements to the database using MQTT(Message Queuing Telemetry Transport) protocol. Active power measurements have been used for the baseline calculations and prediction of CVR capacity. When voltage violation occurs, another application at DNO sends a message to TSO in CIM format through AMQP interface of ECCo SP. Time delay between two end points of ECCo SP at AMQP interface is measured and varies in the range from 0.5 to 1.1 seconds. We can conclude that besides the fact that ECCo SP provides secured and reliable information transfer, it can be used also for near real-time applications.

The second BUC demonstrated Common Grid Model Exchange Specification (CGMES) format between TSO and DSO/DNO for the long-term planning purposes (i.e. 2, 5 and 10-year). For this purpose, FSSF (File System Shared Folders) mechanism was used. The status of exchanged messages was tracked through the ECP (Energy Communication Platform) Toolbox of ECCo SP. It was concluded that FSSF mechanism of ECCo SP meets requirements for information exchange for the long-term planning purposes, which puts requirements on security and reliability, while time delay is not of interest.

Functional performance of data exchange platform ECCo SP

The implementation of French EDF demonstration on ECCo SP was successful which shows the Interoperability of the new platform. Moreover, EDF didn't find any security issues while testing ECCo SP and all data exchanges were reliable. Although EDF used Web Services for sending and receiving offers in the Market Offering Use Case, ECCo SP presents many other technologies operations like AMQP, Pull mode, FSSF, FTP (File Transfer Protocol).

Interoperability between data exchange platforms

Both implementations of BUC 2 used respectively OpenESB and ECCo SP as data exchange platform. The implementations use same data exchange formats definition (XSD files), that provide proof of independence between specification and implementation of the data exchange platform.

ebalance-plus

The platform was developed first in the e-balance Framework Programme 7 project and developed further in ebalance-plus, it is based on the concept of distributed data storage (middleware) that is deployed on management units. The management units are installed at different points of the energy grid (customer homes, secondary substations, and similar) and have a hierarchical relation - customer management units (CMUs) are children of a low voltage grid management unit (LVGMU) that is located in a secondary substation that supplies the customer area with energy. This hierarchical approach allows implementing hierarchical applications by design. Applications (services) are implemented on top of the middleware and access the data stored in the middleware via a defined API - the Data Interface. Services can be installed on each management unit and allow implementing distributed energy related decisions taking. The Services are executed on behalf of different stakeholders and the middleware checks if the Services access data they have access to, or not. This is done according to the security and privacy policy of each data owner (the data generator). The approach is secure - the services have to prove their identity on data access, the management units prove their identity on each data exchange between units using secure channels. The data in the middleware is stored in time-series of values identified by identifiers - called Variables. The service level allows implementing all possible kinds of energy related management. In the projects we implemented several of these related to flexibility.

RENAISSANCE

RENAISSANCE stands for RENewAble Integration and SuStainAbility iN energy CommunitiEs.

The RENAISSANCE Information Platform consists of different layers that tackle interoperability from a data exchange perspective. This is achieved by harmonising the incoming data from several data sources at pilot sites to guarantee compliance with international standards for protocols and data models. Similarly, the data models and protocols used as output for the services provided by the platform are also maximised when applicable.

Atos provides the core components for exchanging and storing data with external data sources and platforms (e.g.: APIs, Context Broker, Databases), as well as a communication channel between services provided and the infrastructure necessary for supporting a blockchain network. On top of the above-mentioned core platform, CERTH provides components for advanced functionalities that include a data modelling and forecasting layer and decision support system to support business functionalities. Lastly, the business functionalities include a social engine provided by CERTH to increase end user participation; a trading supervision system developed in partnership by Atos, CERTH and IKERLAN to support communication with RENAISSANCE's blockchain; and a set of smart contracts provided by IKERLAN and CERTH to govern energy exchanges in pilot sites.

3.2.3 Status of projects

In Figure 19 the status of implementation is illustrated for the projects that participated in the questionnaire. The aim behind this question is twofold; primarily, to endorse further synergies between projects, but also to incorporate their initiatives and developments in the effort towards the establishment of a common European reference architecture for the electricity sector, if suitable. The status of implementation is also correlated with the responses provided to the subsequent questions to capture which interoperable functionalities are in practice and which are meant to be in adoption for data exchange platforms. From Figure 19 it can be observed that more than half of the projects are still in open discussion regarding the development of interoperable tools and frameworks for data platforms. There is only one completed solution[10] that has fully operational and validated novel ICT tools and techniques to facilitate scalable and secure information systems and data exchange between TSO and DSO.

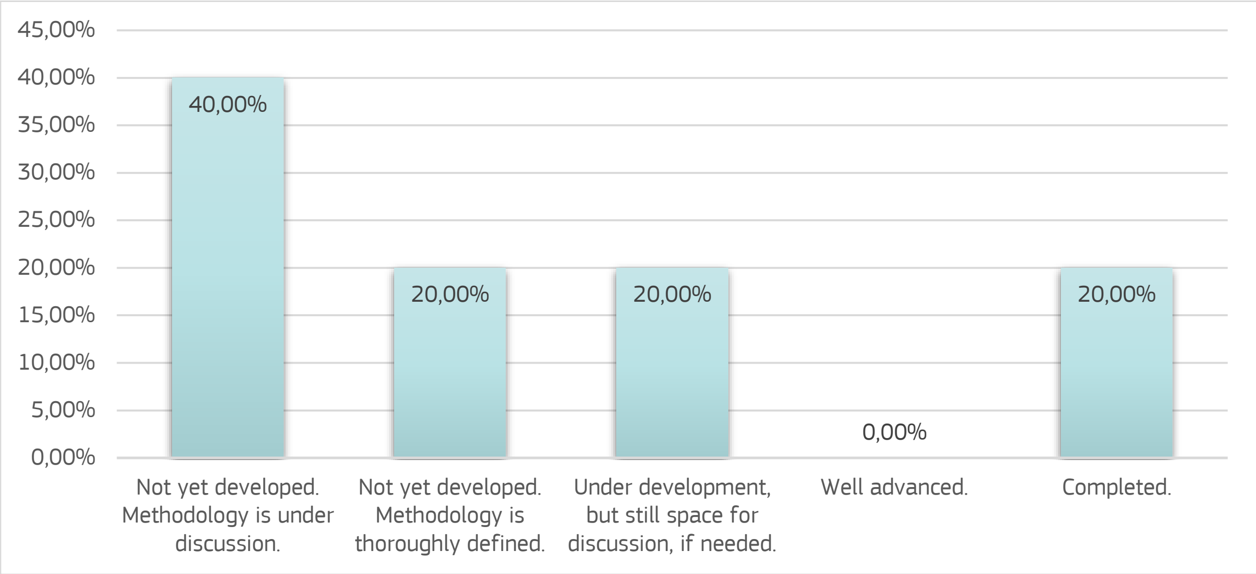


Figure 19: Project Status

3.2.4 Proposed standardisation processes among data platforms

One issue that is being explored via this survey, is the standardisation[11] of processes in each proposed data exchange platform. The obtained responses focus particularly on standardised processes related to data governance, not only limited to data exchange and collection, but also to the data source integration, as well as consent management and data users' authentication among services. This essentially implies that all data providers need to be able to exchange data with the other players, creating a large number of interfaces. The main driver for standardising the data exchange related processes can be insufficient data quality (i.e. this can be impacted by two elements: the expected periodicity of data and the large volumes of data).

Based on Figure 20 there are several functional processes that are widely standardised in the proposed data exchange platforms, beside data governance processes also more specific processes related to novel flexibility services. All such flexibility data types comprehensively cover both retail and wholesale market processes (e.g.

[10] It should be kept in mind that the BRIDGE projects are at different stages (with different starting/ending dates) and that projects stop being active in BRIDGE once they are completed, so it is normal not to have fully operational solutions while the projects are still ongoing.

[11] In this context, 'standardisation' does not refer to international/European standards necessarily, but may indicate national standards and non-standard specifications (including as proposed by projects) also.

flexibility baseline calculation, flexibility prediction, prequalification). Therefore, regarding the aforementioned processes, there is common consensus along the participating projects.

All in all, the anticipated data aggregation, data curation, data sharing and data analytics functionalities are substantially delivered via several data-driven services, which may be accessed via well-defined interfaces to ensure their seamless integration and streamlined operation.

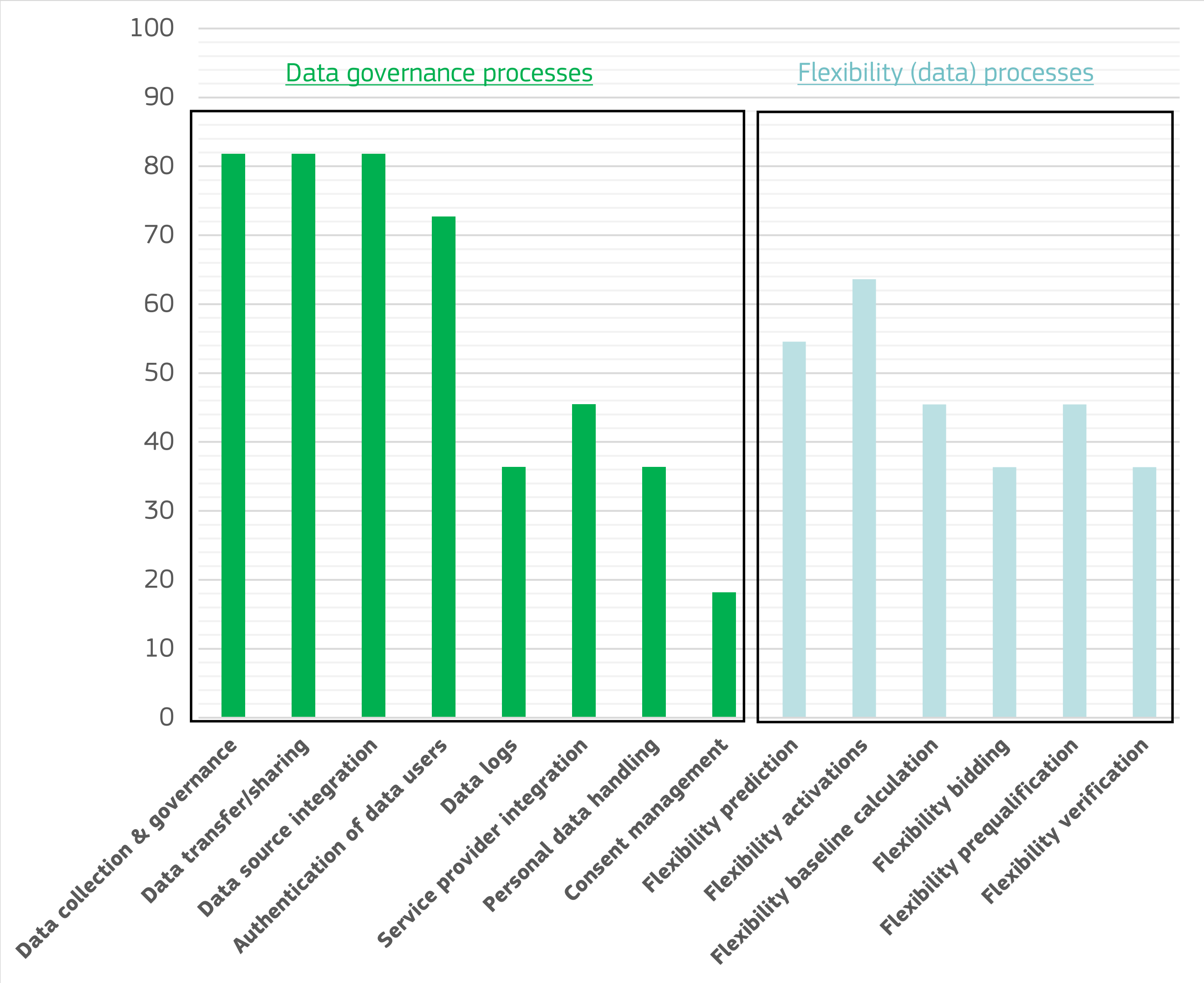


Figure 20: Standardised functional data processes proposed

To sum up, the common ground identified on the standardisation of processes is mainly observed in the data collection services for real-time and batch data assets to be properly registered and handled. Data integration processes, data security and data sharing services are also highly observed as core functionalities. Since the majority of the data exchange platforms aim to integrate demand side flexibility into the marketplaces, several flexibility processes are generally standardised among platforms.

3.2.5 Mapping of data platform properties into interoperability layers

The projects were questioned to which SGAM layers their proposed data exchange platform contributes.

The SGAM framework [CEN-CENELEC-ETSI, 2012] provides a three-dimensional (based on 1-D: interoperability layers, 2-D: domains, 3-D: zones) 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 realized by functions, as objects of the function layer, which are in turn executed by components, as objects of the component layer. The execution of the functions requires the components to support data models, as objects of the information layer, and communication protocols, as 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 21, 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 authorization 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.

In Figure 21, there is a two-fold illustration of the layers that each participating project focused their efforts on, regarding the development of interoperability functionalities, as well as indicating the layer that are lacking utmost in the underdeveloped data exchange platforms. The responses provided to the questionnaire have clear projections to the interoperability layers as depicted in Figure 21. The results have been sorted from higher to lower layer of SGAM. Summarising each layer individually, one could address the following characteristics and examples provided by the projects per interoperability layer.

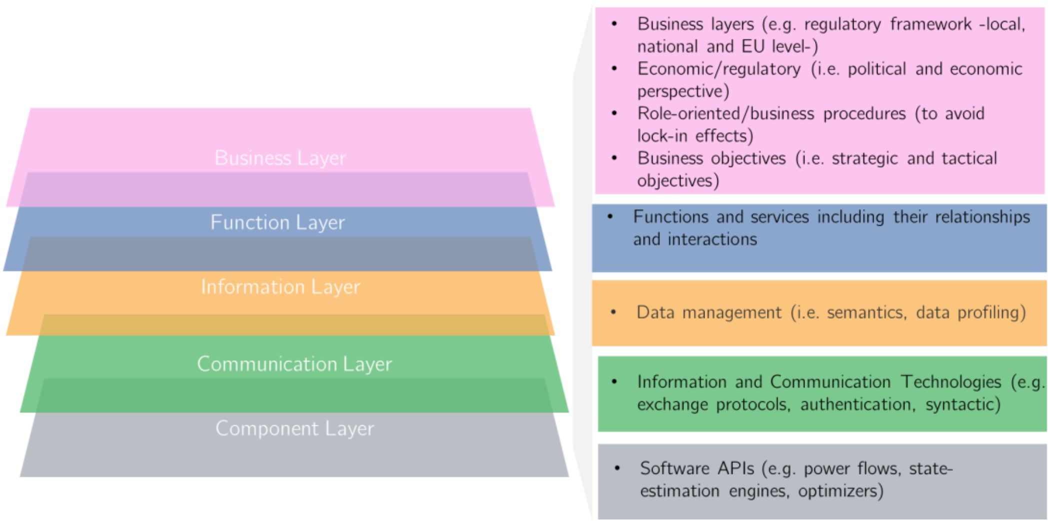


Figure 21: SGAM interoperability layers and implications to the properties of data exchange platforms

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.

In this layer, it can be seen that there is relatively balanced and low percentage of focused effort and lack of functionalities related to the data exchange platforms. Data platforms provide a more comprehensive manner to bundle processes and improving coordination and market functionalities; yet, there should be a neat regulatory framework. There is clear focus, by the majority of the participating projects in this survey utilizing the HEMRM in order to provide a comprehensive and well-defined architectural model. Roles and actors have to be clearly defined to avoid misperceptions and overlaps amongst them, particularly in the case of data exchange platforms which in most cases deliver novel functionalities.

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.

There is much focus attended on bundling processes for the aggregator, the grid observability system, weather services, energy supply and demand and price predictions systems, along with external information from DSOs, BRPs and municipalities. The implementation of the middleware, in many cases, takes place following the concept of Enterprise Service Bus (ESB), some using the OpenESB delivery. The ESB enables the communication and data management for the whole system. Such system will be used for congestion management and local energy communities' management. The data exchange platforms in the proposed frameworks is merely utilized to unlock (i.e. avoiding lock-in effects) and channel the information flows related to: Devices, Sensors, Users, DSO (and local technical aggregator or forecaster supportive functions) via the platform and interoperability layers to energy and non-energy actors and services.

Big Data Platform and AI (Artificial Intelligence) Analytics Marketplace is also set in place as matter of delivering inferences to applications and innovative energy services to the involved stakeholders towards serving their individual interests, while realizing common electricity sector goals for de-carbonization, power quality and security of supply. Big Data Platform and AI Analytics Marketplace, are set in place to bundle innovative energy applications and services will be configured, addressing the business and optimization needs of the variety of stakeholders involved in the electricity value chain (e.g. TSOs, DSOs, Renewable Generators, Electricity Retailers, ESCOs, Facility Managers, etc.). The basis of functional operation majorly observed lies on the coordination and more robust operation of the power systems, enabling, also, communication and data exchange between all involved actors enhancing transparency and allowing market access and participation of new actors, such as prosumers. The whole processes for market participation allow flexibility service providers to register their resources, to request grid qualification and subsequently product qualification in an automated way.

Following this, data platforms are foreseen to provide for the system operators a holistic view over the available flexibility resources in their grids at any time and based on this information to post their needs on the respective markets. Other functional propositions aim to utilize the data platforms for predictive asset (i.e. transformer, power plant) maintenance and energy balance as well as microgrid management under different conditions (islanded, interconnected, restoration).

Participants indicated much focus on the data source integration but providing real-time and batch data assets are properly registered in data platforms. Additionally, there are functionalities based on data handling responsible for safeguarding and securing any data asset (and most importantly trained analytics). There are also steps towards data functionalities for exploratory data analysis, designing and monitoring analytics workflows and visualizing the analytics results in intuitive dashboards, and running pretrained industrial / personal / edge analytics to generate new insights and knowledge for all energy stakeholders.

All such aforementioned processes and functionalities are typically performed within a middleware accommodated in data exchange platforms handling the adopted sharing / trading mechanisms, effective remuneration approach and the multi-party data contracting lifecycle and in some cases is powered by blockchain technologies. Particular effort in this level is given on the data sovereignty upon ensuring GDPR policies.

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. The focal point as a functional requirement is to provide high-level transparency by allowing streamlined access to marketplaces. The precondition of free flow of data (i.e. including sensitive private data) is deemed necessary to take place in a secure and transparent manner. The proposition of enabling flexibility within such data platforms brings clear advantages to other services which stem from the enhanced coordination of system operators (cross-border and cross-domain). Such services include grid monitoring & operation, market operation and aggregation & disaggregation, operation and maintenance, network planning, fraud detection, smart houses/buildings/industries energy management, blockchain transactions and flexibility aggregation for demand response.

Those services describe somehow the commonly reported features by the majority of the participating projects. Finally, the incorporation of proper service APIs[12] are there as the interface to expose the aggregated data (including meta-data) resources to the respective data platform applications. The service APIs are the mediator to enable both access to data internally stored and to the external resources via corresponding communication channels. The need of data management services prescribes that data platforms need to deal with data ingestion, preparation, analysis and exposition; the latter allows to harmonize the resources available through the platform and its local representation.

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 the subsequent proposed or utilized data models. On the interconnection of actors via data platforms, information objects and canonical data models do need to represent the common semantics for functions and services in order to allow an interoperable information exchange. This component is highly addressed by the participating projects, since all of them have implemented centrally managed data exchange platforms that can be compatible with the use of different data formats/models and communication standards and protocols; hence, data interoperability is achieved with in-platform parsers and adapters. But equally the interoperability between platforms needs to be ensured.

The data models of the information exchanges of data exchange platform with the subsequent components developed are commonly defined in the form of a Canonical Data Model. Emphasis shall be given to interoperability through the use of domain standards (e.g. CIM), whilst the design of the solution will follow the paradigm of best practices in the domain e.g. IEC 61968-100 “Application integration at electric utilities - System interfaces for distribution management - Part 100: Implementation profiles” [2013].

The information interoperability layer is the main focus of the R&D projects focusing on well-defined canonical data models not limited to semantics, but also to ontological approaches. The information layer has to provide proper functionalities and interfaces supported by service APIs. The designation of a well-defined semantic repository (e.g. semantic vocabulary and ontologies) is of vital importance.

[12] APIs are formally addressed on SGAM Component Layer.

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.

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.

CIM information model uses UML syntax. From UML, profiles can be defined. But CIM could be exported in other syntaxes (like OWL), from which profiles would also be generated. Profiles are a restriction of the Information Model. These profiles are using a syntax: XML 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. The syntax is different but the semantic remains the same.

In particular, the main information model syntax clearly appears to be CIM XML (XSD schemas or JSON) 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 XML RDF syntax. This format is used between TSO and DSO for the long-term joint planning or for coordinated operational purposes.

The definition of the conceptual architecture design of the system, focusing on communications' interoperability can be achieved utilising strong coordination between ICT providers subsequent field applications and vendors, in order to define the anticipated needs and available resources. In regard with protocols and standards, the main consideration is to identify suitable protocols and appropriate standards to be used and incorporated with the data exchange platform. Projects 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. During activation of the balancing product in the distribution grid, voltage profile is monitored through power quality (PQ) meters that send voltage and power measurements to the database using MQTT protocol. Active power measurements have been used for the baseline calculations and prediction of CVR capacity. When voltage violation occurs, another application at DNO sends a message to TSO in CIM format through AMQP interface of ECCo SP. The communication layer is also relying on IEC well known communication standards like IEC 60870 series (Inter Control Center Protocol – ICCP), IEC 61850 series.

Component Layer

The component layer refers to the physical distribution of all participating components in the data exchange platforms. This includes system actors, devices and applications. There is clear focus in this level on the data exchange platforms to propose Advanced Distribution Management Systems (ADMS) tools, 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 optimization algorithms, congestion management and peak shaving, price analysis strategies, dispatching module, operation in islanding mode. At this level, 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.

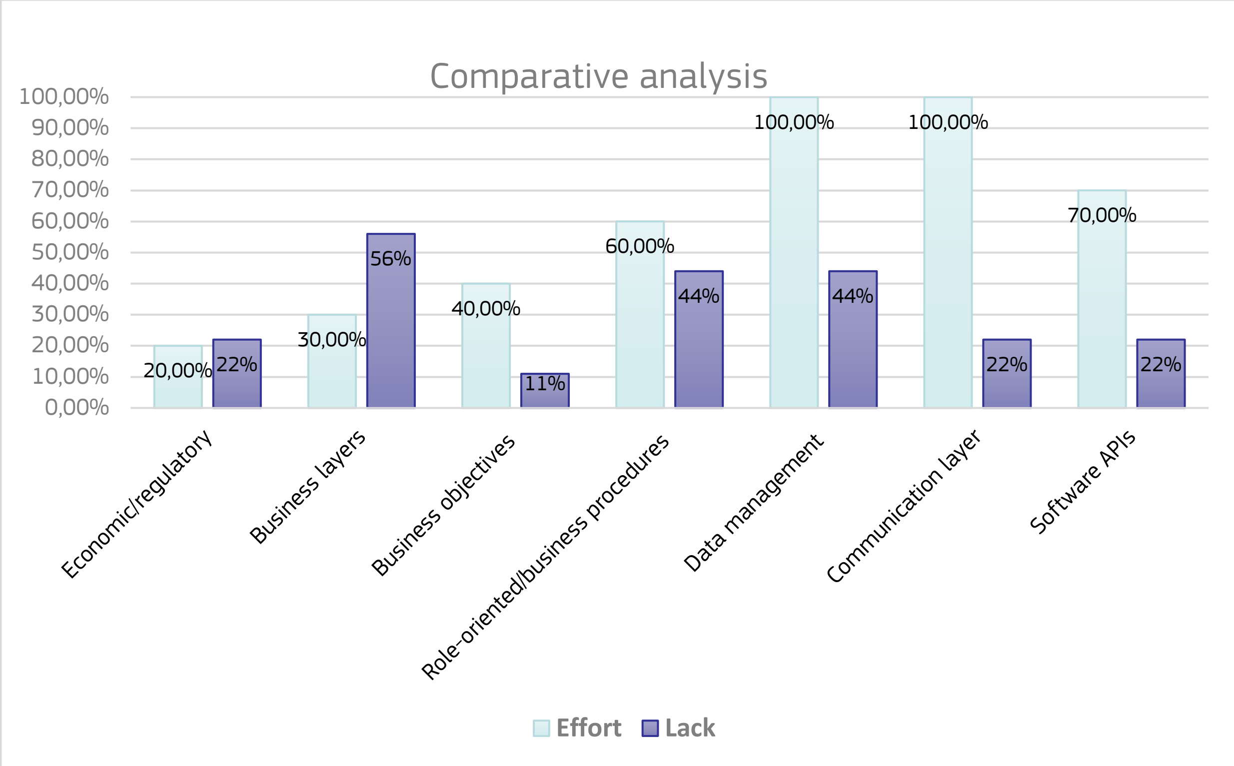


Figure 22: Results obtained regarding the effort

All in all, it is clear from the majority of the received and explored responses in this survey that interoperable data exchange platforms embody functionalities across all the interoperability layers as defined in the SGAM framework. Nonetheless, there should be further focus in business layers and objectives in the sense of deploying such data platforms in well-established regulatory framework along with the adoption of standardised roles and responsibilities. One should also mention at this point, that the explored data platforms are designed and deployed for several different objectives amongst them. As per this discussion, that all interoperability layers are foreseen crucial for the effective implementation of data exchange platform, it is rather vital to capture the current efforts of data exchange platforms mapped within SGAM framework as a plane of zones and domains.

3.2.6 Methodological approach

In this matter there is an exploration on the methodological approach adopted by each project in order to develop, test and deploy interoperability functionalities in the data exchange platforms under examination. It can be observed that it is unanimously accepted within all projects to follow IEC standards and most particularly the CIM standard within several components and modules of the data exchange platforms and the participating stakeholders (e.g. system operators, markets, balance responsible party *etc.*). The need to incorporate demand side flexibility is evident in the original CIM model, which aims at guaranteeing interoperability between the different applications that are part of a management system. For this, the CIM profiles are defined and extended.

Taking into account several interoperability tools and standards such as the SGAM and the IEC 62559 template, the majority of participants in this survey stated that the solution providers have been included in the design process to ensure their alignment with the architecture and use cases. Additionally, systems will be tested using a thoroughly defined methodology and a testbed framework in many cases. All solutions included in this system will implement standards enabling their interoperability.

The selection of standardised ICTs appears to be also a common practice to achieve interoperability functionalities. ECCo SP was also selected as a platform enabling secured and reliable data exchange. AMQP interface was used by different applications, enabling automatic information exchange between external applications. Measurements from the filed devices were collected using MQTT protocol and broker, and written into time-series database. External application accesses this data base, process the data and exchange messages through ECCo SP and AMQP 1.0 protocol.

In Figure 23, the methodological approaches are presented.

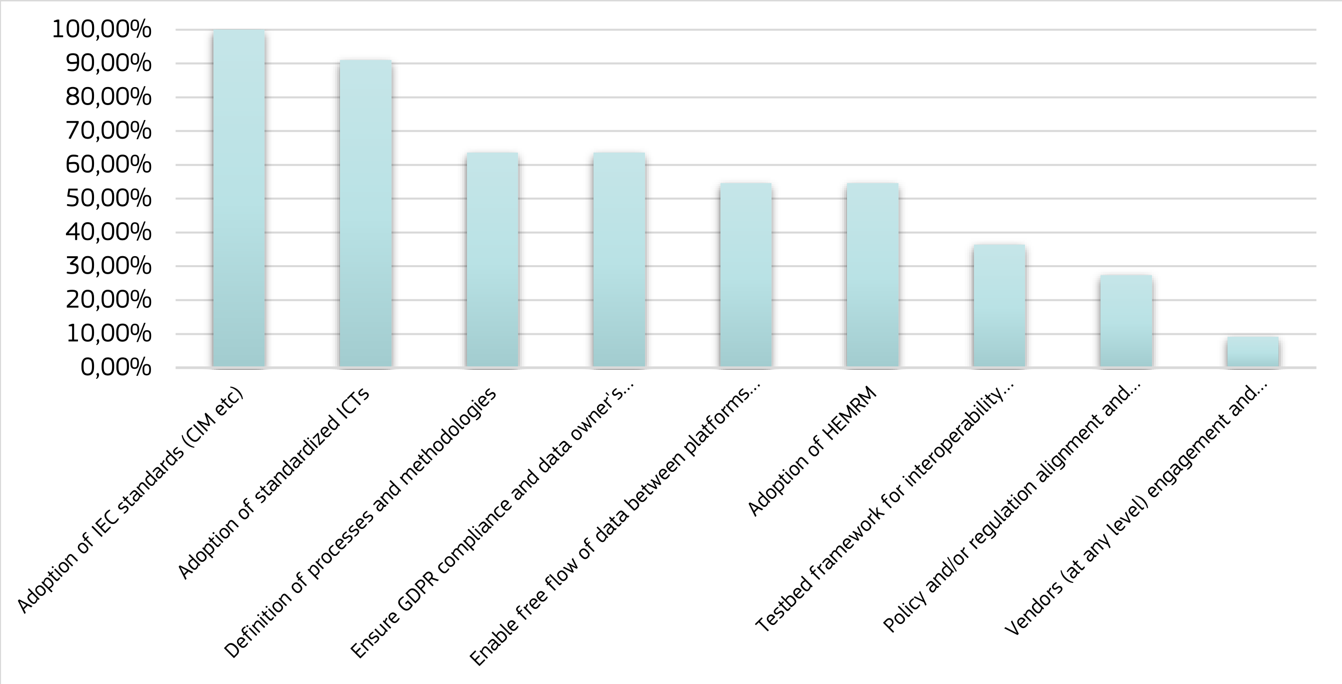


Figure 23: Methodological approaches adopted to develop, deploy and validate interoperability functionalities for data exchange platforms (share of participating projects)

3.2.7 Capturing visions for the definition of a common European reference architecture

Participants unanimously agreed that the definition of a common European reference architecture for the electricity sector is complex, but it constitutes an initiative that may deliver multitude benefits to all participating actors. Based on Figure 24, a common European reference architecture may deliver benefits from the enhanced cooperation between actors in electricity sector to the customers (engagement, improved Quality of Service). Additionally, equally important benefits may be delivered based on market parties' coordination (facilitate Demand Side Flexibility, integration of DER) as well as due to TSO/DSO coordination mechanisms: optimal-decision-making leads to lower operational costs. Participants mentioned in addition that the implementation of a common architecture may lead to decreased ICT development and maintenance costs, which, in turn, reduces the costs of operation for the power system. Finally, it was added that there might be benefits for technology providers, enabling the creation of market ready solutions with increased applicability across the EU. There can be benefits for technology providers, through increased interoperability of solutions and clean competition.

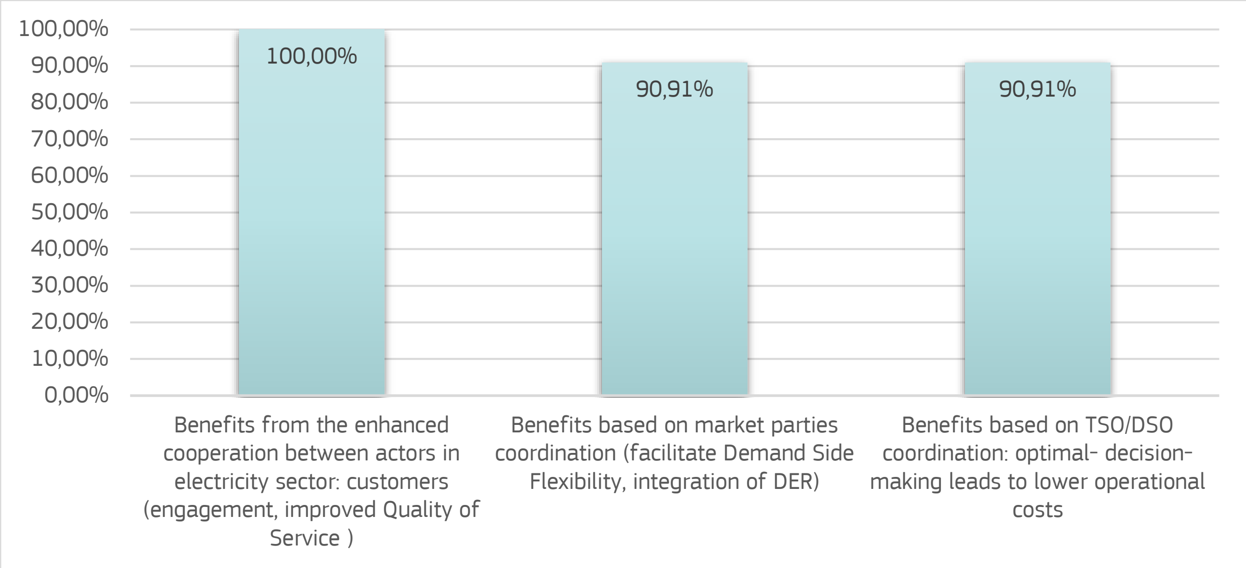


Figure 24: Benefits delivered with the adoption of a common European reference architecture or the electricity sector (share of participating projects)

The most important pillars for the establishment of a common European reference architecture of the electricity sector are illustrated in Figure 25. The pathway towards the definition of a common European reference architecture in the electricity sector is a very complex task to be achieved according to responses obtained, since it requires all actors to be open for participation. The latter is often not easy also because of efforts and investments in certain ideas and directions. Yet, working on this direction can certainly enhance cooperation between actors in the electricity sector, which is key for the next steps. The establishment of a novel EU entity for interoperability could organize the various innovation tools that are introduced by the projects and the stakeholders. This would provide more focused sterilizations for the new approaches and it would steer towards identifying the new challenges and providing new solutions and mechanisms for different interoperability issues.

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.

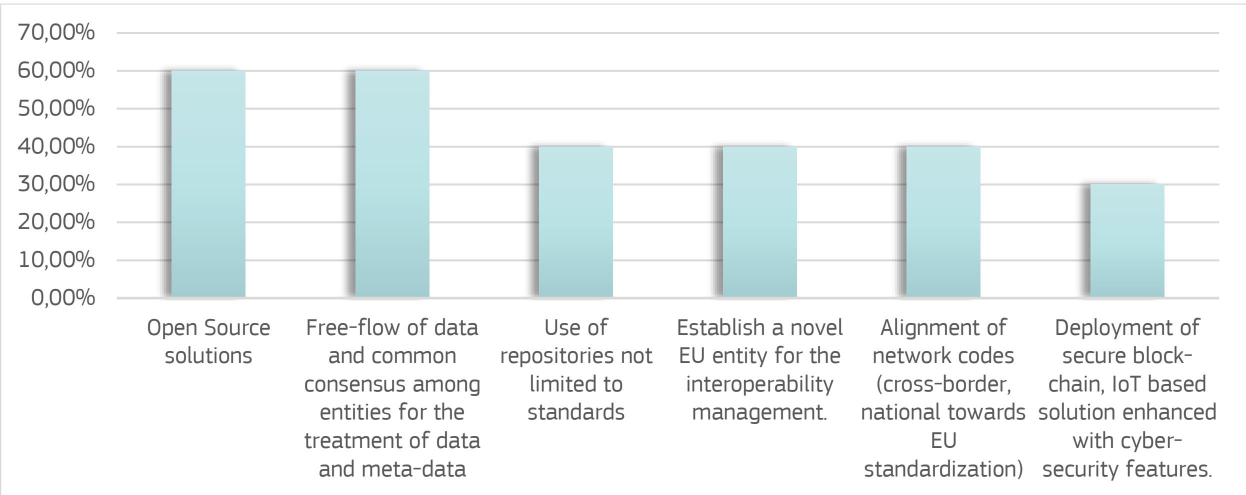


Figure 25: Most important pillars for the establishment of a common European reference architecture or the electricity sector (share of participating projects)

The projects were questioned to rate the impact of the following assertions as per the development of interoperability functionalities within data exchange platforms. The need for further advancement of standardised protocols appears to be the most important among others for the implementation of interoperability functionalities in data platforms. This conclusion was also reported by the participants in former question, identifying particularly that all of the projects adopt IEC standards and standardised manner of data exchange such as CIM standards; whereas there is a clear need to incorporate advancement particularly due to the evolving flexibility products. The issue of vulnerability attacks may have some impact on data exchange platforms, which can be though effectively addressed if an advanced merit order of schemes and standardised processes is commonly agreed. 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:

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.

Figures 26-29 present the analytical score of each element (1-4 above) as per their impact on the development of interoperable functionalities.

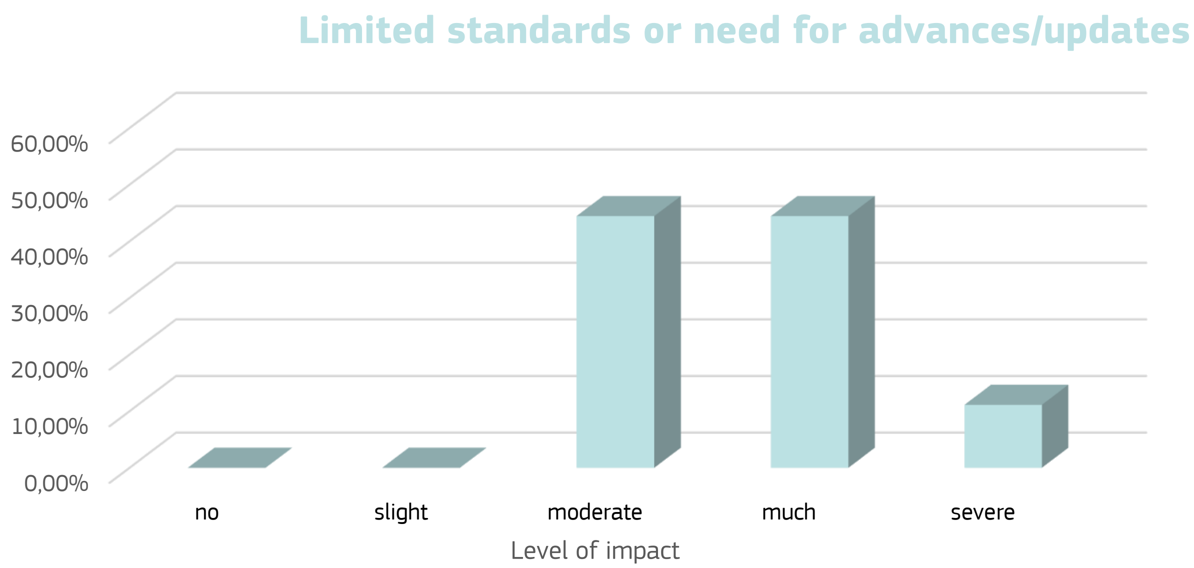


Figure 26: Limited standards or need for advances/updates (share of participating projects)

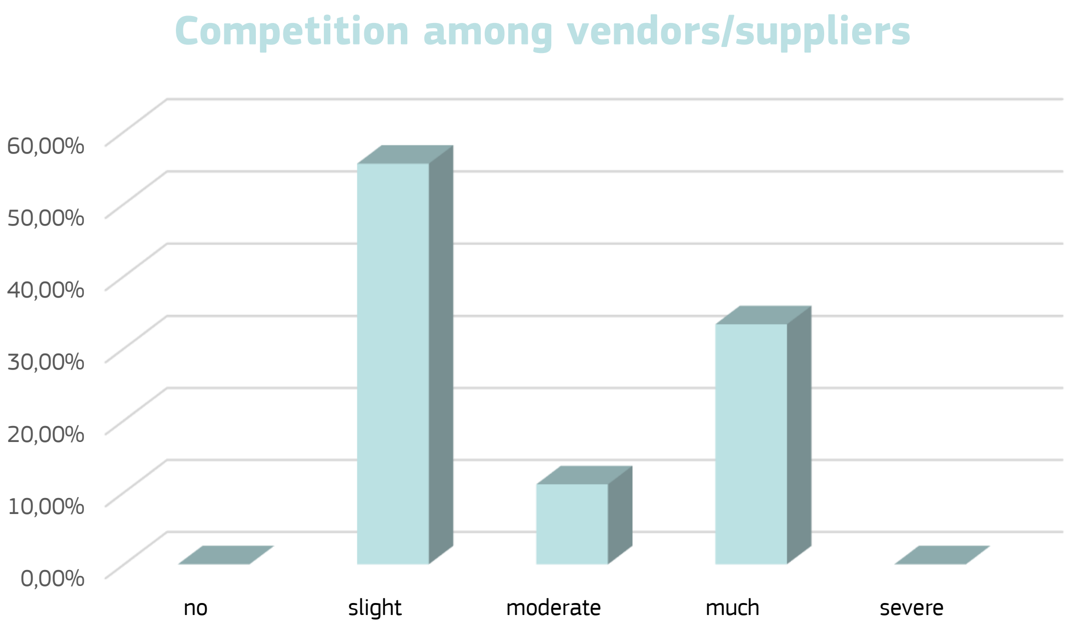


Figure 27: Competition among vendors/suppliers (share of participating projects)

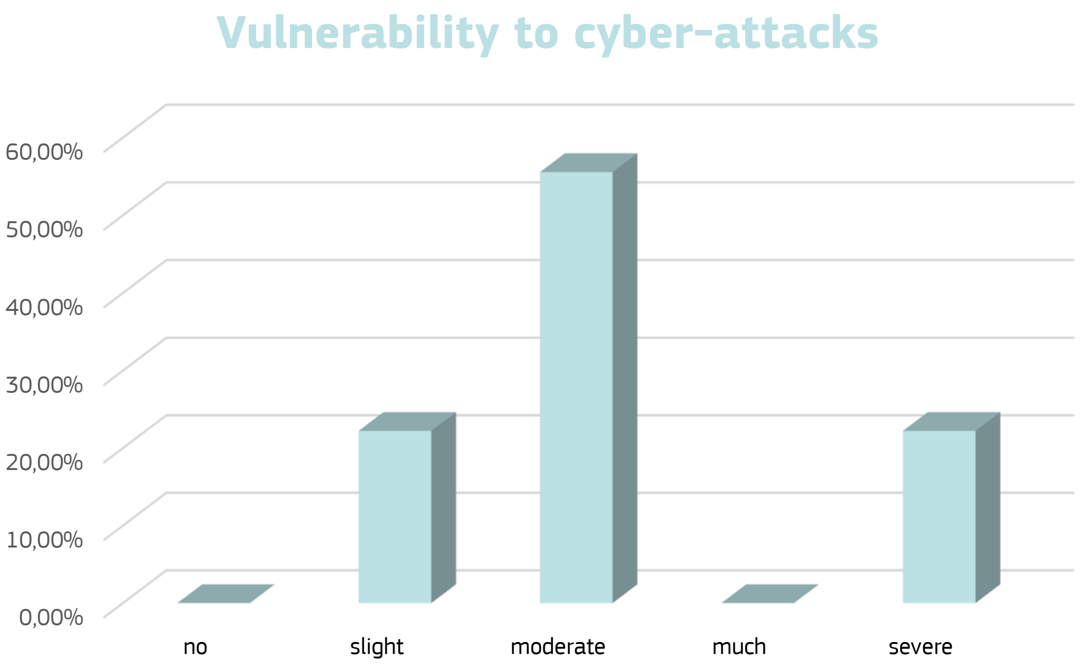


Figure 28: Vulnerability to cyber-attacks (share of participating projects)

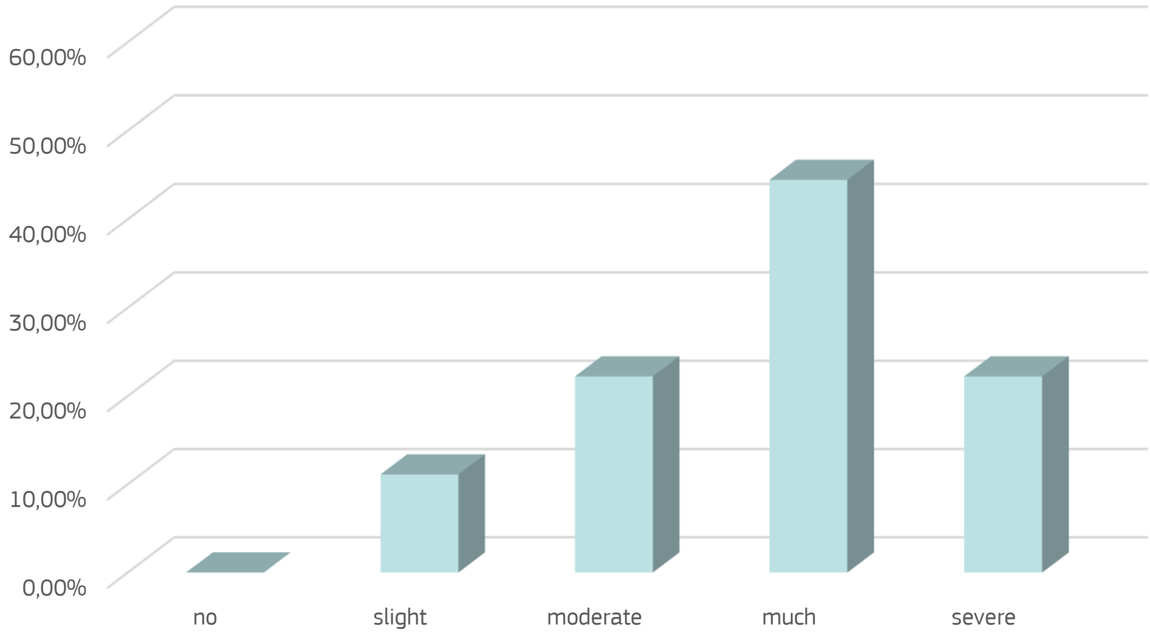


Figure 29: The unwillingness among players to exchange private data and models due to privacy issues (share of participating projects)

3.3 Cross-sector considerations

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 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 for electricity sector 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.

For the purpose of this report a dedicated questionnaire (see Annex III) was sent to several initiatives outside electricity domain. Answers were received from ICT4Water association representing water domain.

3.3.1 Water sector

The proposed architecture by ICT4Water builds upon NGSI-LD specification which introduces several compatible architectures to provide Context Information Management. The main objectives of the envisioned interoperable platform are:

- Offer a common mechanism to explore information on batch and real-time.
- Harmonise the information of the water sector under common and reusable data models.

- Provide a common reusable IT/digital infrastructure to elaborate analytical services on top of the collected information.
- Connect and share different data catalogues to reduce water siloes and contribute to a cohesive water sector (break the fragmentation of the sector).

FIWARE Foundation animates an ecosystem of several hundreds of technology providers and users with a focus on the NGSI(-LD) specification. Building upon NGSI-LD thus limits the risk of vendor lock-in for buyers while opening the ground to new innovations and business opportunities for technology providers, and more especially SMEs.

Regarding benefits provided by the usage of FIWARE and Context Information Management (NGSI-LD) are:

- Provide reliable data and information under a common open-API to elaborate common visualization and exploration tools.
- Offering a catalogue of common understanding of the water entities, infrastructures and value chains.
- Offering reliable data and information at intra- and cross-domain level.

The proposed architecture introduces several compatible architectures to provide Context Information Management:

- Centralized architecture: A Central Broker stores all the context information. There are Context Producers that use update operations to update the context information in the Central Broker and there are Context Consumers that request context information from the Central Broker, either using synchronous one-time query or asynchronous subscribe/notify operations.
- Distributed architecture: All information is stored by the Context Sources. Context Sources implement the query and subscription part of the NGSI-LD API as a Context Broker does. They register themselves with the Context Registry, providing information about what context information they can provide, but not the context information itself.
- Federated architecture: The architecture works in the same way as the distributed architecture except that instead of simple Context Sources, whole domains are registered with the respective Context Broker as point of access. Typically, the domains will be registered to the federation Context Registry on a more coarse-grained level, providing scopes, in particular geographic scopes that can then be matched to the scopes provided in the requests. Alternative architecture (i.e. mesh) are also under consideration.

From a software developer's perspective, FIWARE is a huge advantage as it makes far easier to work with IoT and complex device data. FIWARE has a core set of functionalities that are transferable to other areas and allow developers to pull in data from other domains.

The features of FIWARE are open and extensible: JSON data formats for key domain specific data structures, a language agnostic approach making it straightforward to develop FIWARE-centric solutions in a range of languages and platforms, and a set of off-the-shelf components (orion, stellio etc.) that remove the need to write time-consuming solutions to fairly generic problems allowing developers to spend more time working on the actual issues.

Actual issues can range from near (real) time detection of leaks in water networks to optimised control of wastewater treatment processes. Having access to data streams that are otherwise not conveniently available (such as weather data for optimised control of WWTP – Wastewater Treatment Plant) can lead to a higher level of efficiency in its problem solving and potentially also lead to more accurate and scientifically sound findings.

Using FIWARE allows to develop and deploy generic solutions with a large amount of conceptual and functional reuse - which is incredibly helpful for a developer.

The proposed framework specifies both a cross-domain data model, a Pub/Sub architecture (a query-subscribe API) and also an open API to interact with the different water entities and subsequent generated information. The data model builds above a RDF grounding to define a knowledge graph serialised using JSON-LD to be consumed by web services. Domain specific models (i.e. SAREF), are mapped over the cross-domain to allow for cross-domain data exchanges.

Key drivers are the use and contribution of/to formal open standards like Context Information Management (NGSI-LD) and SAREF. Moreover, from ICT4WATER and specifically from the I&S work ICT4Water is willing to promote the use and adoption of open ICT/digital tools (reference architectures and context brokers as FIWARE) in order to empower the elaboration of newer digital services for the sector and the users. We also are committed to the elaboration of open data and catalogues that open the water sector to support the free flow of information between organizations.

In addition to supporting free flow of information between organisations, use of open standards can aid the integration of systems and models that currently operate with different formats (e.g. integration of the water distribution system modelling tool EPANET with sources of real time data).

3.3.2 Remarks

Integrated operation of multiple energy carriers promises hitherto unused synergies in terms of efficient generation, storage, and consumption. The electrification and the general dependence of energy sector on weather, seasonality and other socio-economical parameters substantiates the design and operation of multicarrier energy systems and such functional architectures. Concurrently, the increasing installation of sensory devices along grids, buildings and devices brings direct concerns about the manner of information and data exchange and management as well as the sharing of proprietary data. Interoperable data exchange platforms can act as the middleware for handling information and data exchange among several parties (providing access to more actors such as end-users) bundling planning, operational and market processes.

Examining particularly the water sector and the initiative of ICT4WATER proposes a modular architecture open to be interconnected with other sectors as well. Main objectives focus on offering a common mechanism to explore information on batch and real-time, harmonising the information of the water sector under common and reusable data models as well as to provide a common reusable IT/digital infrastructure to elaborate analytical services on top of the collected information.

4. Common Information Model

4.1 Introduction

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). Therefore, different information models, such as 61970-301 [2020], 61968-11 [2013] and 62325-301 [2018] as well as their associated profiles have been leveraged in the TDX-ASSIST, EU-SysFlex, INTERRFACE projects. CIM supports several IEC network codes and guidelines. In general, CIM profiles strengthens the coordination between different TSOs, but it will more and more used between TSOs, DSOs and other market participants.

Two Questionnaires were submitted to concerned projects: a questionnaire on **CIM usage** (see Annex IV), and another on **Business objects and associated CIM profiles** (see Figure 32).

The projects are not at the same development stage, therefore it was difficult to provide answers to all questions. Three levels of projects could be identified based on answers:

- Stage 1: identification of standards,
- Stage 2: Use Cases and Business Objects defined, profiling phase not started,
- Stage 3: CIM used in profiles and implemented in demonstrators. Proposals of CIM enhancement to standard development organisations.

The following projects contributed to this chapter on CIM: CoordiNet, E-LAND, EU-SysFlex, FARCROSS, InterConnect, MERLON, PlatOne, PLATOON, SYNERGY, TDX-ASSIST, TRINITY, X-FLEX. Some of them, depending of their stage, answered the Questionnaires (SYNERGY, EU-SysFlex, TDX-ASSIST, E-LAND, MERLON).

4.2 Synthesis of CIM Usage survey

4.2.1 General consideration

This questionnaire was structured as depicted in Figure 30.

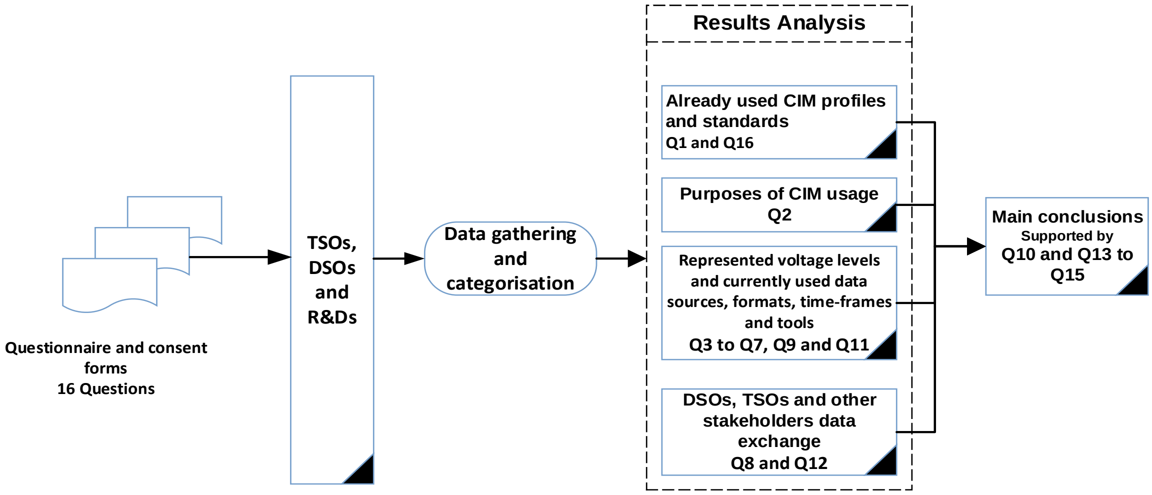


Figure 30: Questionnaire structure [TDX-ASSIST Deliverable 1.11, 2020]

The goal was to identify main CIM usage in contributing to European projects. This Questionnaire could be reused by future projects. 12 CIM usage questionnaires were answered from 5 contributing projects (SYNERGY, EU-SysFlex, TDX-ASSIST, E-LAND, MERLON). TDX-ASSIST provided 8 separate answers from some of its participants.

CIM profiles were defined when there was a strong interest to implement a solution. Business Objects definition are important material that could be proposed to standard organisation for future CIM profile definition if there is a business need.

EU-SysFlex & TDX-ASSIST share the same methodology which is a model driven methodology using UML (Unified Modelling Language) framework: Business and System Use Case definition, Business Object definition, Profile definition.

EU-SysFlex defined 27 Business Objects from 13 SUCs (System Use Cases), the definition of CIM profiles has started end of 2020. TDX-ASSIST defined 84 Business Objects from 11 BUCs, 56 Business Objects defined from 18 SUCs. In TDX-ASSIST 15 Business Objects were modelled with CIM, 10 associated with CGMES, 4 with ESMP, 1 with other CIM profile.

CIM Market (IEC 62325-45x series, ESMP) and IEC 61970-600 series, (CGMES) are well known by TSOs, less by DSOs. DSOs are using or interested to use IEC 61968 related standards, and more specifically IEC 61968-9 for smart metering interfaces [2013]. Nevertheless also CIM market series (IEC 62325-45x) gain more and more attention from DSOs, as they develop more interactions with aggregators or other market participants. DSOs are also becoming more and more familiar with CGMES profiles. CIM can be used at any voltage level.

Main obstacles which prevent to use CIM are: implementation issues, training of human resources. CIM usage future interest according to the answers provided: Battery, Storage, EV, Charging station.

Participants are free to use different tools, and different CIM versions. Interoperability of tools is required: for instance a profile defined with one tool could be modified using another tool. Customer lock-in must be avoided. It is for this reason that IEC developed and is still developing standard documents that will allow interoperability between tools used for CIM message definition: IEC 62361-103 Interoperability in the long term - Part 103: Standard profiling [2018], IEC 61970-401 Energy management system application program interface (EMS-API) - Part 401: Component interface specification (CIS) framework [2005], IEC 62325-351 Framework for energy market communications - Part 351: CIM European market model exchange profile [2016].

Defining CIM profiles implies to have access to the CIM UML information model. Moreover, trying to improve existing profiles requires to have the UML model associated to these profiles. Figure 31 describes the methodology to extend CIM UML model and to reuse some CIM profiles (like the profiles in CGMES), and which has been experimented in TDX-ASSIST. When CIM Profiles are defined, they will need more work to determine if these profiles can be part of official standard documents.

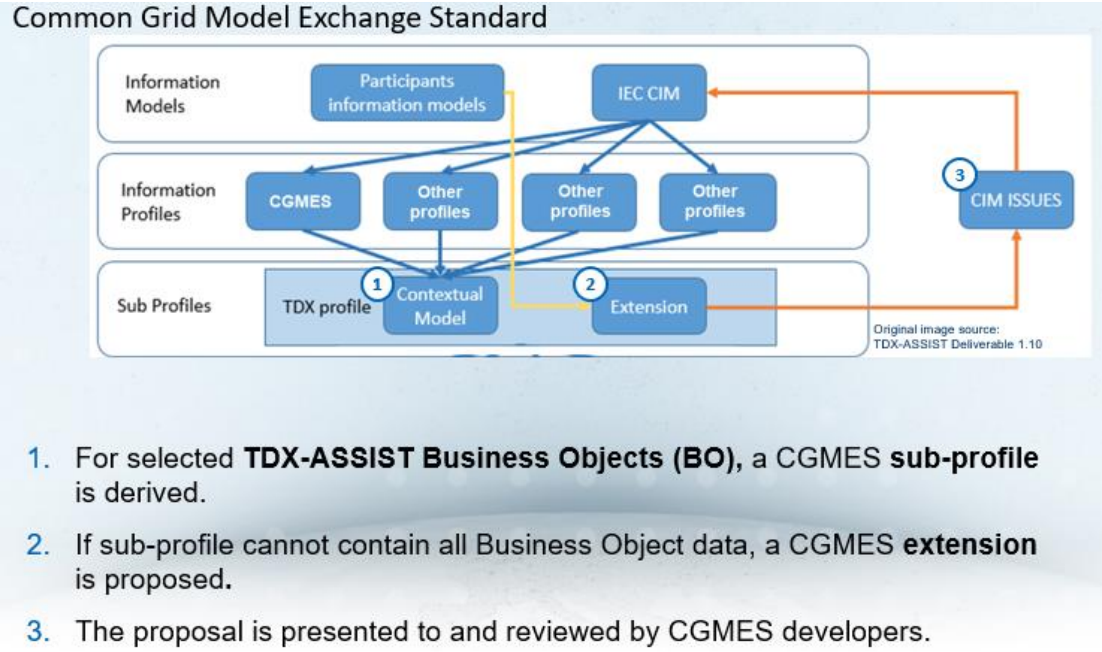


Figure 31: Extending CIM, reusing CIM Profiles [TDX-ASSIST, not published]

4.2.2 CIM usage

According to the survey results shown in Table 2 (question Q1), CIM profiles are mostly used for network modelling (67%), and less implemented for market purposes by the demonstration partners of TDX-ASSIST (33%). In particular, there are some DSO organisations that have already used network studies related profiles such as the ones defined by IEC 61970-301 [2020], CGMES profiles defined by 61970-600-x and CIM based data models defined by IEC 61970-600-1 [2017].

Also, there exist utility integration profiles, such as CIM Distribution Model defined by IEC 61968-11 [2013], standard profiles based on CIM Model IEC 61968-x (3 to 9), IEC 61850 series and IEC 61968-13 Common Distribution Power System Model (CDPSM) profiles [2008].

On the other hand, although being required, standard CIM profiles related to market, such as the ones defined by IEC 62325-45x and harmonisation between CIM and IEC 61850 defined by IEC 62361-102 [2018], have not been implemented yet by the DSO partners. This is also the case for most R&D organisations.

Some TSO organisations, on the contrary, have reported to have already implemented the market related profiles as well as the harmonisation between CIM and IEC 61850, although having still pending the IEC 61968-13 (CDPSM) [2008], the IEC 61850 series and the CIM based data model related to network studies (defined by 61970-600-1 [2017]) implementations. The fact that there are several CIM profiles and standards that have already been used in the practice is promising since this shows the maturity of the services offered by these organisations.

Table 2. Survey results for Question 1: “From the following options, please specify the required and already used CIM profiles and standards linked to CIM.”

Question	Options	Status	Percentage
Q1	IEC 61850 series	Required	67%
		Already used	44%
	Utility application integration profiles- CIM Distribution Model - defined by IEC 61968-11	Required	57%
		Already used	68%
	Network studies related profiles - CGMES profiles - defined by 61970-600-x	Required	57%
		Already used	67%
	Network studies related profiles - defined by IEC 61970-301	Required	57%
		Already used	56%
	Standard profiles related to Utility Integration based on CIM Model IEC 61968-x (3 to 9)	Required	57%
		Already used	56%
	Standard profiles related to Network studies based on CIM base model - defined by IEC 61970-45x (“CIM Market”)	Required	57%
		Already used	33%
	Market related profiles (IEC 62325-45x, mainly based on IEC 62325-301 CIM Market model)	Required	57%
		Already used	33%
	Common Distribution Power System Model (CDPSM) profiles (IEC 61968-13 Ed1 2008, Ed2 will be released in 2020 S1)	Required	56%
		Already used	56%
	Harmonisation between CIM and IEC 61850 - defined by IEC 62361-102	Required	56%
		Already used	22%
	CIM based data model related to network studies - defined 61979-600-1	Required	44%
		Already used	33%

In Table 3 (question 16) it can be seen that transformers, OH (Overhead) towers, generators (synchronous, asynchronous – IG (Induction Generator), DFIG (Double-Fed Induction Generator) and Static), busbars, T-points, nodes, switches, loads (domestic, industrial, commercial and others), sites, substations, battery storage, fuel cells and controllers (tap, primary and secondary) are among the network components prominently modelled by CIM.

Moreover, organisations have expressed their interest in modelling capacitors (switched and fixed), inductors (switched and fixed), active network management (generator control), reactive power control nodes (PQ, PV), dynamic asset ratings (transformers / cables) and voltage dependency loads (constant power, constant current, constant voltage). Nevertheless, regarding market profiles and harmonisation tools, their implementation is still pending for most of the surveyed TSO organisations and all of the surveyed DSO organisations as discussed previously. In this line, adopting CIM market and harmonisations profiles has the potential to achieve more harmonisation between TSOs and DSOs as well as to extend the coordination possibilities between different actors in the energy sector.

Table 3: Survey results for Question 16: "Which network components included in the list below are modelled in CIM?"

Question	Options	Status	Percentage
Q16	Transformer (2W, 3W, Earth, Phase Shift)	Currently Modelled	78%
		Future/current interest	11%
	Line (OH & UG), OH Towers	Currently Modelled	78%
		Future/current interest	0%
	Generator (Synchronous, Asynchronous - IG, DFIG and Static)	Currently Modelled	78%
		Future/current interest	0%
	Busbar, T-Point, Node	Currently Modelled	78%
		Future/current interest	0%
	Switch - CB, Isolator, Disconnector, Load switch etc	Currently Modelled	78%
		Future/current interest	0%
	Site, Substation	Currently Modelled	78%
		Future/current interest	0%
	Load (Domestic, Industrial, Commercial, others)	Currently Modelled	78%
		Future/current interest	0%
	Capacitor (switched and fixed)	Currently Modelled	67%
		Future/current interest	11%
	Inductor (switched and fixed)	Currently Modelled	67%
		Future/current interest	11%
	Protection - Relays (all types) CTs, PTs, CPT, Fuses	Currently Modelled	44%
		Future/current interest	44%
	Static Reactive Power Compensators - Switched and fixed	Currently Modelled	44%
		Future/current interest	33%
	Neutral Earthing Reactor / Conductor	Currently Modelled	44%
		Future/current interest	11%
	Battery Storage and Fuel Cells	Currently Modelled	11%
		Future/current interest	56%
	Power Converters (AC-DC, DC-AC, AC-AC)	Currently Modelled	11%
		Future/current interest	22%
	Motor, Motor Starters	Currently Modelled	11%
		Future/current interest	11%

In general, Table 4 (question 2) shows that the surveyed organisations mostly use CIM standards to facilitate the data exchange with other stakeholders within a standardised format (78%), understand network connectivity without the use of geographic data (78%), perform power flow analysis (56%) and map their network geographically (67%).

Table 4: Survey results for Question 2: "What are the purposes of using CIM? Please specify the current and required (but not yet used) purposes."

Question	Options	Status	Percentage
Q2	Facilitating the data exchange with other stakeholders within a standardised format	Required	67%
		Currently used	78%
	Understanding network connectivity without the use of geographic data	Required	56%
		Currently used	78%
	Mapping network geographically e.g. view paths of lines/cables, locations of substations	Required	56%
		Currently used	67%
	Power flow analysis e.g. for planning new connections	Required	56%
		Currently used	56%
	Obtaining asset data e.g. the mix of asset types	Required	56%
		Currently used	33%
	Other Market Coordination	Required	33%
		Currently used	33%
	CIM/61850 Harmonisation real cases (like for DER integration)	Required	33%
		Currently used	0%
	Balancing mechanism and demand planning	Required	22%
		Currently used	44%

On the other hand, CIM standards are less frequently used for obtaining asset data, such as the mix of asset types (33%), and for balancing mechanism and demand planning (44%), being necessary to make CIM profiles better suited for supporting such applications. Here, it is important to highlight that, as suggested above, TSO organisations are highly concerned about market coordination. Some of them have reported to use CIM models to manage market data flows shared with market agents. In addition, they have highlighted that there is a need for distinguishing the use of CIM with external stakeholders versus its internal usage at the utility level between applications, since some utilities prioritise the use of CIM to communicate with external stakeholders. Finally, they have highlighted the need for having access to data from assets as well as to relevant geographical data of power lines and substations for usage on SCADA (Supervisory Control and Data Acquisition) level, and for CIM/61850 harmonisation real cases, such as the one available for DER integration.

4.2.3 CIM version used

It has to be pointed out that there are different CIM versions and associated profiles. The answer to this question is illustrated in Table 5. CIM100 was a CIM17 version frozen by IEC TC57 working groups in 2019. Its main goal was also to help to get a new base line in order to generate next CGMES version (CGMES 3.0.0) which was released in 2020. At the present time IEC TC57 CIM related working groups are establishing the list of issues to solve in order to define the content of next CIM version (CIM 18).

Table 5: Survey results for Question 9: "What is the CIM version/Profile you are using "

Q9. What is the CIM version/Profile you are using?	CIM 16	79%
	CIM 17	57%
	CIM 100	11%
	CGMES 2.4.15	11%
	CIM 10	10%

4.3 Proposal to structure a CIM repository

Based on second questionnaire named "Business Objects and CIM related profiles", this report proposed to structure a CIM repository as described in following steps.

1) Fill in the **Business Object and CIM Profile Questionnaire** which was developed for this report (Figure 32).

updated CIM profile			Use Case Background			Demo	
Profile name	CIM extension (UML package name)	profile is based on	BO (Business Object)	SUC (System Use case)	BUC (Business Use case)	Profile was used in demo	CIM was used in demo
TDXFunctionalAnalysisResultsInformationProfile	no extension required	CGMES	Functional Analysis Results Information				
TDXPreQualificationReportProfile	ExtPrequalificationReport	CGMES	Pre-qualification report				
TDXPreQualificationTechnicalDataRequestProfile	ExtPrequalificationTechnicalDataRequest	CGMES	Pre-qualification technical data request				
GeneralOffer	no extension required	ESMP	General offer information	Market offering	BUC 2		
MarketResults	no extension required	ESMP	General market results information				
ConsumptionAndProductionForecastInformationDependancy	no extension required	ESMP	Consumption and production forecast (internal) information				
ReactivePowerSetpoint	no extension required	ESMP	(Request/Response) Reactive Power Setpoint	Contribution of DSO to voltage regulation / scenario : Mandatory/ …	BUC 5/6		
				…Voluntary reactive power service request nearby real-time			
TDXShortCircuitPowerForecastProfile	ExtShortCircuitPowerForecast	CGMES	Short-Circuit power forecast	Exchange short circuit levels at bay level for the next 24 hours	BUC 7		
TDXEnergyScheduleProfile	ExtTDXEnergySchedule	CGMES	Consumption and production forecast for operational planning purposes	Disaggregated consumption and generation forecast for operational planning purposes	BUC 7		
			Consumption and production historical profiles (external) for long-term planning	Definition of historical profiles disaggregated by type of consumption and	BUC 9		

Figure 32: CIM repository – questionnaire (example) [based on TDX-ASSIST Deliverable 1.11, 2020]

2) Manage a **Global Business Object and CIM profile spreadsheet** by merging the answers to questionnaires in step 1. A proposal has been started between EU-SysFlex, INTERRFACE, TDX-ASSIST (Figure 33).

EU-SysFlex		INTERRFACE		TDX ASSIST	
SUCs	Business Objects	SUCs	Business Objects	SUCs	Business Objects
Authenticate data users	Authenticate Information				
	Representation Rights				
Calculate flexibility baseline	Baseline				
	Flexibility Bid				
Collect energy data	Authenticate Information				
	Metering Data				
	Market Data (e.g. Flexibility Bid)				
	Request on market data				
	Congestion Matrix (same as Results of Grid Validation or Grid Impact Assessment Result)				
Exchange data between DERs and System Operators	DER Structural Data				
	DER Real Time Data				
	DER Activation				
Manage access permissions	Authorization information				
	Customer Consent				
Manage data logs	Data log request				
	Data log				
	Flexibility Bid				

Mapping objects to use cases | Mapping profiles to objects

Figure 33: CIM repository – Global Business Object and CIM profile spreadsheet (example) [based on EU-SysFlex Deliverable 5.2, 2020]

3) Manage a **UML repository for Business Objects and CIM profiles.** UML repository allows to export reports and is the foundation to use tools which are already used on the international level in order to define profiles. Figure 35 regroups Business Objects per System Use Cases and those which are exchanged through a Data Exchange Platform.

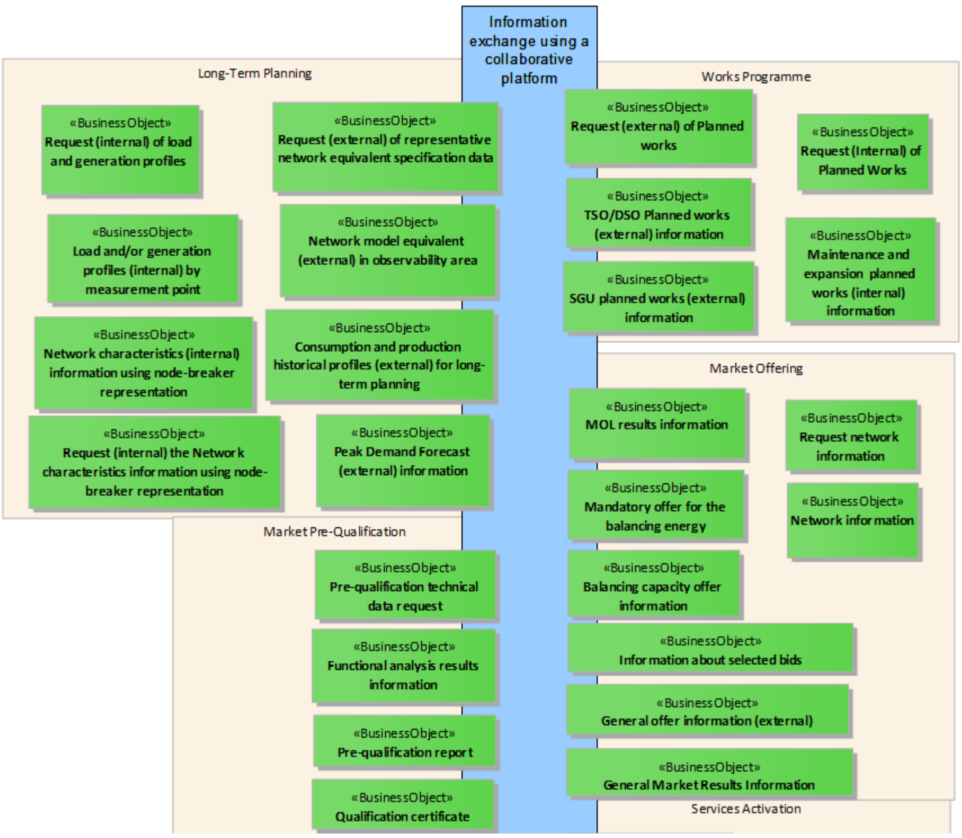


Figure 34: CIM repository – UML repository for Business Objects (example from TDX-ASSIST UML repository)

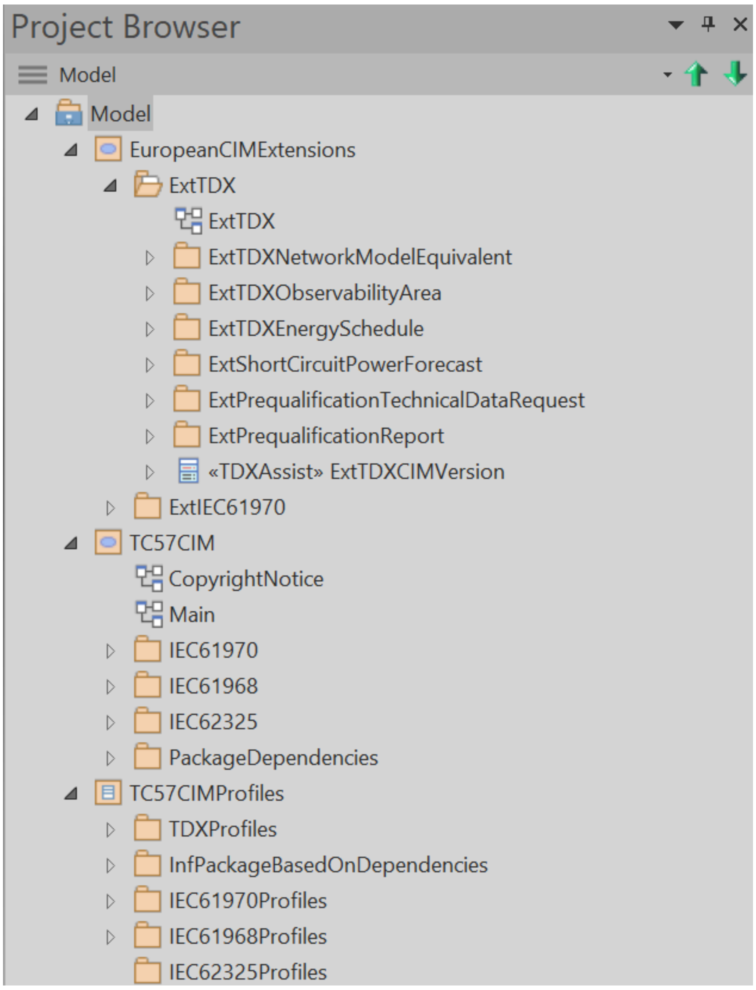


Figure 35: CIM repository – UML repository for CIM Profiles, incl. extensions proposals (example from TDX-ASSIST UML repository)

4) Manage **repository of instance files.** An instance file is a data set which is structured conformant with the profile. Therefore an instance file can be validated against a profile, using several tools. These instance files will have to respect GDPR key principles: lawfulness, fairness and transparency, purpose limitation, data minimisation, accuracy, storage limitation, integrity and confidentiality (security), accountability.

Instance files could also support interoperability tests, or feed European platforms demonstrating interoperability features. For instance we could have typical European networks using CGMES standard, proving that CGMES can model any voltage level – Extra High Voltage (EHV), High Voltage (HV), Medium Voltage (MV), Low Voltage (LV). This would be the task assigned to a CIM user group.

Governance of repositories

As explained above different kind of CIM repositories would have to be managed. There should exist governance mechanism to update these repositories based on projects' feedback, but also mechanism to make available these repositories to European projects and to educate European projects about CIM.

4.4 Education and promotion of usage of CIM in electricity domain

CIM plays a significant role in reaching data interoperability within electricity sector and facilitates exchange of information and data between all stakeholders. While CIM represents the common ground enabling semantic and syntactic data interoperability, achieving the final goal requires wide acceptance of CIM by all stakeholders in the electricity domain. Therefore, it is necessary to define the strategy to disseminate advantages and benefits that CIM usage provides as well as to develop a systematic approach in provision of education and consulting to all interested parties across Europe.

The educational strategy should be adapted to the role of the trainees in their companies and institutions, providing different contents and technical details, while applying appropriate methodical approaches for each group profile. For the technical persons (engineers), educational process should involve hands on with practical assignments, also favouring the European CIM design tools, such as MODSARUS ®, CimConteXtor and Cimphony. In other words, engineers and students should be educated in CIM through the practical usage of the above mentioned tools.

Systematic approach will be achieved by a definition of study and training programs divided into the modules with a number of hours defined, including the competences and skills that such programs will provide to the participants. It would be a huge advantage to establish some CIM educational programs at the European level, supported by electricity industry and institutions such as ENTSO-E. A teaching process should originate from understanding the need for general interoperability and data interoperability in particular, and leverage the design of smart grid system founded on Use Case methodology.

It is also important that CIM education includes aspects of semantic data modelling and understanding the advantage of such approach in sharing knowledge across the semantic web since CIM is aligned with this approach. Another important aspect is storage of CIM-based data in databases (DBs) such RDF-based DBs and graph DBs, as well as incorporation of those DBs utilising data federation architectures and data retrieval based on semantic web technologies (e.g. SPARQL, CYPHER).

4.5 Proposal to set-up a European CIM User Group

Various possibilities on organizing CIM related training and knowledge sharing exist:

- IEC CIM working groups providing guidelines, technical reports, WG notes.
- UCAIug (CIMug) training services – CIM University: US based organisation with fees for members.
- Community open web sites enabling knowledge sharing.
- Dedicated consultancy services to support training to bridge different activities.
- Involving universities or research institutes in CIM training.
- Rely on the IEC National Committees to organise at national level with national scope.
- Two initiatives federating CIM users exist: Smart Grid Forum conference[13], and UCA CIM User group[14]. Attending Smart Grid Forum conference has a fee. Being member of UCA CIM User group has also a fee, depending on the company type and number of employees. UCA, which is a North American association coordinates User Groups in North America and in Europe. Beside these two organisations, ENTSO-E has a CIM expert group[15] and trains its TSO members. ENTSO-E is involved in IEC TC57 and leads several IEC CIM standards (IEC 61970-600 series associated to Common Grid Model Exchange Specification, and IEC 62325-45x series associated to European Style Market Profiles) which are supporting European Network Codes.

[13] https://www.smartgrid-forums.com/forums/common-information-model/
[14] https://cimug.ucaiug.org/
[15] https://www.entsoe.eu/digital/cim/

An **European CIM User Group (ECUG)**, and maybe a **European Smart Energy Standard User Group** (**ESESUG**) managed by Europeans and answering Europeans users first could/should be set up **at the European level**, in order to train and provide material on smart energy projects funded by EC, but potentially going beyond that by also capturing, for example, relevant industry. The advantage would be to answer specific European requirements, and to stay focussed on European priorities.

EC's science and knowledge service JRC (Joint Research Centre) could play this role with support of external R&D centres and academics or this user group could be set up in coordination with European Standardisation Organisations (CEN-CENELEC-ETSI CG-SEG), possibly involving IEC. Funding scheme of this European CIM User group should be studied.

The mission (of ESESUG) would be to set up training on some standards like Use Case methodology, SGAM, CIM, 61850, COSEM, Ontology like SAREF, HEMRM, and other key smart energy standards, etc. JRC can contribute by helping the users to test their Use Cases in JRC's lab infrastructures both in Ispra[16] and Petten[17].

European projects would have to be familiar with standardisation process and how they can contribute to fill standardisation gaps as identified by CEN-CENELEC-ETSI CG-SEG. CG-SEG elaborates a standardisation roadmap for Europe and provides some of its gaps to IEC System Committee Smart Energy, which integrates these gaps in its international roadmap. This contributes to elaborate Smart Grid Standardisation Roadmap [IEC 63097, 2017] which is described as follow:

"IEC 63097 provides standards users with guidelines to select a most appropriate set of standards and specifications. These standards and specifications are either existing or planned, and are provided by IEC or other bodies also fulfilling use cases. It also aims at creating a common set of guiding principles that can be referenced by end-users and integrators who are responsible for the specification, design, and implementation of Smart Energy Systems. As a living document, this roadmap will be subject to future changes, modifications. "

4.6 Handling Code Components in IEC standards and its impact on CIM usage

4.6.1 Code component insights

IEC sets out the process and rules to be used by IEC groups (TCs, WGs, SyCs, etc.) and experts in charge of editing IEC documents to ensure a proper handling of copyright licensing of code components included in IEC deliverables. It also defines the technical and process requirements to consider to optionally offer a free access to certain code component(s) through the IEC web site.

A code component is any piece of information, intended to be directly processed by a computer and encoded in accordance with specific software code language rules (typically XML, XSD, Java, C, etc.) [IEC, 2018]. Code components (if applicable) are part of the official IEC publication and thus are published by IEC together with the IEC publication on the web-store.

IEC CIM is managed in UML, and IEC Code Component Handling document [IEC, 2019] specifies how the copyright on UML (XMI – XML Metadata Interchange) should be indicated:

[16] https://ec.europa.eu/jrc/en/research-facility/european-interoperability-centre-electric-vehicles-and-smart-grids
[17] https://ec.europa.eu/jrc/en/research-facility/smart-grid-interoperability-laboratory

> COPYRIGHT © IEC, 2016. This version of this UML model is part of IEC xxx; see the IEC xxx for full legal notices. In case of any differences between the here-below code and the IEC published content, the here-below definition supersedes the IEC publication; it may contain updates. See history files. See www.iec.ch/CCv1 for copyright details

In case of XMI transposition, the XMI file shall contain the transposition of this UML Note. In case of draft code component, the “draft” aspect of the code component shall be explicit, under a format to be defined case by case (for example associated to a specific attribute defining the maturity status of the concerned element. This mention will be deleted at the time of official publication.

The availability of code components opens the possibility for IEC to offer new services to users such as:

- Ability to get access to full content;
- Automatic notification in case of change/update;
- Browsing capabilities of the whole content of code components from the different parts of the series (so called web-access);
- Change tracking; etc.

4.6.2 Impacts of using IEC CIM in European projects

In order to use CIM in European projects without contravening IEC policy and copyright, CIM UML model(s) and associated profiles should be made available following a clear procedure.

Therefore, it should be sufficient if at least one European project participant can prove that IEC standards and associated Code Components have been bought from IEC and that this gives the right to use IEC CIM standard in the context of the project.

At this stage solving this issue is still an open question which has to be solved between European Commission, European Standard Organisations, and IEC.

5. Data exchange roles

5.1 Mapping of different role models used by projects

Five models and four projects were identified and compared:

- EU-SysFlex – project specific model
- BD4OPEM – IDSA
- CoordiNet – HEMRM
- PHOENIX – project specific model
- USEF framework was added for the reference

Detailed description of the roles collected from the four projects is presented in Annex V. Table 6 summarises the roles and makes an attempt to map these to each other.

Table 6: Mapping of role models

HEMRM	EU-SysFlex	IDSA	PHOENIX	USEF
Consent Administrator				
Data Provider	Data Hub Operator	Data Provider	Electricity Data Administrator, Cybersecurity Data Administrator, Cybersecurity Knowledge Administrator	
Market Information Aggregator			Cybersecurity Knowledge Administrator	
Meter Administrator				
Meter Operator				
Metered Data Aggregator				
Metered Data Collector				Meter Data Company
Metered Data Responsible	Metered Data Operator			Meter Data Company

HEMRM	EU-SysFlex	IDSA	PHOENIX	USEF
Metering Point Administrator				
Metered Data Administrator	Metered Data Operator, Data Hub Operator		Electricity Data Administrator, Cybersecurity Data Administrator	
	Authentication Service Provider			
	Customer Portal Operator			
	Data Delegated Third party			
	Data Owner	Data Owner		
	Data User	Data User		
	DEP Operator			
	Foreign Customer Portal Operator			
		Data Consumer		

5.2 Repository of data roles

It should be ensured that consistent set of business roles (both role names and definitions) are used by projects. This would help to avoid unnecessary duplications and inconsistencies. This report is concerned with data roles, however the same applies to other roles. Ideally, HEMRM could be used as the reference model but updating HEMRM seems to be slow to take on board new proposals made by R&D projects and to disseminate these to the rest of R&D community. Therefore, other possible candidates could be the Use Case Repository elaborated in other BRIDGE report [BRIDGE Regulation WG, 2021] and the CIM repository proposed in Chapter 4.3 of this report. This way also the consistent usage of roles in use cases and CIM profiles would be supported.

5.3 Role model for data roles

Figure 36 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. Roles and classes in green are existing in HEMRM. Roles and classes in red are not existing in HEMRM. Roles in orange have quite different definition in HEMRM.

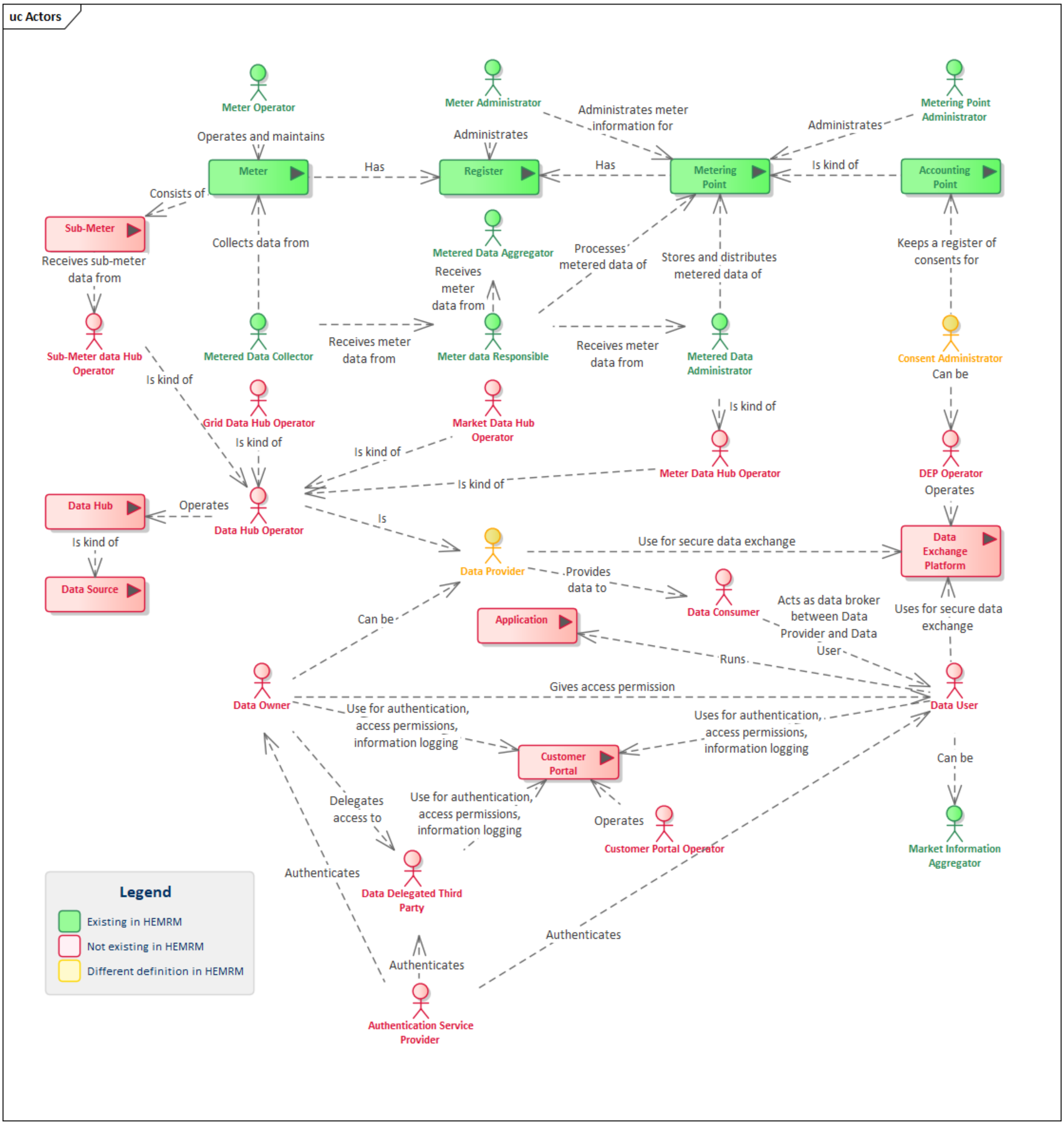


Figure 36: Data exchange role model

5.4 Proposals for HEMRM update

Table 7 presents the data exchange business roles and Table 8 related classes which are missing in HEMRM but proposed in cooperation with BRIDGE Regulation WG to be added. In this case also some new relationships need to be added. For few other roles (e.g. Data Provider) the HEMRM definitions should be adapted. HEMRM is a document developed and maintained by ebIX, EFET and ENTSO-E. New role propositions must be presented as Maintenance Request for a review of the above-mentioned parties. They will check if existing roles can fulfil new needs (based on the data exchange diagram of each case). After that, HEMRM can be updated accordingly (or not).

Considering the universal nature of these data exchange roles HEMRM could be renamed to Harmonised Energy Role Model – HERM.

Table 7: Candidates for new HEMRM data exchange business roles [BRIDGE Regulation WG, 2021]

Business Role	Description
Authentication Service Provider	Trust authority. Verifies the identity of authenticating parties. Some countries will have their own authentication service provider. For country which will not, there may be a more global and to be defined one.
Customer Portal Operator	Customer Portal Operator manages data user's authentication, access permission and data logs. Customer Portals store data related to its services (e.g. authentication information, representation rights, access permissions, data logs).
Data Delegated Third party	Any natural person or legal entity who has received representation rights from data owner.
Data Owner	Any physical person or legal entity that owns data and can give authorization to other parties to access them. He can create data and / or execute control over them. Every role in the model can be a data owner (it can be also meant as a specification of the role).
Data User	Any person who uses data. Can be a Data Owner or a Data Delegated Third party. He has the right to use the data of a Data Owner as specified by a contract policy (It can be also meant as a specification of the role).
Data Consumer	Entity receiving data. Act as an intermediary (third-party) among entities providing data and using data. In most cases identical to data User.
Data Hub Operator	Data Hub Operator operates an information system which main function is to store and make available measurements (e.g. meter data, operational data) and associated master data. It can be: • Grid Data Hub Operator in the sphere of grid data; • Market Data Hub Operator in the sphere of market data; • Meter Data Hub Operator in the sphere of meter data; • Sub-Meter Data Hub Operator in the sphere of sub-meter data. It makes data available for being exchanged between Data Owner and Data Consumer.
DEP Operator	Data Exchange Platform (DEP) Operator operates a communication system which basic functionality is data transfer between Data Provider and Data User. DEP stores data related to its services (e.g. cryptographic hash of the data requested). DEP does not store core energy data (e.g. meter data, grid data, market data) while these data can be stored by Data Hub Operator.

Table 8: Candidates for new HEMRM data exchange classes

Class	Description
Customer Portal	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).
Data Exchange Platform	Data Exchange Platform 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.
Data Hub	Data Hub is an information system which main functionality is to store and make available measurements (e.g. meter data, operational data) and associated master data.
Application	Any kind of system used by a Data User who wishes to receive data.
Data Source	Any kind of system used to store data (e.g. Data Hub).
Sub-Meter	A Meter to enable measurements from In-House Devices.

6. Proposal for European energy data exchange reference architecture

6.1 Description of reference architecture

Figure 37 depicts a high-level SGAM based reference architecture for data exchange. 'European' refers to the cross-border data exchange capability. While on the left side of the figure elements related to electricity domain are highlighted, the focus of this report and reference architecture is on middle part – cross-sector domain. This is where biggest efforts in terms of interoperability are needed.

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.

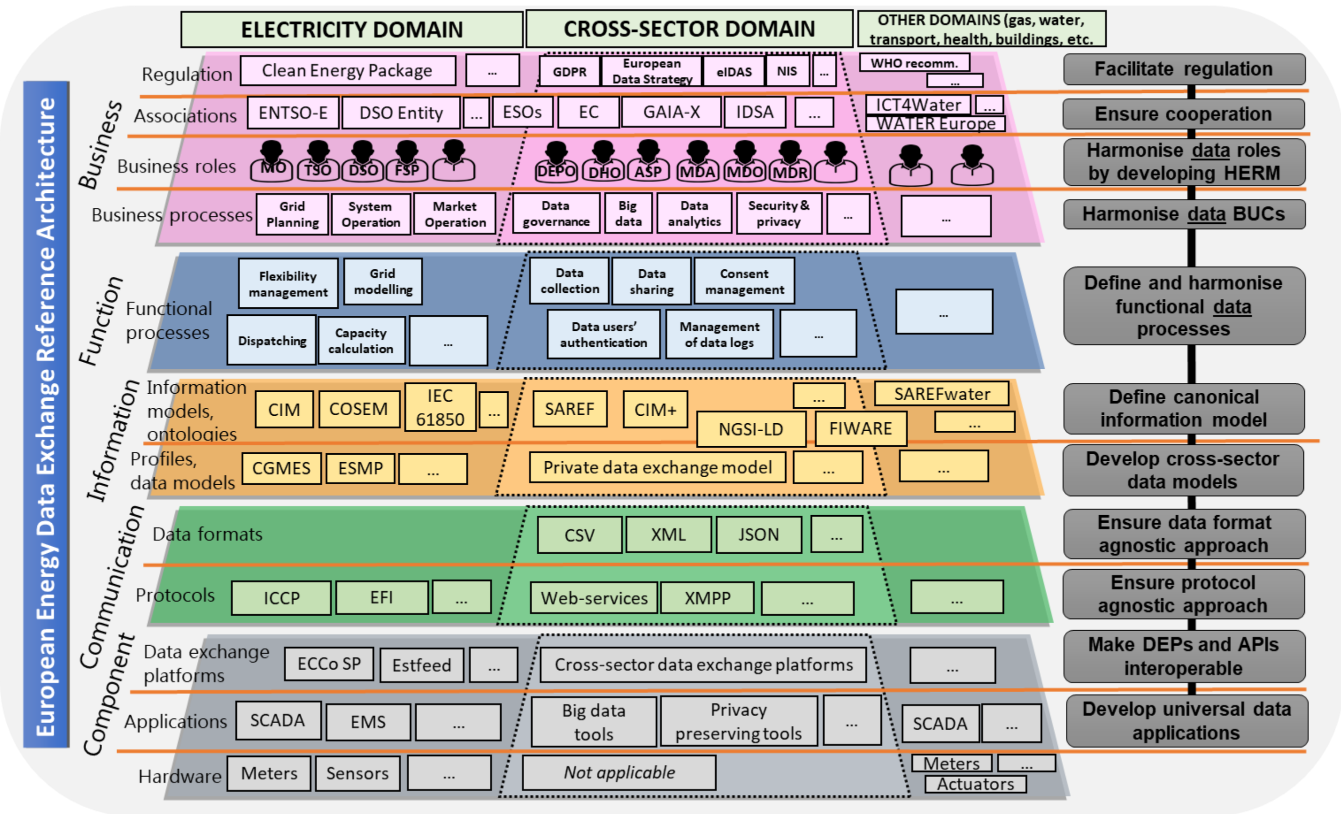


Figure 37: High-level SGAM based reference architecture for European energy data exchange

Regulation sub-layer

While CEP (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.

Associations sub-layer

ENTSO-E and soon to be established 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).

Business roles sub-layer

Some usual business roles in electricity are TSO, DSO, MO, FSP. 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).

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.

Function layer

Examples of electricity sector functions: flexibility management, grid modelling, dispatching, capacity allocation. For cross-sector interoperability data related functions should be addressed: data collection, data sharing, consent management, data users' authentication, management of data logs.

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. Also CIM+ is there which could be 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.

Profiles and data models sub-layer

Commonly used groups of electricity sector profiles are CGMES and ESMP. An example of cross-sector data model could private data exchange model since this is a challenge for many sectors.

Data format sub-layer

Data formats should generally not be sector-specific. Commonly used formats like CSV, XML and JSON can be used in any sector.

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.

Data exchange platforms sub-layer

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 (see Table 1). 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.

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.

On the right side of the figure in grey boxes there are recommendations per (sub-)layer which are further elaborated in Chapter 6.2.

6.2 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). The Business Layer is related to Business Use Cases, as Function Layer is associated to System Use Cases. The Information Layer hosts Canonical Data Models, data models and profiles, and semantics of exchanged data between systems, applications, equipment. Communication Layer refers to communication protocols (how the information is exchanged) and data formats (syntactics). The Component Layer represents the physical distribution of all participating components in the smart grid context.
Recommendation	Leverage Smart Grid Architecture Model (SGAM) usage and study its extension to other sectors.

Topic	Business layer – regulation
Findings	CEP (Clean Energy Package) and GDPR (General Data Protection Regulation) are most often mentioned by projects – CEP (i.e. electricity market directive) 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. In addition, CIM is promoted through electricity network codes and guidelines.
Recommendation	Facilitate regulation for cross-sector exchange of any type of both private data and public data, e.g. through the means of regulation for data spaces 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, Data Bridge Alliance, IDSA, OPEN DEI. Also the associations from different sectors (e.g. ICT4Water) could learn from each other and cooperate for further synergies.
Recommendation	Ensure cooperation between appropriate associations to work on cross-sector and cross-border data management.

Topic	Business layer – data roles
Findings	BRIDGE projects are using several data exchange business roles which are missing in HEMRM (Harmonised Electricity Market Role Model). After comparing and matching similar roles, and in cooperation with BRIDGE Regulation WG new data roles were identified: Authentication Service Provider, Customer Portal Operator, Data Delegated Third party, Data Owner, Data User, Data Consumer, Data Hub Operator, DEP Operator. Linked to these roles also some new classes are proposed: Customer Portal, Data Exchange Platform (DEP), Data Hub, Application, Data Source, Sub-Meter. Also some new relationships need to be added. For few other roles (e.g. Data Provider) the HEMRM definitions should be adapted.
Recommendation	Propose to ENTSO-E, ebIX and EFET new roles and classes to be included and definitions to be adapted in existing HEMRM. Develop mechanism for proposing new roles by BRIDGE projects.

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).
Recommendation	Harmonise data roles across electricity and other energy domains by developing HERM – Harmonised Energy Role Model. Look for consistency with other domains outside energy based on this HERM – cross-sectoral roles.

Topic	Business layer – data roles
Findings	It should be ensured that consistent set of business roles (both role names and definitions) are used by projects. This would help to avoid unnecessary duplications and inconsistencies. This would require an easily accessible repository. To avoid creating a further stand-alone repository possible candidates could be the Use Case Repository and or CIM repository elaborated in other BRIDGE actions. This way also the consistent usage of roles in use cases and CIM profiles would be supported.
Recommendation	Create a central repository for roles used by BRIDGE (and other) projects as part of ‘Use Case Repository’ and/or ‘CIM repository’.

Topic	Business layer – processes
Findings	Given the exploration of cross-sectoral architectures, it was derived that there are 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. Furthermore, waste water management is performed utilizing great amount of energy resources, the fact which has implications for coordination among sectors. 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 and content of data exchange business use cases for cross-sector domain.

Topic	Function layer
Findings	The analysis of obtained responses from both BRIDGE projects for the electricity as well as from the cross-sector interaction highlights that the key transformation of both electricity domain and the cross-sector domain is the data exchange and management. 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.

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).
Recommendation	Define 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. Study the benefit to use ontologies to support cross-sector interactions.

Topic	Information layer – data models and profiles
Findings	European electricity sector has put in place a robust methodology based on system approach, which promote 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.

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; power quality (PQ) meters send voltage and power measurements to the database using MQTT protocol; IEC 60870 series based Inter Control Center Protocol – ICCP; IEC 61850 series based protocol.
Recommendation	Ensure protocol agnostic approach to cross-sector data exchange.

Topic	Communication layer – data formats
Findings	Data profiles are using a data format, i.e. syntax: XML 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 (XSD schemas or JSON) format in its different versions according to the application. European Style Market Profile (ESMP) uses CIM XML format. Data exchange of network models (CGMES) follows CIM XML RDF syntax.
Recommendation	Ensure data format agnostic approach to cross-sector data exchange.

Topic	Information and communication layers – CIM repository
Findings	It is important to promote reusability among European projects. Complementary to set-up a use case repository, it is important to identify which business objects and profiles have been defined by other projects and to share knowledge. It is important to take into account that CIM evolves (versioning), and that profiles are derived from CIM. Different kind of CIM repositories can be managed (repository of Business Objects, repository of CIM profiles). Ideally Unified Modelling Language (UML) repositories will have to be managed, using versioning system. Having UML repositories will also facilitate the generation of CIM profiles.
Recommendation	Set up and manage a CIM repository for BRIDGE projects and beyond.

Topic	Information and communication layers – CIM User Group
Findings	Continuous training and knowledge sharing is essential as IEC CIM is a moving target as its scope grows to cover new, emerging data exchange requirements and we are more and more into a cross-sector energy mode. CIM training and knowledge sharing is important in order to help European projects' participants to implement CIM standards in a fast-track mode; to be aware of the standardisation process and how to contribute to it; to involve people with different expertise as contributors; to ensure the areas of benefits are well understood and where new work is planned. In general, the whole process needs resources (human and financial). Building strong community via knowledge sharing would boost opportunities for projects on key topics. A European CIM User group would foster European CIM community needs and will help to liaise with other user groups. European standardisation organisations (CEN, CENELEC, ETSI), European academics, European institutions like JRC could participate in this European CIM user group. Moreover, smart energy grids are complex systems and it could be valuable to set-up a European Smart Energy Standard User Group.
Recommendation	Set up a European CIM User Group and eventually a Smart Energy Standard User Group.

Topic	Information and communication layers – education and promotion
Findings	While CIM represents the common ground enabling semantic and syntactic data interoperability, achieving the final goal requires wide acceptance of CIM by all stakeholders in the electricity domain. Systematic approach will be achieved by a definition of study and training programs divided into the modules with a number of hours defined, including the competences and skills that such programs will provide to the participants. It would be a huge advantage to establish some CIM educational programs at the European level, supported by electricity industry and institutions such as ENTSO-E.
Recommendation	Define the strategy to disseminate advantages and benefits that CIM usage provides as well as develop a systematic approach in provision of education and consulting to all interested parties across Europe.

Topic	Information and communication layers – access to CIM
Findings	IEC sets out the process and rules to be used by IEC groups (TCs, WGs, SyCs, etc.) and experts in charge of editing IEC documents to ensure a proper handling of copyright licensing of code components included in IEC deliverables. It also defines the technical and process requirements to consider to optionally offer a free access to certain code component(s) through the IEC web site. The availability of code components opens the possibility for IEC to offer new services to users. It should be sufficient if at least one European project participant can prove that IEC standards and associated Code Components have been bought from IEC and that this gives the right to use IEC CIM standard in the context of the project. At this stage solving this issue is still an open question which has to be solved between European Commission, European Standardisation Organisations, and IEC.
Recommendation	Make CIM UML model(s) and associated profiles available following a clear procedure.

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. Majority of the projects answering the questionnaire reveal that interoperable data exchange platforms embody functionalities across all the interoperability layers as defined in the SGAM framework.
Recommendation	Make DEPs (Data Exchange Platforms) 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.

6.3 Next steps

- Based on the reference architecture (6.1) and recommendations (6.2) an MVP (minimum viable product) could be demonstrated between interested BRIDGE projects by implementing European data exchange reference architecture. 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.
- Implement CIM Repository and European CIM User Group.
- Implement repository for data roles (and other business roles) as part of Use Case Repository and/or CIM Repository.

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7. 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/IEC42010
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.	[Brittion]
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.	Wikipedia
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], IEC61850-2010
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

Term	Definition	Source
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 synchronization 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]
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, 23.03.2017]

Term	Definition	Source
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, 23.03.2017]
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

8. Annex II. Reference architecture questionnaire

BRIDGE questionnaire on proposing a European reference architecture

August 2020

Fields marked with * are mandatory.

Outlook of Questionnaire

Lately, the ambitions of European Commission to embody consumers and pro-sumers to take part in the energy transition, have been highlighted in several initiatives such as the Clean Energy Package [Directive (EU) 2019/944]. This is aimed to take place by equipping end-users with proper tools and rights to access energy markets. The former has enabled consumers to access and assess their own energy data and share it among -contracted- third parties, under their consent. Along with novel commercial services based on data sharing, there are evolving services relying on demand-side flexibility.

Both traditional retail processes and emerging services require data and information to be accessed by relevant eligible parties and exchanged among multitude of actors, networks, systems, devices, applications and components. Consequently, there is a struggle to leverage legacy and newly developed systems that 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.

In EU-wide scale, conceptual data exchange reference architecture, Common Information Model (CIM) and Harmonised Electricity Market Role Model (HEMRM) are set in place on several H2020 projects, involved also in BRIDGE. From your latest involvement in such EU projects please address the following questions.

Project information

* Name of the EU project you are representing:

* Please describe the data platform that is used or being developed within your project (i.e. main objectives, actors involved, main use-cases (if applicable, briefly mention a few details for the main use-cases)):

If you wish, you may upload an explanatory file for the above question.

The maximum file size is 1 MB

* What processes are (being) deployed/facilitated by the data platform used or to be developed? (*Multiple Choice Question*)

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

☐ Flexibility bidding

☐ Flexibility prequalification

☐ Flexibility verification

☐ Flexibility baseline calculation

☐ Flexibility prediction

☐ Other (please write down on text-box below, if necessary):

Please add, hereby, more processes/functionalities (if necessary) and explain.

* What is the current status of implementation on interoperability features and functionalities in relation to the data platforms that are used or being developed in your project?

- ○ Not yet developed. Methodology is under discussion.
- ○ Not yet developed. Methodology is thoroughly defined.
- ○ Under development, but still space for discussion, if needed.
- ○ Well advanced.
- ○ Completed.

* In which of the following levels are interoperability features developed or aimed to be developed/proposed in relation to the data platforms that are used or being developed in your project? (*Multiple Choice Question*)

☐ Data management (i.e. semantics and syntactic, data models)

☐ Software APIs (e.g. power flows, state-estimation engines, optimizers)

- Information and Communication Technologies (e.g. exchange protocols, authentication)
- Business layers (e.g. regulatory framework -local, national and EU level-)
- Role-oriented/business procedures (i.e. definition of responsibilities aligned with HEMRM instead of specific parties to avoid lock-in effects)
- Business objectives (i.e. strategic and tactical objectives)
- Economic/regulatory (i.e. political and economic perspective)

* What type of methodological approach is embodied to achieve interoperability in relation to the data platforms that are used or being developed in your project? (*Multiple Choice Question*)

- Testbed framework for interoperability validation
- Enable free flow of data between platforms (e.g. cross-border data exchange)
- Ensure GDPR compliance and data owner's control over their data
- Vendors (at any level) engagement and alignment with the adopted architecture
- Adoption of IEC standards (CIM etc)
- Adoption of standardised ICTs
- Adoption of HEMRM
- Definition of processes and methodologies
- Policy and/or regulation alignment and propositions towards

Please elaborate on your above answer on the text-box (provide a description of your methodological approach):

Please upload your file, if you wish to ease the explanation of the methodology used for the above question.

The maximum file size is 1 MB

* Please enlist the communication standards adopted by the data platform used or to be developed in your project, to achieve interoperability features:

* Which levels do you consider as the ones lacking utmost interoperability features in relation to the data platforms that are being developed in your project? (*Multiple Choice Question*)

- [ ] Data management (i.e. semantics and syntactic, data models)
- [ ] Software APIs(i.e. power flows, state-estimation engines, optimizers)
- [ ] Information and Communication Technologies (e.g. exchange protocols, authentication)
- [ ] Business layers (regulatory framework -local, national and EU level-)
- [ ] Role-oriented/business procedures (i.e. definition of responsibilities aligned with *HEMRM instead of specific parties to avoid lock-in effects)
- [ ] Business objectives (i.e. strategic and tactical objectives)
  Economic/regulatory (i.e. political and economic perspective)

* Which pillars do you envisage for the implementation of interoperability towards the definition of a reference EU architecture in the electricity sector? (*Multiple Choice Question*)

- [ ] Free-flow of data and common consensus among entities for the treatment of data and meta-data
- [ ] Open Source solutions
- [ ] Use of repositories not limited to standards
- [ ] Deployment of secure block-chain, IoT based solution enhanced with cyber-security features.
- [ ] Establish a novel EU entity for the interoperability management.

☐ Alignment of network codes (cross-border, national towards EU standardisation)

Propose other, share your own insights on the question above.

Vision for common European reference architecture for the electricity sector

* Do you believe that the initiative towards the definition of a common European reference architecture in the electricity sector has versatile benefits?

○ Yes

○ No

Which of the following are the substantial benefits of a common European reference architecture in the electricity sector?

☐ Benefits from the enhanced cooperation between actors in electricity sector: customers (engagement, improved Quality of Service)

☐ Benefits based on market parties coordination (facilitate Demand Side Flexibility, integration of DER) Benefits based

☐ on TSO/DSO coordination: optimal- decision-making leads to lower operational costs

Please add, hereby, more thoughts on the question above concerning the possible benefits on the development of a common European reference architecture.

Rate the following assertions considering their impact as a barrier on interoperability implementation? Scale: one markup circle stands for no impact, 3 means moderate and 5 severe impact)

Limited standards or need for advances/updates	○ ○ ○ ○ ○
Competition among vendors/suppliers	○ ○ ○ ○ ○
Vulnerability to cyber-attacks	○ ○ ○ ○ ○
The unwillingness among players to exchange private data and models due to privacy issues (e.g. end-users' to utilities etc)	○ ○ ○ ○ ○

Comment or add further barriers on the implementation of interoperability features and functionalities.

9. Annex III. Cross-sectoral questionnaire

Questionnaire for cross-sectoral interlinks

Lately, the ambitions of the European Commission to embody consumers and prosumers (i.e., electricity end-users that produce electrical energy themselves) to take part in the energy transition, have been highlighted in several initiatives such as the Clean Energy Package. This is aimed to take place by equipping end-users with proper tools and rights to access energy markets. The former has enabled consumers to access and assess their own energy data and share it among -contracted- third parties, under their consent. Along with novel commercial services based on data sharing, there are evolving services relying on demand-side flexibility. The system operators (i.e., transmission and distribution system operators) are currently equipping their networks with sensory devices and advanced automation not only to enhance observability towards optimized planning and operation but also for the incorporation of demand-side flexibility into the electricity market.

Both traditional retail processes and emerging 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. Consequently, there is a struggle to leverage legacy and newly developed systems that need to cooperate and exchange data and information to enable existing, emerging and future energy services. The definition of a common EU Reference Architecture may serve as a key driver towards the essential engagement of demand side flexibility, enabling utilities coordination beyond national borders. A fundamental element towards the definition of a reference architecture is the data exchange platforms which have been lately introduced in several European countries driven by the need for efficient processes and better data quality, initially in retail markets. Lately, the endeavour directed by 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. Hence, future data exchange platforms can take on a role in the overall power system and point towards an integrated wholesale-retail market.

In EU-wide scale, conceptual data exchange reference architecture, Common Information Model (CIM) -for standardised data exchange (semantics and syntactics)- and Harmonised Electricity Market Role Model (HEMRM) -clearly defining roles and responsibilities- comprise the linchpin on the definition of a common EU reference architecture. Hence, those are set in place on several H2020 projects, involved also in BRIDGE.

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 regulation. This approach requires holistic analysis of these systems to assess their interdependencies and facilitate energy interactions. The fusion of sensory devices along with advanced Information and Communication Technologies (ICT) 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 or common technical architectures.

From your latest involvement in such EU projects in other domains aiming to the development of interoperable data exchange frameworks towards the establishment of common EU reference architecture, please address the following questions.

1) **Title of the project/ initiative/ foundation:**

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

2) **Phase of implementation:**

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

3) **Sector/domain applied:**

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

4) **Could you provide the name and the main objectives of the proposed interoperable technical architecture defined in the project you participated in?**

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

5) Which were the main contributions and novelties of the proposed framework from a technical/operational perspective?

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

6) Could you please enlist interoperable features and functionalities of your proposed framework regarding the data exchange and information sharing, interoperability of platforms to provide common services, extinction of silos and integration of proprietary systems *etc*?

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

7) What are the derived benefits of your implementation in the applied domain(s)?

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

8) Which were the key-drivers (e.g. standardisation of processes, free-flow of data, ICT, regulatory business) that allowed the implementation of your interoperable framework? -please provide an analytical response-

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

9) Which were the obstacles towards your envisioned innovation?

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

10) Could you provide a brief overview of the proposed architectural pillars and their modularity (data management and integration, centralised/decentralised)? -please provide a brief breakdown of your conceptual/technical architecture-.

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

11) Do you foresee the proposed framework to be adopted in other domain(s)? If yes, could you elaborate your answer and whether there are use cases defined for other sectors?

EU Data Exchange Architecture group of BRIDGE	Other cross-sectoral initiative

10. Annex IV. CIM usage questionnaire

Organisation Name*	
Type of Organisation*	
Recipient name	
Recipient email address*	
Recipient phone number	
1.From the following options, please specify the required and already used CIM profiles and Standards linked to CIM (Tick all that apply)	
Network Modeling - defined by IEC 61970-301	
☐ Required	☐ Already used
Utility application integration profiles- CIM Distribution Model - defined by IEC 61968-11	
☐ Required	☐ Already used
Standard profiles related to Network Studies (61970-45x mainly based on CIM base model (61970-301)	
☐ Required	☐ Already used

IEC 61850 series	
☐ Required	☐ Already used
Harmonisation between CIM and IEC 61850 - defined by IEC 62361-102	
☐ Required	☐ Already used
Standard profiles related to Utility Integration based on CIM Model IEC 61968-x (3 to 9)	
☐ Required	☐ Already used
Market related profiles (IEC 62325-45x, mainly based on IEC 62325-301 CIM Market model)	
☐ Required	☐ Already used
Network studies related profiles -CGMES profiles - defined by 61970-600-x	
☐ Required	☐ Already used
Common Distribution Power System Model (CDPSM) profiles (IEC 61968-13 Ed1 2008, Ed2 will be released in 2020 S1)	
☐ Required	☐ Already used
CIM based data model realted to network studies - defined 61970-600-1	

☐ Required	☐ Already used
☐ Others	
If others, please specify. Also, please specify any future interest	
Others:	Future interest:
2. What are the purposes of using CIM? Please specify the current and required (but not yet used) purposes **(Tick all that apply)**	
Power flow analysis e.g. for planning new connections	
☐ Required	☐ Currently used
Mapping network geographically e.g. view paths of lines/cables, locations of substations	
☐ Required	☐ Currently used
Facilitating the data exchange with other stakeholders within a standardised format	
☐ Required	☐ Currently used
Obtaining asset data e.g. the mix of asset types	
☐ Required	☐ Currently used

Balancing mechanism and demand planning	
☐ Required	☐ Currently used
Understanding network connectivity without the use of geographic data	
☐ Required	☐ Currently used
Other Market Coordination	
☐ Required	☐ Currently used
Others	
☐ Others	
If others, please specify, and please specify other planned purposes/usage for CIM model use	
Others:	Future interest:
3. Please specify which data sources you already take from (tick all that apply)	
☐ Utility data exchange	☐ Data Portal_please specify below
☐ SCADA EMS, DMS, ICCP, OMS	☐ Capacity Maps
☐ Custom data requests	☐ TSO/DSO data sources
☐ Other	
If other, please specify	

Others:
4. What is the used frequency / frequencies for different data sets (Tick all that apply, and specify any future interest)
☐ One-off ☐ Day-ahead ☐ Close to real time ☐ Intraday ☐ Real Time Operations ☐ Planning Operation ☐ Others
If other, please specify
Others:
5. Which are the data formats for the CIM data sets that are provided in your demonstration phase or within your organisation operation? (Tick all that apply, and specify any future interest)
☐ CIM RDF XML ☐ ACSII CSV ☐ COMTRADE (Common Format for Transient Data Exchange) ☐ DGS _ DigSILENT ☐ Export geographic and schematics to PDF ☐ Other
If others, please specify. Also, please specify any future interest

Others:	Future interest:

6. Used Tools: **6.a Please specify the used tool(s) in CIM Modelling and/or Management.**
☐ Enterprise Architect ☐ UML tools, If yes, please specify ☐ Other

Others:	UML tools?

6.b. Do you see an interest in having interoperability between UML modelling tools ? Please explian
6.c. Which tool(s) do you use to define CIM based profiles ?
☐ CIMtool ☐ CIMContextor ☐ Modsarus ☐ Enterprise Architect Schema Composer ☐ Other
If others, please specify. Also, please specify any future interest

Others	Future interest

6.d. Are you interested to see profiling tools being interoperable? Please explain (this would mean to have a profiling methodology implemented by different tools, a profile defined by a tool could be imported and modified by another tool)

7. Which validation tool(s) do you use? for instance data against a profile?

☐ XMLSpy	☐ CIMSpy
☐ CIMDesk	☐ CIMTool
☐ RiseClipse	☐ Other

If others, please specify. Also, please specify any future interest

Others	Future interest

8. With whom CIM data is exchanged? Please specify the different stakeholders that you communicate with using CIM format including the internal parties within your utility.

Stakeholders/Parties :

Used tools:

9. What is the CIM version you are using ?

☐ CIM16	☐ CIM17
☐ Other	

If others, please specify. Also, please specify any future interest
Others:

10. Do you have CIM Data Sets that you could propose to CIM community in order to organise/contribute in the followings:

☐ interoperability tests	☐ Balanced networks
☐ Unbalanced networks	☐ Others

If others, please specify. Also, please specify any future interest	
Others	Future interest

11. Which voltage levels are operated by your Utility, and what voltage levels are utilized in CIM usage? **(Please specify any future interest)**
Operated Voltage levels: Utilised Voltage Levels using CIM Future interest:

12. Is the customisation of CIM profiles already performed and in which cases/to what extent
13. Do you have any suggestion to include any improvements within the current CIM profiles and why? Please clarify if you have extensions to CIM ?
14. Please specify the CIM Profiles that you think they need extensions/improvements to include more details. **Please specify the required details**

15. What are hurdles of using CIM in the demos?

- [ ] Implementation issues
- [ ] Technical complications in the softwares
- [ ] Costs associated with the adaptation of software to be CIM-compatible
- [ ] Missing or insufficient information/documentation/manuals
- [ ] Others
- [ ] Training and human resource issues

If other, please specify

16. Which network components included in the list below are Modelled in CIM (Tick all that apply, and specify any future interest)

Transformer (2W, 3W, Earth, Phase Shift)	
☐ Currently Modelled	☐ Future/current interest
Line (OH & UG), OH Towers	
☐ Currently Modelled	☐ Future/current interest
Generator (Synchronous, Asynchronous - IG, DFIG and Static)	
☐ Currently Modelled	☐ Future/current interest
Busbar, T Point, Node	

Currently Modelled	Future/current interest
Switch - Circuit Breaker, Isolator, Disconnector, Load switch etc	
Currently Modelled	Future/current interest
Motor, Motor Starters	
Currently Modelled	Future/current interest
Load (Domestic, Industrial, Commercial, others)	
Currently Modelled	Future/current interest
Capacitor (switched and fixed)	
Currently Modelled	Future/current interest
Inductor (switched and fixed)	
Currently Modelled	Future/current interest
Power Converters (AC-DC, DC-AC, AC-AC)	
Currently Modelled	Future/current interest

Site, Substation	
☐ Currently Modelled	☐ Future/current interest
Protection - Relays (all types) CTs, PTs, CPT, Fuses	
☐ Currently Modelled	☐ Future/current interest
Neutral Earthing Reactor / Conductor	
☐ Currently Modelled	☐ Future/current interest
Static Reactive Power Compensators - Switched and fixed	
☐ Currently Modelled	☐ Future/current interest
Battery Storage and Fuel Cells	
☐ Currently Modelled	☐ Future/current interest
FACTS Devices	
☐ Currently Modelled	☐ Future/current interest
Smart Sensors/Meters	
☐ Currently Modelled	☐ Future/current interest

Electric Vehicle and charging stations	
Currently Modelled	Future/current interest
Virtual Components (Equivalent impedance, Grid, Voltage & Current Source)	
Currently Modelled	Future/current interest
Controllers (Tap, Primary and Secondary)	
Currently Modelled	Future/current interest
Power electronic controllers (e.g. Soft Open Points (SOP))	
Currently Modelled	Future/current interest
Active Network Management (Generator control)	
Currently Modelled	Future/current interest
Reactive Power control Nodes (PQ, PV)	
Currently Modelled	Future/current interest
Dynamic Asset Ratings (Transformers / Cables)	

Currently Modelled	Future/current interest
Voltage Dependency Loads (Constant Power, Constant Current, Constant Voltage)	
Currently Modelled	Future/current interest
Others	
If others, please specify. And please specify any future interest	

11. Annex V. Collection of role information from projects

Table 9: Data exchange business roles identified by EU-SysFlex project and mapping to HEMRM

EU-SysFlex		HEMRM 2020-01	
Business Role	**Description**	**Business Role**	**Description**
Authentication Service Provider	Trust authority. Verifies the identity of authenticating parties. Some countries will have their own authentication service provider. For countries which will not, there may be a more global and to be defined one.	Not available	
Customer Portal Operator	Operates a Customer Portal. *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).*	Not available, except for: Consent Administrator	A party responsible for administrating a register of consents for a domain. The Consent Administrator makes this information available on request for entitled parties in the sector.
Data Delegated Third party	Any natural person who has received representation rights from a data owner.	Not available	
Data Hub Operator	Data hub operator owns and operates an information system whose main function is to store and make available electricity (also gas, heat) metering data and associated master data. Can be : • Grid Data Hub Operator in the sphere of a System Operator	Data Provider	A party that has the mandate to provide information to other parties in the energy market. A party responsible for storing and distributing validated measured data.

EU-SysFlex		HEMRM 2020-01	
	• Market Data Hub Operator in the sphere of a Market Operator • Meter Data Hub Operator in the sphere of a Metered Data Operator • Sub-meter Data Hub Operator in the sphere of an Energy Service Provider	Metered Data Administrator	
Data Owner	Any person who owns data and can give authorization to other parties to access them. Can be, inter alia: • Flexibility Services Provider • Market Operator • Consumer • Generator	Not available	
Data User	Any person who uses data. Can be a Data Owner or a Data Delegated Third party.	Not available	
DEP Operator	Data exchange platform operator owns and operates a communication system which basic functionality is data transfer.	Not available	
Foreign Customer Portal Operator	Customer Portal Operator in another country. Can also mean an operator of a separate customer portal in the same country.	Not available	
Metered Data Operator	Provides metered data to authorized users in a transparent and non-discriminatory manner	Metered Data Responsible	A party responsible for the establishment and validation of measured data based on the collected data received from the Metered Data Collector. The party is responsible for the history of metered data for a Metering Point.

EU-SysFlex		HEMRM 2020-01	
		Metered Data Administrator	A party responsible for storing and distributing validated measured data.

Table 10: Data exchange business roles identified by BD4OPEM project and mapping to HEMRM

IDSA (from BD4OPEM project)		HEMRM 2020-01	
Business Role	**Description**	**Business Role**	**Description**
Data Owner	Entity creating data and/or executing control over it.	Not available	
Data Provider	Entity making data available for being exchanged between a Data Owner and a Data Consumer. In most cases identical with the Data Owner.	Data Provider	A party that has a mandate to provide information to other parties in the energy market.
Data User	The entity that has the right to use the data of a Data Owner as specified by a contract policy.	Not available	
Data Consumer	Entity receiving data. Act as an intermediary (third-party) among entities providing data and using data. In most cases identical to data User.	Not available	

Table 11: Data exchange business roles identified by CoordiNet project and mapping to HEMRM

HEMRM (from CoordiNet project)		HEMRM 2020-01	
Business Role	**Description**	**Business Role**	**Description**
Consent Administrator	A party responsible for keeping a register of consents for a domain. The Consent Administrator makes this information available on request for entitled parties in the sector.		A party responsible for administrating a register of consents for a domain. The Consent Administrator makes this information available on request for entitled parties in the sector.
Data Provider	A party that has a mandate to provide information to other parties in the energy market. **Note:** For example, due to Article 2 of the European Commission Regulation 543/2013 of the 14th of June 2013, a data provider may be a Transmission System Operator, or a third party agreed by a TSO.		A party that has a mandate to provide information to other parties in the energy market. **Note:** For example, due to Article 2 of the European Commission Regulation 543/2013 of the 14th of June 2013, a data provider may be a Transmission System Operator or a third party agreed by a TSO.
Market Information Aggregator	A party that provides market related information that has been compiled from the figures supplied by different actors in the market. This information may also be published or distributed for general use. **Note:** The Market Information Aggregator may receive information from any market participant that is relevant for publication or distribution.		A party that provides market related information that has been compiled from the figures supplied by different actors in the market. This information may also be published or distributed for general use. **Note:** The Market Information Aggregator may receive information from any market participant that is relevant for publication or distribution.

HEMRM (from CoordiNet project)		HEMRM 2020-01	
Meter Administrator	A party responsible for keeping a database of meters.		A party responsible for keeping a database of meters.
Meter Operator	A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters.		A party responsible for installing, maintaining, testing, certifying and decommissioning physical meters.
Metered Data Aggregator	A party responsible for the establishment and qualification of metered data from the Metered Data Responsible. This data is aggregated according to a defined set of market rules.		A party responsible for the establishment and qualification of measured data from the Metered Data Responsible. This data is aggregated according to a defined set of market rules.
Metered Data Collector	A party responsible for meter reading and quality control of the reading.		A party responsible for meter reading and quality control of the reading.
Metered Data Responsible	A party responsible for the establishment and validation of metered data based on the collected data received from the Metered Data Collector. The party is responsible for the history of metered data for a Metering Point.		A party responsible for the establishment and validation of measured data based on the collected data received from the Metered Data Collector. The party is responsible for the history of metered data for a Metering Point.
Metering Point Administrator	A party responsible for registering the parties linked to the metering points in a Metering Grid Area. The party is also responsible for registering and making available the Metering Point characteristics.		A party responsible for administrating and making available the Metering Point characteristics, including registering the parties linked to the Metering Point.

Table 12: Data exchange business roles identified by PHOENIX project and mapping to HEMRM

PHOENIX		HEMRM 2020-01	
Business Role	**Description**	**Business Role**	**Description**
Electricity Data Administrator	A party responsible for distributing validated electricity metering data and meter data.	Metered Data Administrator Data Provider	A party responsible for storing and distributing validated measured data. A party that has a mandate to provide information to other parties in the energy market.
Cybersecurity Data Administrator	A party responsible for distributing cybersecurity related raw data.	Metered Data Administrator Data Provider	A party responsible for storing and distributing validated measured data. A party that has a mandate to provide information to other parties in the energy market.
Cybersecurity Knowledge Administrator	A party responsible for collecting and distributing cybersecurity knowledge, as a result of cybersecurity raw data processing.	Market Information Aggregator Data Provider	A party that provides market related information that has been compiled from the figures supplied by different actors in the market. This information may also be published or distributed for general use. A party that has a mandate to provide information to other parties in the energy market.

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